COUNTERPOINT.aero

Avionics 2024

THE SECOND REVIEW OF THE AVIONICS MARKET

CONTENTS

LIST OF FIGURES

LIST OF TABLES

1 EXECUTIVE SUMMARY

Avionics is a broad category, and different observers can have different viewpoints of what is included and where the value chain begins and ends. Traditionalists may say that avionics is confined by the real estate within the cockpit, i.e., the dashboard, or by the primary functions of navigation, communication and surveillance adding in intelligence and specific mission functions for military applications.

We have elected to include a broader scope definition that captures a number of dynamic shifts including the greater role of software-based functions, sharing and/or partitioning of computing resources, the improvements in sensors technology and the role of data and data fusion in improving both health management and situational awareness.

Equally, we note that the airborne infrastructure required to support avionics today spreads far beyond the cockpit in terms of data transmission and communication, the use of remote data concentrators and the role that high speed, broad bandwidth networks play in achieving new levels of mission performance in real time.

Avionics has always functioned 'beyond the cockpit' in terms of Air Traffic Control, but today the number of external links and the associated data traffic is growing significantly. This is driven by such factors as the need for more autonomous flight (ADS-B), satellite navigation means (GPS), download/upload links in real time, SATCOM based communications and services, and the ability to provide in flight health and performance monitoring.

The full scope of our avionics definition can be found in Section 3. Our equipment covers avionics equipment manufacturer income from turbine-driven fixed-wing aircraft and helicopters. We examine both the forward-fit OE and the aftermarket (which is composed of spares/repairs and retrofits/upgrades).

Market size

The table below show the total avionics market sector in the scope of this report as being worth $17.0 billion in 2023. The report identifies the market segmented into 11 product groups or avionics functions which we have broadened beyond traditional areas to include digital services and sensors for example.

Our estimates for the total avionics market size are shown in the table below which identifies the major avionic subsystem categories together with revenues split between OE, spares/repairs and retrofit/upgrade activity.

2023 Avionics Market	OE	Repairs/Spares	Retrofit/Upgrade	Total
Display	1,931	1,418	566	3,916
Sensors	1,035	1,160	405	2,601
Navigation	892	549	270	1,712
FMS	616	486	166	1,268
Mission	548	546	175	1,269
Communications	566	528	152	1,245
Surveillance	524	547	124	1,195
IMA	707	380	91	1,177
Software	526	512	80	1,118
Data	469	475	118	1,062
Auto-pilot	303	139	36	478
Grand Total	**8,119**	**6,739**	**2,183**	**17,041**

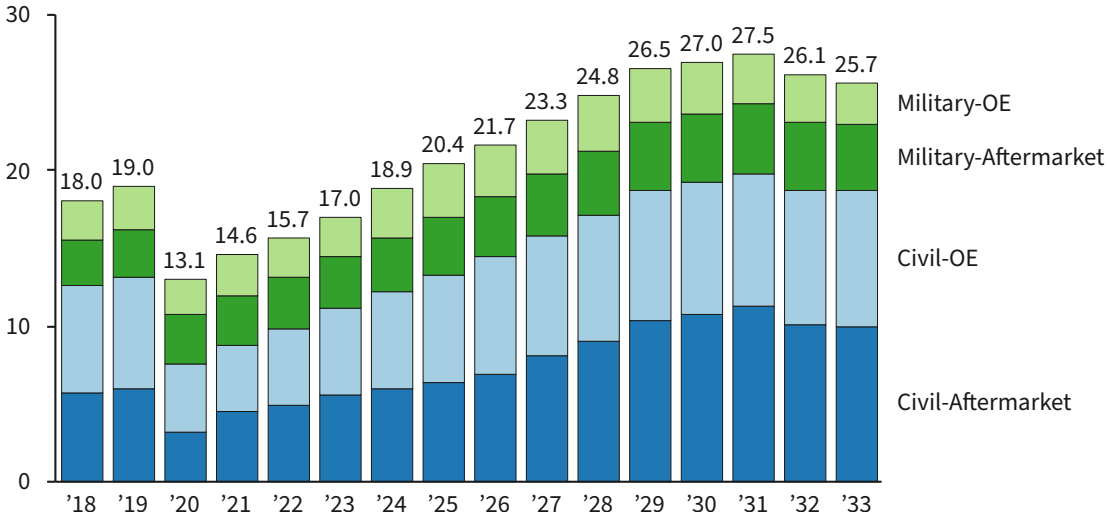
OE and aftermarket

Our analysis breaks out the total aftermarket market which equates to $8.9 billion in 2023. This is an important sector as it operates independently of the OE forward fit cycle and it is comprised of many discrete opportunities.

The dichotomy represented by the in-service life of the airframe (decades) vs. that of modern electronic avionics (several years) generates a significant retrofit and upgrade market. A consequence of this is an avionics market with multiple insertion point opportunities arising at any one point in time.

The chart below displays the split of OE and aftermarket across civil and military platforms. Covid-19 had a significant impact on both OE and aftermarket for the avionics industry.

Avionics market forecast by civil versus military
USD billions



Covid-19 continues to have an effect in multiple ways. On the one hand, supply chain disruption continues to affect the industry. Even if avionics suppliers are not directly affected in their own supply chains, this has knock-on effects for production as a whole. Delivery from OEMs remains behind schedule for many programmes. On the other hand, the lack of new aircraft has created an opportunity

Within the report we have identified 51 key suppliers of avionics. There remains a long tail of 3rd party providers which we do not include in the scope of the report.

Avionics can be impacted by airworthiness regulatory changes over time. It can take years to upgrade the equipment installed in existing fleets to comply with mandatory or attrition-based notices that come into force. Key changes in recent years include the need to adopt greater navigation performance (FANS/Next Gen) largely through to the adoption of GPS based systems, the Reduced Vertical Separation Minima (RVSM) necessary to reflect increasingly congested air traffic, the adoption of Traffic Collision Avoidance Systems (TCAS) and the move to a more autonomous flight regime enabled via ADS-B/A and associated transponders.

Regulatory changes and upgrades to the broader infrastructure can be a major driver of upgrade activity, which is shown in our report. In particular, in Section 11.3.1, we discuss how changes in PBN and CPDLC will drive additional growth due to retrofits and upgrades. In our forecasts, this leads to a peak of aftermarket activity by 2031; it is plausible that further regulatory changes will drive more growth beyond these date, but none are foreseeable at this point in time that would give us confidence from a detailed modelling perspective.

Commercial off-the-shelf

These avionic solutions traditionally came with 'big ticket' prices reflecting the cost to design, develop, validate and certify these products that perform safety critical functions. However, a number of suppliers have been adept at offering lower cost variants with similar functionality. This is possible within the less regulated market sub-sectors including smaller business jets, general aviation, rotorcraft and military trainers where certification costs are lower. Suppliers have achieved market penetration in certain sectors by adopting a commercial off-the-shelf (COTS) approach or by pursing an STC certification route. By doing so they avoid the very high certification costs associated with large OEMs and highly regulated air transport markets.

That is not to say that the large avionic providers have ignored this market sector, quite the contrary. Honeywell services these sectors via its Bendix King subsidiary whilst both GE Aviation and Collins Aerospace have operating divisions that are focused on servicing the business jet/GA/rotorcraft sectors.

All of the major avionics suppliers have a list of products certified for a range of platforms via the STC route.

Many suppliers have focused upon COTS based or TSO certificated products and are clearly in tune with the lower cost market sectors. These include Garmin, Universal Avionics, Innovative Systems & Support, Genesys, Astronics and Meggitt.

These same suppliers also support legacy civil and military transport aircraft that require minor upgrades. Often these niche opportunities fall outside of the scope of the OEM constructors and the larger avionics integrators. For example, Universal Avionics offers a range of avionic upgrades for older C-130H aircraft.

Technology and architecture

The application of new technology can often be categorised as either evolutionary or revolutionary. Most airframe systems benefit from evolutionary technology that ratchets forward over time. Incremental improvements, in respect to avionics, include the ongoing improvements in SWaP (size, weight and power) associated with electronic devices. Avionics-related computers are getting smaller, with associated increases in performance, often accompanied by lower weight and lower acquisition costs.

Thermal management techniques, which can affect the reliability and life of electronic componentry, are improving by becoming an integral part of the design of avionics e.g., active internal liquid cooling of avionics housings.

Visual cockpit display graphics have steadily improved which reflects a combination of better display media (e.g., multi-function flat panel LCD displays) and the associated software engines that drive the display graphics.

The same can be claimed for Enhanced or Synthetic Vision Systems (EVS/SVS) that often rely upon multiple sensor inputs and software that, in combination, 'stitch' together graphical representation. These SVS/EVS improvements have largely come about due to the improvements in data fusion (or interlinking) from different sensors resulting in a high fidelity 'synthesised' output graphical representation.

A step change has been provided in avionics architectures moving from federated individual avionic boxes to reliance upon common computing resources or integrated modular avionics. This integrated approach, via shared computing resources, brings with it challenges in partitioning a number of various critical avionic functions with non-critical utility functions. This in turn has introduced the need for new solutions provided by suppliers who are focused on developing software.

We have identified the involvement of software companies, often working with the OEMs and Tier 1s, in order to develop partitioned RTOS software for the new integrated architectures. These companies typically include Wind River, Mercury, Green Hill sSoftware and Lynx Software Technologies.

A major potential benefit of the IMA (Integrated Modular Avionics) approach is not just the reduction in box count but also the adoption of 'open software' architectures which allow operators and end-users to have more control over subsequent upgrades and/or functional additions in service.

Early versions of IMA utilised for the Boeing 777 and those offered via Collins ProLine Fusion and Honeywell's Primus Epic have not always adopted 'open architectures' in terms of ease of access for upgrade or adding new functionality.

Newer more 'open' IMA architectures have been successfully adopted now by a number of civil and military platforms including Boeing 787, F-35, A350, A400M. We believe that all next generation platforms will adopt an IMA approach, with open architectures, as a baseline for avionics functions.

In Section 13, we examine both single-pilot operation and autonomous flight. Technology continues to advance in both areas, but we note that several challenges remain, both from a technology and regulatory perspective.

A further potential paradigm shift in air transport technology is the rapid growth in demand for both UAVs and urban air mobility aircraft. The current conceptual and development phase vehicles bring with them a range of issues in terms of airworthiness approval (especially when mixed with existing air transport aircraft). Air taxis operating in congested airspace over urban areas will also require significant investment in infrastructure support (parking, storage, re-charging, servicing etc).

The various civil airspace authorities around the world are trying to generate a consistent set of airworthiness rules specifically relating to UAVs/UAMs/Drones as we write this report. The need for low cost/high utilisation/high volume urban air vehicles will create a new set of challenges for avionics providers.

Overall, we see a trend towards more standardised offerings of complete avionics packages within aircraft and fewer options for upgrades or customisation. This is driven by both supply chain and inventory savings and the greater

integration of avionics by the system suppliers. The avionics OEMs have increased integration of their own products to increase their share of avionics real estate and to further enhance their own positions by warding off the availability of avionics component options for other sub-tier suppliers.

Market structure and consolidation

The avionics industry has undergone considerable consolidation in recent years, and we see evidence of this continuing. This will could also extend to the service providers, software specialists and 3rd party providers who are active within the avionics sector and will benefit from significant growth.

The last few years have seen a number of smaller acquisitions of technology companies that enhance a supplier's overall offering, such as digital services or artificial intelligence. We also note that private equity has increased slightly since the last report was published. However, given the more concentrated nature of this market, private equity involvement may be more limited than in other, more fragemented areas of the aerospace supply chain.

Consolidation and inward investment we see as continuing, driven by the above-trend line growth potential associated with avionics and associated services. This growth trend is supported by avionic equipment upgrade potential, the additional services that are derived from avionics-based software and data and the connected world in which all these platforms operate.

The largest avionics providers are subsidiaries of corporations that are often equal to the OEM constructors, in terms of market capitalisation, which can be a concern to the latter. Both Airbus and Boeing have, in recent years, adopted initiatives that attempt to regain control of both IP and service offerings from within the supply chain. This OEM initiative is not unique to avionics and applies to other systems and equipment. Boeing and Airbus have used these initiatives with varying success to address areas of the supply chain with few, concentrated suppliers, such as APUs, nacelles and avionics.

Most of the suppliers identified in this report are based in North America or Europe. China continues to advance in its maturity in airliner production. Major western avionics producers are already developing in-country partnerships with China. Other potential entrants to this market will almost certainly need to do the same.

Profitability and investment

Relative to other parts of the aerospace supply chain, the avionics sector has a tendency to produce attractive margins. While not true for ever supplier, several are able to produce operating margins in the high teens or low twenties. The product sub-sectors in avionics are underpinned by Intellectual Property (i.e., design to spec) requiring highly specialised engineering. The entry barriers to avionics are relatively high which restricts new entrants. We believe that the total aftermarket for avionics products and services, including significant retrofit/upgrade opportunities, is equal to the OEM forward fit market in revenue terms. We further believe that this large aftermarket generates higher margins than the OEM forward fit market.

Garmin is a classic example of a manufacturer that has quickly established a credible track record within aerospace, offering a wide range of product and services whist reporting 20%+ operating profit margins.

Designing, developing and certifying critical function avionics requires high up-front investments which the OEM constructors expect the supplier to provide. In recent years, the increasing role of software has added to the overall programme risk. It also reflects why the largest avionics providers today rely more upon their software sub-contractors and out-source key elements of the software IP.

We see a trend towards OEMs insisting on a greater level of risk-sharing from their Tier 1 and 2 suppliers in regards to new programmes. This tends to also drive a more consolidated market, as only large suppliers with sufficient scale and balance sheets can afford such risk sharing agreements.

Similar to the commercial aircraft constructors, business aircraft OEMs are requiring similar risk-sharing partnerships from their avionics supply chain. These demands coincide with a goal of reducing the certification risk of offering multiple avionics options and to shift this burden to a single supplier for each given aircraft program. The tempo of business aircraft programs is considerably faster than the development of commercial aircraft programs. As commercial OEM constructors strive to maintain commonality with prior aircraft series to assist operators in managing training costs, business aircraft OEMs are less burdened by this requirement. For example, Gulfstream has launched significant

new aircraft programs (G600, G700, G800) in the last ten years. Textron Aerospace (Cessna, Beechcraft) have unveiled a number of new aircraft programs (Latitude, Longitude, Denali, SkyCourier)

Key challenges ahead

Looking forward, we see several active areas of investigation for further advancements in technology. Recent high-profile news stories have put emphasis on the dangers of clear air turbulence and the need for better detection methods to keep passengers and crew safe. GPS spoofing has also become a greater concern as the number of reported incidents continues to rise.

With the issues surrounding the 737 MAX programme, we expect regulatory oversight to increase in several areas, including avionics. This will have an impact not only on new aircraft, but also aftermarket modifications.

In conclusion, the avionics market is undergoing a significant transformation marked by technological innovation, regulatory shifts, and evolving business models. The integration of advanced software functions, open architectures, and enhanced data capabilities is redefining traditional avionics boundaries and creating new opportunities across both civil and military sectors. While challenges such as supply chain disruptions, increased regulatory scrutiny, and the need for substantial investment persist, the sector's profitability and growth potential remain strong. The convergence of these factors suggests that companies adept at leveraging technological advancements and navigating the complex market landscape will be best positioned to capitalise on emerging opportunities.

2 INTRODUCTION

As we initiated research into the avionics world across the aerospace and defence spectrum, it quickly became apparent that this is arguably the most dynamic aerospace equipment sector today in terms of evolution and change. Clearly, a significant factor in this dynamic is the rapidly changing world of electronic computing and associated software.

A further major factor is the evolving regulatory environment in which avionics operates. Congested airspace has resulted in regulatory changes including reduced vertical separation minima, NextGen or FANS-based navigation performance, and the need for autonomous surveillance, thereby relieving overloaded Air Traffic Control (ATC).

The military world has its own set of dynamics driven by factors such as the need for network-centric operations, multi-source data fusion, high-speed data networks, and real-time operating systems (speed of response being mission-critical).

Repeatedly throughout our research, we found many 'common themes' cited by industry bodies, government agencies, OEMs, suppliers, and end-users alike.

These common themes included digitisation, Internet of Things, Artificial Intelligence, data fusion, 'smart' sensors, 'office in the sky', real-time maintenance diagnostics, satellite-based navigation and communications.

All these factors are often heavily interdependent with avionics architectures, and this report attempts to cover these within the context of the relevant sections that follow.

Avionics is in a state of continuous development driven by:

- the external platform operating environment (e.g. regulatory, network-centric)
- the changes required to their architectures within the platform (IMA, distributed computing)
- the rapidly changing cost, size, power, and memory of the associated electronics
- the significant increase in the application of software replacing mechanical functions

Modern avionics operate in a networked, digital environment that provides a multitude of terrestrial links between aircraft, satellites, ground stations, air traffic control, mission planners, and maintenance services, with many of these links operating in real time.

A number of avionics service providers and software developers are implementing solutions that rely upon cloud-based computing and the emerging 5G communications networks.

Avionics-related 'dynamic drivers' include increases in equipment computing power, greater flexibility and dependence upon software (especially open architectures that provide low-cost upgrade paths), the ability to transmit and process terabytes of data, real-time operating systems (RTOS), increasing levels of integration between functions (e.g. IMA architectures), and high-speed data buses that link all elements of an avionics system.

In terms of the external operating environment, the need for greater safety, accuracy, operating performance, and reduced pilot workload continuously drives regulatory changes that are imposed across the global aerospace and defence industry. These regulatory improvements are often implemented via the avionics suite in terms of improved navigation, communications, flight management, surveillance, and mission accomplishment.

As this report will show, the dynamics noted above result in significant retrofit/upgrade opportunities. A modern commercial aircraft with an expected life of 30–40 years can expect multiple opportunities for upgrades to many components.

A further notable feature, specific to avionics, is the trend of reducing cost, weight, and power consumption. As a result of this, 'plug and play' avionics, containing many of the features and performance associated with large commercial airliners, can be bought off the shelf by owners/operators of general aviation, rotorcraft, and modest business jets. Prohibitively large and expensive avionics, once found only on large commercial air transport and high-specification military fighters, have decreased significantly (often referred to as size, weight and power, or SWaP, metrics), resulting in increased market penetration at the lower end of the market.

Whilst the report will show that the avionics industry has clearly consolidated around three or four large players, there are still 50+ suppliers operating in specialised areas. Within the 50+, there are a significant number of newer players who specialise in new growth areas such as advanced electronics, software, data provision, and service provision.

Avionics can be very broadly interpreted, so it is often difficult to delineate what comprises 'avionics' in precise terms. Equally, there is overlap and interaction between certain functions (e.g. Flight Management, Autopilot, Flight Control), which can make it difficult to define exactly where avionics starts and stops.

In preparation for this report, Counterpoint Market Intelligence has sought to define the boundaries within the next section titled 'Scope'.

3 SCOPE

As noted above, Counterpoint has undertaken to produce a report that includes the multitude of aircraft functions, both civil and military, that can be considered to be determined as 'Avionics' in general.

There are a number of key enablers or infrastructure products that relate to avionics equipment, the absence of which would render the cockpit to be less than optimised at best, and non-functional at worst. Examples of these, such as high-speed data-buses, remote data concentrators, integrated modular avionics computing and avionics software have therefore been considered within this report.

We also have assumed that the definition of 'Avionics equipment' can be taken to comprise hardware, firmware and software. Clearly upgrade paths exist for both firmware and software without removal of the Avionics hardware. This avoids major disruption to operators where a firmware/software upload can be performed in-situ via portable data loaders utilising high speed data transfer networks.

We purposefully emphasise the word 'cockpit' within any discussion around Avionics scope because, currently, the cockpit represents the key human/machine interface within all flying platforms (with the exception of UAVs).

It would not be possible for an OEM provider of cockpit displays and interfaces to bring a product to market that had not considered the significant science that surrounds man/machine interface issues.

Essentially Counterpoint has taken the Avionics scope to include all equipment necessary for the flight crew to achieve its mission safely, reliably and within the operating parameters set by the operator (cost, on time, quality of service etc).

For a commercial flight this may be defined as a flight trajectory that navigates from A to B in the optimum time and cost (fuel burn) allowing for factors such as adverse weather conditions and traffic congestion.

For a military platform a mission may be defined as the delivery of a payload with pinpoint accuracy and for the platform to return to base undetected from the ground, sea and air. And, in the unforeseen event of detection to be able to identify all threats and to successfully engage in effective countermeasures.

One early decision was to consider the role of advanced military sensors as a key adjunct to avionics architectures. In this case we have elected to include the advanced high value sensors such as radar, electro-optics, infrared and multi-sensor suites. These sensor suites link directly to avionics including enhanced vision systems, head up displays, electronic warfare, electronic countermeasures and target acquisition.

Whilst Counterpoint has considered these military sensors to be within scope their associated sensitivity and limited available data can restrict the level of detailed analysis. Many Tier 1 defence contractors report up to 30% of their revenues as being 'classified', usually within the area of sensors development.

Included within the scope of this report are the traditional Avionics functions that we believe are largely recognised throughout the Aerospace & Defence sector. These are identified as follows:

- Integrated Modular Avionics
- Flight Management Systems
- Auto-Pilot
- Navigation
- Communications
- Radios
- Surveillance
- Mission
- Sensors
- Data

Not included within the scope of this report are the following areas:

- Space related avionics
- In-Flight Entertainment (IFE)
- Flight Control systems (although some elements of Flight Guidance/Flight Warning Computers are included within FMS systems)
- Full Authority Digital Engine Controls (Engine FADECs)
- Onboard passenger communication systems

The cockpit also contains, in addition to the major functions described above, a significant number of relatively low value panels. These panels are typically utilised to select and/or switch between flight-related functions by the flight crew. They can be designed and manufactured by the airframers in-house and/or a diverse range of 'panel' suppliers. We have not considered these products to be within the scope of this report.

Our market and financial modelling considers turbine-driven aircraft. Both civil and military aircraft are included. Fixed-wing and helicopters are included. Smaller general aviation aircraft driven by piston engines are not included. For this reason, our market revenue estimates for certain companies may be lower than what they report publicly (such as in the case of Garmin).

Accordingly, our UAV estimates focus primarily on larger programmes (Groups 4 & 5) in the military sector. Although avionics are a key factor in commercial and smaller military platforms, these systems and suppliers can differ considerably from more traditional avionics architectures.

Our financial models also consider only hardware, firmware, and software from in-production aircraft, spares/repairs and retrofits/upgrades. We do not consider revenue from services such as R&D studies.

4 METHODOLOGY

All monetary values are in constant US dollars and relate to 2023.

All numbers and charts in this report are Counterpoint estimates apart from the financial results, unless attributed otherwise.

4.1 SOURCES OF INFORMATION

Counterpoint gains intelligence from overt, publicly available sources.

We also gain information and opinions from the following sources:

- Customers of our market reports, with whom we have discussed issues arising around avionics
- Industry observers with experience in the avionics sector
- Technologists in aerospace avionics companies and their customers
- Salespeople, marketers, and strategic planners in the industry
- Economists in government departments and trade associations

No confidential information is contained in this report.

4.2 OUR MARKET MODEL

At the heart of our report, there is a quantitative market model and database, covering the following:

- An estimate of companies' avionics sales by product area
- Segment size and growth rates
- Segment shares by major company
- Overall market size and growth
- Avionics contracts by company where individually identified

We have carried out a comprehensive review of information in the public domain.

Unless otherwise stated, all charts and diagrams have been derived from Counterpoint Market Intelligence's estimates.

Many companies in the avionics market do not publish figures for sales of avionics systems. Where no figures are available, Counterpoint has estimated avionics sales on the basis of current contracts. Where financials have been provided, Counterpoint estimates the extent to which those financials fall within the scope of this report. Together with an analysis based on the total numbers of aircraft delivered by the aircraft OEMs, this has enabled us to create an original market model.

In order to show the market effects of mergers & acquisition moves we assume that all ownership changes occur on the 1st of January in each year for our market share estimates.

4.3 COMPANY PROFILES AND ANALYSIS OF TRENDS

The purpose of our company profile sections is not only to identify the numerous companies in the avionics market, but to note and estimate some of the material that we use to analyse trends in the market. In doing this we also draw on the interviews that we have had with participants in the market over the past year.

5 GLOSSARY

The range of acronyms generated in relation to Avionics can be measured in the 1000s. We have distilled out the top 100 or so that we believe are most relevant and are utilised within this report.

Term	Definition
ACARS	Aircraft Communications Addressing and Reporting System
ADAHRS	Air Data and Attitude Heading Reference System
ADC	Air Data Computer
ADIRS	Air Data Inertial Reference System
ADIRU	Air Data Inertial Reference Unit
ADS-A	Automatic Dependent Surveillance — Address
ADS-B	Automatic Dependent Surveillance — Broadcast
ADS-C	Automatic Dependent Surveillance — Contract
AFDX	Arinc 664. Avionics Full-Duplex Switched Ethernet (AFDX) is a data network, patented by international aircraft manufacturer Airbus.
AHRS	Attitude Heading Reference System
A/P	Autopilot. A computer-commanded system for controlling aircraft control surfaces.
ARINC 429	ARINC 429 is the Aeronautical Radio INC. (ARINC) technical standard for the predominant avionics data bus used on commercial and transport aircraft
ARINC 629	ARINC 629 bus operates as a multiple-source, multiple-sink system; each terminal can transmit and receive data from every terminal on the data bus.
A/T	Automatic throttle, also known as auto-thrust, is a system that allows a pilot to control the power setting of an aircraft's engines by specifying a desired flight characteristic, rather than manually controlling the fuel flow.
BEIDOU	Global Navigation Satellite System - China
CAA	Civil Aviation Authority (UK)
CNS	Communications, Navigation, Surveillance
CNS/ATM	Communications, Navigation, Surveillance/Air Traffic Management
CV/DFDR	Cockpit Voice and Digital Flight Data Recorder
CVR	Cockpit Voice Recorder
DME	Distance Measuring Equipment. A system that provides distance information from a ground station to an aircraft.
DO-160	RTCA Document 160, Environmental Conditions and Test Procedures for Airborne Equipment.
DO-178	RTCA Document 178, Software Considerations in Airborne Systems and Equipment Certification.
EASA	European Union Aviation Safety Agency
ECM	Electronic Counter Measures
ECAM	Electronic Centralised Aircraft Monitoring
EFB	Electronic Flight Bag
EFD	Electronic Flight Display
EFIS	Electronic Flight Instrument System
EGPWS	Enhanced Ground Proximity Warning System
EHSI	Electronic Horizontal Situation Indicator

Term	Definition
EICAS	Engine Indication Crew Alerting System
ESM	Electronic Support Measures (typically Military)
EVS	Enhanced Vision System (e.g., HUD, Synthetic Vision Display)
FAA	Federal Aviation Authority (USA)
FADEC	Full Authority Digital Engine Control
FANS	Future Air Navigation Systems. FANS is the internationally agreed 'next-generation' plan for more efficient communication, navigation, surveillance and air traffic management (CNS/ATM), based heavily on satellite technology. The FANS modification package typically consists of the following systems:Flight Management System software upgrade packageGPS (Global Positioning System)SATCOM (satellite communications)ACARS/Data Link (Aircraft Communication And Reporting System)EFIS (Electronic Flight Instrument System) display
FDR	Flight Data Recorder
FLIR	Forward-Looking Infrared
FLTA	Forward Looking Terrain Avoidance
FMC	Flight Management Computer
FMCG	Flight Management Control Guidance
FMS	Flight Management System
FOD	Foreign Object Damage
FOG	Fibre Optical Gyro (used in inertial navigation)
GALILEO	Global Navigation Satellite System - EU
GCAS	Ground Collision Avoidance System
GLNS	GPS Landing and Navigation System
GLNU	GPS Landing and Navigation Unit
GLONASS	Global Navigation Satellite System - Russia
GPS	Global Positioning System
GPWS	Ground Proximity Warning System
HSI	Horizontal Situation Indicator. An indicator that displays bearing, glideslope, distance, radio source, course and heading information.
HUD	Head-Up Display
IDS	(1) Integrated Display System (2) Information Display System
IFE	In-Flight Entertainment
IFF	Identification Friend or Foe
ILS	Instrument Landing System. The system provides lateral, along-course and vertical guidance to aircraft attempting a landing.
IMA	Integrated Modular Avionics
INS	Inertial Navigation System
ISIS	Integrated Standby Instrument System
LCD	Liquid Crystal Display
LRM	Line Replaceable Module
LRU	Line Replaceable Unit
MCDU	Multi-Function Control Display Unit (usually part of the FMS)
MEL	Minimum Equipment List. The list of equipment the FAA requires onboard and working on an aircraft before flying.

Term	Definition
MFD	Multi-Function Display
MFDS	Multi-Function Display System
MLS	Microwave Landing System
MTBF	Mean Time Between Failures.
NextGen	NextGen is short for Next Generation Air Transportation System - an FAA program developed to modernise today's national airspace system with the help of the entire industry. NextGen is made up of a series of initiatives designed to make the airspace system more efficient.
PFD	(1) Primary Flight Director (2) Primary Flight Display. An EFIS presentation substituting for the ADI.
PND	Primary Navigation Display
QAR	Quick Access Recorder
QZSS	Global Navigation Satellite System - Japan
RAI	Radio Altimeter Indicator
RALT	Radio Altimeter
RCVR	Receiver
RDC	Remote Data Concentrator
RDMI	Radio Distance Magnetic Indicator
RDR	Radar
RIU	Remote Interface Unit. Used to consolidate data locally and to transmit data around the aircraft via databuses.
RLG	Ring Laser Gyro (used in inertial reference navigation systems)
RMI	Radio Magnetic Indicator
R-NAV	Area Navigation (usually GPS based independent of ground aids)
RNP	Required Navigation Performance
RTCA	Radio Technical Committee on Aeronautics
RTOS	Real Time operating System (used in avionics computing for time partitions)
RVSM	Reduced Vertical Separation Minimum
Satcom	Satellite Communications
Satnav	Satellite Navigation
SSCV/DR	Solid-State Cockpit Voice/Data Recorder
SSCVR	Solid-State Cockpit Voice Recorder
SSFDR	Solid-State Flight Data Recorder
SSR	Secondary Surveillance Radar
STC	Supplemental Type Certificate
STOL	Short Take-off and Landing
SVS	Synthetic Vision System
SWaP	Size, weight and power
TA	Traffic Advisory (TCAS)
TACAN	Tactical Air Navigation System, which provides azimuth and distance information to an aircraft from a fixed ground station.
TAD	Terrain Awareness Display (maps the ground terrain for avoidance purposes)
TAS	True Airspeed

Term	Definition
TAT	Total Air Temperature.
TAWS	Terrain Awareness Warning System
TBO	Time Between Overhauls
TCAS	Traffic Alert Collision Avoidance System. This standard became mandatory in Europe for all new aircraft 2012, and for all existing aircraft in 2015. The TCAS also contains all the new ATSAW (Air Traffic Surveillance Awareness) capabilities defined by Airbus and is compliant with future US NextGen/SESAR requirements
TDR	Transponder
TSA	Transportation Security Administration
TSO	Technical Standard Order
V/NAV	Vertical Navigation
VOR	VHF Omnidirectional Radio Range. A system that provides bearing information to an aircraft
WAAS	Wide Area Augmentation System (method of differential GPS)
WRT	WXR Receiver/Transmitter
WX	Weather
WXR	Weather Radar System

6 A BRIEF HISTORY OF AVIONICS

The word Avionics was formed in 1949 from the combination of the words 'Aviation' and 'Electronics', hence Avionics. It largely reflects the advent of 'electronic' designs adopted within the traditional areas of radios, navigation and communication.

Early flight instruments used for basic navigation were of barometric/mechanical design allowing altitude and airspeed to be displayed. This was achieved by deriving analogue inputs from pitot static tubes, angle of attack sensors and total air temperature data. Equally early 'attitude' reference displays relied upon mechanical gyroscopes that provided basic inertial reference guidance. Radio communications were based upon valves adopted from designs utilised in the 1920s and 30s. Radar was initially developed during World War 2 as a defensive aid but has subsequently been widely adopted by both civil and military platforms for surveillance functions. Avionic products underwent an ongoing transformation with the arrival of the transistor in the 1950s. Electronic components such as transistors, diodes, capacitors and programmable memory devices allowed for the replacement of traditional heavy mechanical solutions. At that time, the avionics architecture was in a distributed analogue form, where the system had no data buses but had lots of wires. It is very difficult to modify such a system and the system itself is still bulky and heavy. Examples of platforms that adopted the distributed analogue architecture are Boeing 707, VC10, DC-9, and the original versions of the Boeing 737.

In the 1970s the arrival of cathode ray tube displays started to replace the many barometric mechanical instruments. The analogue architecture transformed into a digital system with data buses between components. Each component in this distributed digital architecture now contained its own computer and memory. Each unit has a dedicated function. However, it was still heavy, slow, and difficult to reprogram. Examples of platforms that adopted the distributed digital architecture are Boeing 737NG, Boeing 767, A330, Tornado, and Sea Harrier.

As digital technology evolved, the avionics system moved into the federated digital architecture which some considered as the first generation of true digital avionics systems. Under this architecture, systems communicate via a MIL-STD-1553 (STANAG 3838, or Def-Stan 00-18 Part 2) bus. Modification and reprogramming were now much simpler. The federated digital architecture allowed for a more interrelated functionality between systems that were previously independent in architectures of the past. Data transmission via buses drastically cut down on the weight and cost that traditional point-to-point systems typically required. For instance, the United States Air Force saved approximately 1,200 pounds in wire for the B-52. The 1553 system has become so prevalent over the decades that close to 30,000 aircraft now support the standard with nearly 1 million total 1553 terminals implemented.

In the 1980s Airbus was the first OEM to adopt 'fly by wire' architecture on a commercial platform (although military platforms adopted 'fly by wire' much earlier in the 1960s).

In the 1980s and 90s Electro-optical devices such as the head-up display (HUD), forward looking infrared (FLIR), infrared search and track and other passive infrared devices (Passive infrared sensor) were used to provide imagery and information to the flight crew.

The 'digitisation' of Avionics progressed throughout the 1980s and 90s with the adoption of new functions such as data recorders, flight management systems and modular avionics.

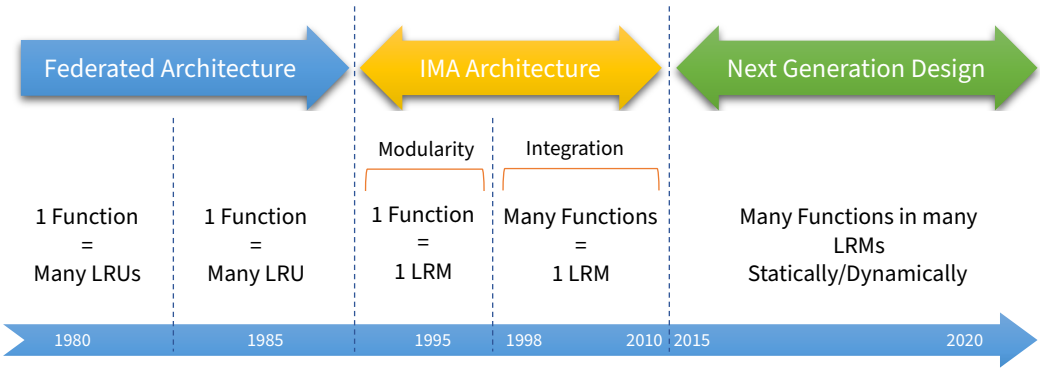


Figure 1: Timeline of avionics architecture paradigms

A number of platforms have adopted the 'integrated modular avionics' architecture in order to share computing resources more efficiently and to allow 'open architectures' that allow for additional functionality, upgrades etc. Typical 'IMA' examples include the F-35, Boeing 787, A350 and A400M platforms.

Since 2000, the availability of high-speed data networks that link to ground stations and/or air traffic control has allowed the uploading of data in real-time operating systems (RTOS) environments. This, combined with a much higher degree of flight autonomy (e.g. ADS-B), has allowed the adoption of newer Avionics functions such as Traffic Collision Avoidance Systems (TCAS), Weather Radar/Mapping and Enhanced Ground Proximity Warning Systems (EGPWS).

Within the scope section above we refer to certain elements of Avionics infrastructure as key enablers. We believe the development of high-speed data networks forms one of these key enablers. Data is rarely 'static' over time and can change throughout an aircraft mission (sometimes quicker than a pilot can be expected to react). The ability of data network systems to 'fuse' data from various sources in real-time and to provide an automatic response is therefore key to modern Avionics.

An example of the progress made in recent years is the comparison below between Arinc/AFDX serial data buses.

Databus standard	Avionics application	Platforms (typical)	Data processing
Arinc 429	Avionics	Boeing 737	12 Kbps
Arinc 629	Avionics/flight controls	Boeing 777	2 Mbps
Arinc 659	IMA	Boeing 777	60 Mbps
AFDX	IMA/Avionics	A350, Boeing 787	100Mbps

Table 3: Serial data bus processing capabilities

Arguably the biggest advance in Avionics has been the role of software in replacing hardware functions in recent years. In terms of sunk cost investment required to design, test and certify an aircraft, many believe that this could be as high as 75%/25% in favour of software for the next generation of both commercial and military platforms.

As growth in Unmanned Aerial Vehicles advance, and the degree of autonomy extends to the point where pilots are no longer necessary for many current platforms, we believe that software will play a key role in future Avionics architectures.

The tabulation below, which identifies the growth in 'lines of software code' for various applications, would appear to support this belief.

Lines of software code by application

Application	Lines of software code	Year
A320	< 1 million	1985
F-22	4 million	2000
Global Hawk UAV	8 million	2010
Boeing 787	14 million	2012
F-35	24 million	2014
Average automobile	50 — 100 million	Current
Microsoft Office	45 million	Current
Google	2,400 million	Current

Table 4: Relative scale of software for various applications

7 MAJOR AVIONICS PRODUCT GROUPS

Within this report, Counterpoint divides the avionics market into eleven market segments. The following section defines and describes the key elements included within the scope of the report.

7.1 SOFTWARE/DIGITAL SERVICES

If we had compiled this report a decade or so ago the section covering software would possibly have been an adjunct at the end of this section. The fact that it is now so prominent reflects the significant increase in both software-based avionics functions and infrastructure that has occurred in recent years.

A number of leading OEMs and avionics integrators state that the development of total platform-related software accounts for between 15% and 30% of the total airframe development costs.

Software development for safety critical avionics functions can be extremely costly due to the very rigorous needs for verification, validation and certification. It is not unusual for level A software, applied in the most critical of applications, to be duplicated and each set to be written by two different teams in order to avoid common mode failures. This approach then requires separate certification processes together with the associated costs.

Avionic-related sensors located around the aircraft are now often designed to be 'smart' i.e., with local embedded I/O and software logic. This, in part, has been driven by the need to be able to interrogate sensor status 'in situ' from a health and maintenance perspective.

The firmware and hardware, upon which software is located, are continuously driven by SWAP (Size, Weight and Performance) metrics within the avionics world. Every few years improvements in electronics are available to airframe designers who are continually challenged by airframe performance needs.

It is neither practical nor affordable for airframe operators to continuously upgrade or swap out older electronics and to benefit from associated improvements in software functionality.

Software has been utilised within avionics in the last decade or so in the following areas:

- The partitioning of disparate avionic functions, with varying criticality, all operating on a common computing platform with a Real Time Operating System (RTOS).
- Software algorithms developed in order to blend navigation data from multiple sensor sources necessary to provide primary navigation
- 'Smart' air data sensing that allows air data sources from airframe-mounted sensors to be subject to software algorithms than can determine correct data inputs.
- Software defined radios that exhibit higher reliability/lower interference

Embedded avionic software usually requires updating on a periodic basis in order to maintain functionality and currency, and this has resulted in advances with software providers who support their product in service.

The software update need has spawned a range of products that enable software to be uploaded quickly and efficiently whenever an aircraft is located at a terminal i.e., software portable loaders, Wi-fi loaders, electronic flight bags, USB loaders etc.

In addition, there are providers of digital services providing a range of services on a periodic subscription service. These include navigation database packages (updated every 28 days typically).

Equally, many end-users/operators will need to subscribe to data or communication services (Wi-fi, Satcom) in order to allow passengers to communicate externally during the flight. These services are usually provided via satellite which requires a monthly subscription.

7.2 INTEGRATED MODULAR AVIONICS

The cockpit in any aircraft platform, be it commercial or military, is constrained in terms of space and volume. This results from the economics of flight that require continual investment in reducing weight and volume.

As a result of these constraints much of the Avionics equipment, that often requires active cooling, is located within a number of designated Avionics bays.

The heat generated by modern Avionics would make the cockpit uninhabitable if all of the equipment were to be co-located there.

A quick inspection of any commercial transport aircraft's Avionics bay, designed in recent decades, would reveal a total count of 50, 60 or 70 discrete Avionics 'boxes'. Each of these bespoke boxes contains packaging, connectors, power supplies, input/output protocols and its own software operating system together with the algorithms appropriate to the specific utility function.

Individual suppliers of these bespoke 'boxes' have their own supply chains resulting in multiple sources of individual components.

The concept of IMA, first adopted within the military sector, is to provide a single source for all of the 'common' hardware and software elements of Avionics. By creating a software environment that can accommodate multiple 'utility' functions on a common platform, with suitably partitioned software, allows OEM airframe specifiers to dramatically reduce the overall cost and weight of the Avionics suite.

Clearly not all suppliers rushed to embrace the concept of IMA given the significant implications for both retention of Intellectual Property and the potential impact upon aftermarket revenues. Equally the suppliers' 'bill of material' will shrink given that the elements common to the core IMA will switch to the provider of the IMA, thereby reducing revenue.

Integrity issues surrounding common mode failures and software partitioning also served to slow the widespread adoption of IMA architectures.

Many of the OE IMA providers/integrators rely upon 3rd party software providers who have expertise in partitioning and embedding software that is operating in real time (RTOS). Companies such as Wind River, Lynx software Technologies and Green Hill software have all supported the development of IMA-related software.

Both Honeywell and Raytheon (Collins Aerospace) will argue that their integrated cockpit offerings, as represented by Primus Epic/Apex and ProLine Fusion respectively, predate the adoption of IMA by OEM airframers.

Honeywell, Collins and Thales have all provided the market with a range of 'off the shelf' integrated cockpits that typically include displays, flight management, auto-pilot, navigation, surveillance and communication functions operating within a common computing framework.

These offerings, however, have not always adopted 'open architectures' that would allow 3rd parties to import additional utility functions (independently of the OEM).

However, this is now changing with the manufacturers of large civil aircraft forcing the adoption of 'open IMA architectures' that allow much greater flexibility and portability.

The block diagram below indicates what a modern commercial IMA architecture looks like with all of the avionics functions identified. We have highlighted those functions, be they avionic, cabin or utility, which are typically hosted and resident within the IMA computing infrastructure. IMA architectures within military platforms derive many of the same benefits to civil applications in terms of common processing, input/output protocols and data-buses.

However, one of the main drivers within military platforms is the need to generate high speed fusion of data drawn from a number of disparate sensor systems. High performance military fighter aircraft operating within multiple threat environments are required to assess threats from land, sea or air and to take the necessary evasive action together with deployment of effective countermeasures.

The limiting factor in these scenarios can be the pilot in terms of data overload and reaction times.

The emphasis therefore from an IMA perspective is to be able to fuse the terabytes of data available from many sensors and to clearly annunciate to the pilot the available options (all within fractions of a second).

Platforms that have adopted IMA started with the Boeing 777 (Honeywell AIMS system) and include the F-22, F-35, A380, Boeing 787, A350 and A400M.

Bombardier's CSeries, now the Airbus A220, adopted Collins Pro-Line Fusion with open architecture IMA as its baseline.

Bombardier also adopted IMA for its range of Global business jets.

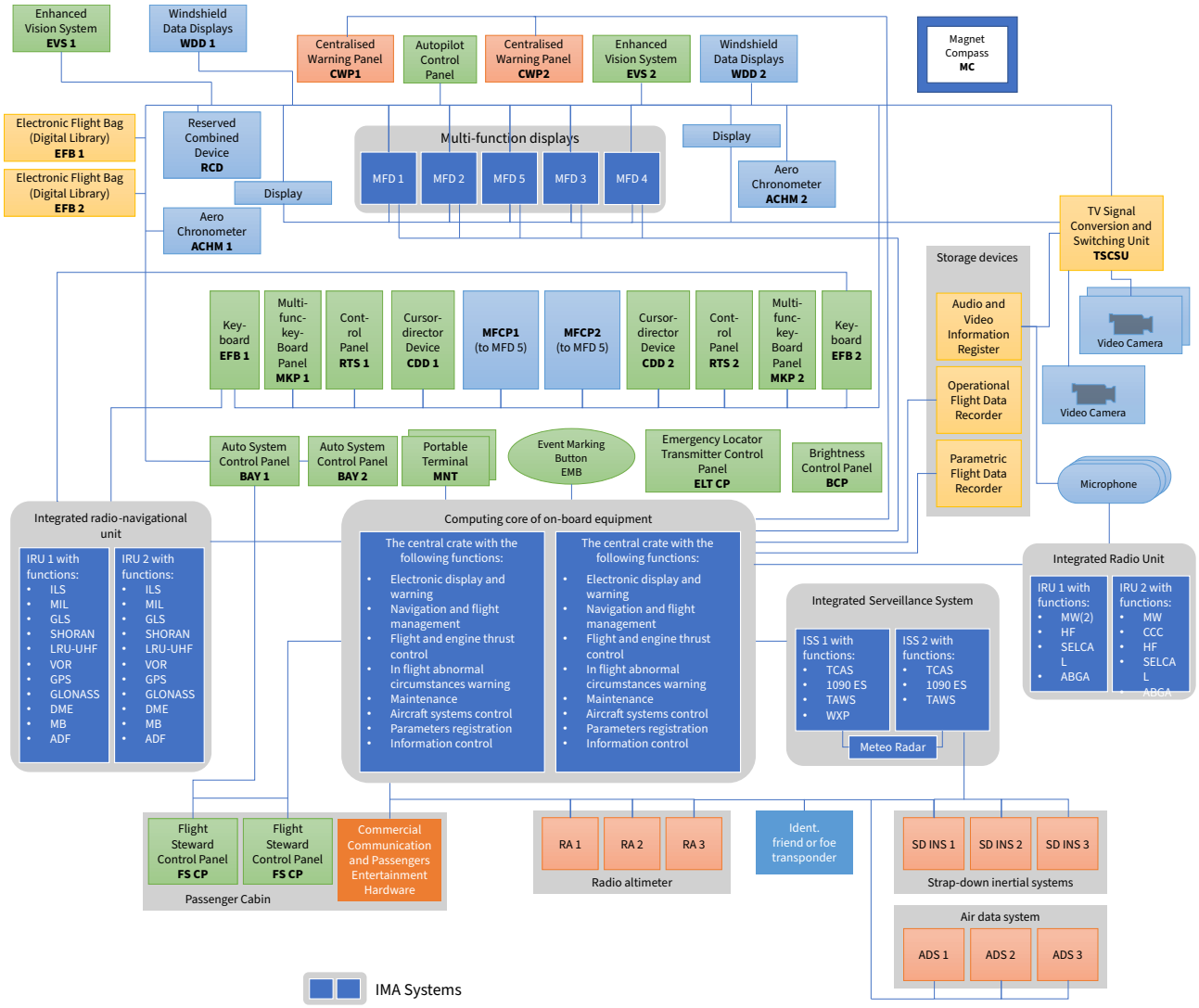


Figure 2: Modern commercial IMA architecture

The Sukhoi 100 Superjet and the Comac C919 have also adopted IMA architectures.

We believe that the benefits of IMA are now well proven in service and that all 'next generation' commercial and military aircraft will adopt open IMA architectures as their baseline. The reducing cost of electronics will likely result in many of the smaller regional jets, business jets and military platforms also being in a position to adopt open IMA architectures.

Whilst major IMA/common computing providers (Honeywell, Raytheon, Thales, L3 Harris and GE Aviation) have established significant market share within the larger Aerospace & Defence sectors, the lower end of the market, in terms of platform size and value, is supported by the likes of Garmin and Universal Avionics.

The cost to develop and procure an IMA/common computing resource for these lower value platforms would be prohibitive and not justified.

In the business aviation marketplace, Collins, Honeywell and Garmin integrated flight decks which, from a pilot's perspective, presents a seamless interface. Collins offers the Pro Line 21 Fusion, Honeywell offers Primus Epic, co-branded by Gulfstream (Planeview) and Dassault (EaSY) and Gramin offers the G3000 and G5000.

7.3 FLIGHT MANAGEMENT/GUIDANCE SYSTEMS

Flight Management Systems link to a number of related avionic systems in order to be able to execute satisfactorily. They require an interface with navigation systems, flight controls and the autopilot in addition, to be able to display progress with the chosen flightpath.

Over many decades of aviation development aircraft and pilots have been provided with many aids designed to assist navigation, which is described more fully in the next section.

The FMS is a specialised computer system that automates a wide variety of in-flight tasks, reducing the workload on the flight crew to the point that modern civilian aircraft no longer carry flight engineers or navigators. A primary function is in-flight management of the flight plan. Using various sensors (such as GPS and INS often backed up by radio navigation) to determine the aircraft's position, the FMS can guide the aircraft along according to the flight plan. From the cockpit, the FMS is normally controlled through a Multi-Function or Master Control Display Unit (MCDU) which incorporates a small screen and keyboard or touchscreen. The FMS sends the flight plan for display to the Electronic Flight Instrument System (EFIS), Navigation Display (ND), or Multifunction Display (MFD).

Most FMS systems contain a navigation database. The navigation database contains the elements from which the flight plan is constructed. The navigation database (NDB) is normally updated every 28 days, in order to ensure that its contents are current. Geographies can change, cities grow, skyscrapers get built etc., all of which needs to be captured within the NDB on a periodic basis.

There are a number of NDB service providers including Boeing (Jeppesen), Honeywell, GE Aviation and NAVBLUE (Airbus subsidiary) who basically provide a subscription service for various NDB services. Garmin supports its product family with navigation database services provided directly from Garmin.

These NDB services can extend to include FMS software for simulators and databases for Electronic Flight Bags (EFB). The EFB is essentially a pilot's 'bag' of navigation charts, preferred routes, airport data that today is all hosted on an iPad or laptop PC.

Whilst the FMS is configured to fly the optimum flightpath consistent with airline cost and performance metrics, the airline can programme a range of preferred routes via the FMS/NDB system.

NDB providers are licenced and can only offer services if approved by the relevant authority e.g., FAA, CAA, EASA, US Air Force.

In operation the FMS 'initiates' a position derived from the various external navigation aids (VOR, DME, GPS) which it 'blends' with the on-board Inertial Reference System (IRS) which in itself is often triplicated on modern airliners.

Once an initial position has been established the flight can commence based upon achieving a successive number of 'waypoints' that, taken together, constitute the overall flight journey.

This flight path will typically be displayed upon the cockpit Navigation Display in order that the flight crew can monitor progress.

The Autopilot can be selected to execute the FMS flight path via commands to the engine throttles and the flight guidance or flight control computers.

FMS systems were first made available on the Boeing 767 (although navigation computers preceded this) followed by the Boeing 737. Airbus also has a long tradition with FMS, having offered it on its early A300/A310 aircraft and all subsequent platforms.

Airlines/pilots spend considerable amounts of time and money training with FMS systems in flight simulators. As a result of personal experience, issues with cross training and historic preferences, it is not unusual for an airframe constructor to offer more than one FMS option on a given platform. Airbus for example offers airlines/operators both the Thales/GE Aviation FMS and the Honeywell FMS systems on the A320 and A330 family of aircraft.

Military fighters do not typically have an FMS system as they are high performance platforms controlled by the pilots and need to be able to react to their environment.

Military transport aircraft on the other hand do rely upon FMS systems as they have a more predictable mission, and they need to have the navaids on board that allow them to fly in highly regulated civil air space.

7.4 NAVIGATION

In addition to basic on-board aircraft instruments (altitude, airspeed, attitude, compass), ground-based systems have also been developed to support take-off and landing. These include Instrument Landing Systems (ILS), Direction Measuring Equipment (DME), VHF Omni-directional Radar (VOR), Automatic Direction Finder (ADF).

For navigation of the aircraft between waypoints/airports, on-board navigation systems have typically consisted of Inertial Navigation Systems (INS) or Inertial Reference Systems (IRS) and, more recently, Global Positioning Systems (GPS). The latter is clearly dependent upon access to a network of satellite-based GPS signals which need to be received by the aircraft, Other GNSS systems, GLONASS (Russia), Galileo (European Union), BeiDou (China), NavIC (India), and QZSS (Japan) provide position, navigation and timing (PNT) services than can be used by multi- navigation systems.

GPS systems are only accurate to about 15m — 30m which is not adequate for aircraft landing or traffic avoidance purposes. There are a number of regional 'enhanced' GPS services including WAAS (US), EGNOS (EU) and GLONASS (Russia) all of which provide improved positional accuracy data.

Most of the current FMS systems noted above will draw upon these services for more accurate position data.

In the 1980s the International Civil Aviation Organisation (ICAO) established the special committee on the Future Air Navigation System (FANS), charged with developing the operational concepts for the future of air traffic management (ATM). The FANS report laid the basis for the industry's future strategy for ATM through digital CNS using GPS satellites and air/ground data links.

In the 1990s Boeing announced a FANS-1 product based on the early ICAO technical work for automatic dependent surveillance (ADS) and air traffic controller - pilot data link communications (CPDLC), which it implemented in the Boeing 747-400. It used existing satellite-based ACARS communications (Inmarsat Data-2 service) and was targeted at operations in the South Pacific Oceanic region. The deployment of FANS-1 was originally justified by improving route choice and thereby reducing fuel burn.

FANS-A was later developed by Airbus for the A340 and A330. Boeing also extended the range of aircraft supported to include the Boeing 777 and 767. Together, the two products are collectively known as FANS-1/A.

Both the Airbus A350 and Boeing 787 have FANS-1/A capability.

The software associated with FANS capabilities is typically located within the aircrafts FMS system.

Significant navigation improvements have involved a transition from inertial navigation to satellite navigation using the GPS satellites. This introduces the concept of actual navigation performance (ANP). Previously, flight crews would be notified of the system being used to calculate the position (radios, or inertial systems alone). Because of the deterministic nature of the GPS satellites (constellation geometry), the navigation systems can calculate the worst-case error based on the number of satellites tuned and the geometry of those satellites. The improvement not only provides the airplane with a much more accurate position, it also provides an alert to the flight crew should the actual navigation performance not satisfy the required navigation performance (RNP).

Airline operators need to have their FANS 1/A capable aircraft connected to both the ATN (Aeronautical Telecommunication Network) and to the Iridium and/or Inmarsat Satellite network for which there is a periodic service charge.

AirSatOne provide advanced FANS 1/A services through their Flight Deck Connect portfolio of products. Flight Deck Connect includes a connection to the Iridium and/or Inmarsat satellites for FANS 1/A (via Datalink), and Safety Voice Services, along with ancillary services (AFIS/ACARS) such as weather information, engine/airframe health and fault reports.

The avionics retrofit market has been boosted significantly by the need to make operators fleet of aircraft 'FANS compliant' in order to be able to fly the best, most economic routes.

The FANS modification package typically consists of the following systems:

- Flight Management System software upgrade package
- GPS (Global Positioning System)
- SATCOM (satellite communications)
- ACARS/Data Link (Aircraft Communication And Reporting System)

- EFIS (Electronic Flight Instrument System) display

Military aircraft need to be more 'autonomous' when it comes to navigation and minimise external links, however, all modern military platforms use GPS as a primary means of navigation.

They also have the same basic navigation tools, when compared to civil aircraft, such as IRS, radar altimeters, DME, ILS etc.

A distinct requirement for many military platforms is the requirement for low level flying at ground hugging altitudes. In this situation it is likely that the aircraft will be fitted with a Terrain Mapping database such as that provided by BAE Systems or Raytheon (commonly referred to as TERPROM) which is linked to the aircraft navigation and flight control system.

Even large military platforms such as the A400M can have a low altitude ground navigation capability as required for the German partners in the programme.

7.5 AUTO-PILOT

The first autopilot was designed by Sperry Corporation in 1914 and successfully demonstrated at a Paris Airshow by the pilot taking his hands off the control wheel and flying flat and level.

Honeywell developed a number of autopilots during WWII largely in order to reduce pilot workload.

Small aircraft (<20 seats) for short haul flights do not require an autopilot but all larger passenger aircraft are required by regulatory authorities to have one fitted.

Auto-pilots can either be one-axis (roll control or wing levellers), two axis (pitch as well as roll) or three-axis devices (pitch, roll and yaw).

Autopilots divide a flight into taxi, take-off, climb, cruise (level flight), descent, approach, and landing phases. Autopilots can automate all of these flight phases except taxi and take-off. An autopilot landing on a runway and controlling the aircraft on rollout (i.e., keeping it on the centre of the runway) is known as a CAT IIIB landing or Auto-land. This CAT IIIB facility is available on many major airports' runways today, especially at airports subject to adverse weather phenomena such as fog.

Current A/Ps (often referred to as 'George') can typically fly 80% or 90% of a long-haul route allowing the crew to focus upon route planning, EICAS messages, communications with ATC, surveillance etc.

There is a distinct difference between A/P and A/T which is simply explained as the A/P controls the flight controls for pitch, attitude etc whereas the A/T control engine for thrust. Most A/Ps can be selected in either "thrust" mode or "speed" mode and both have their differing uses dependent upon whether the aircraft is in take-off (thrust) mode or in cruise mode (speed). In modern aircraft both A/P and A/T are effectively controlled by the FMS and link to the engines via the FADEC.

Older aircraft had a separate A/T and/or A/P avionics box but modern aircraft have the software algorithms built into the FMS with links to the Flight Control System and the engine FADECs.

Servo-motors are installed within the pilot's thrust control stand in order to control the required thrust via the thrust lever position.

Smiths (now GE Aviation), Rockwell Collins (now Collins Aerospace and part of Raytheon) and Sextant Avionique (now Thales) have all developed A/Ps in recent decades. Companies serving other than large commercial aircraft with A/P offerings include Garmin, Safran, Cobham and Universal Avionics.

7.6 DISPLAYS

A key Avionic interface for flight crew is the set of cockpit displays that annunciate all the relevant flight data necessary to execute the mission.

These displays have evolved over many decades from 'steam driven' barometric instruments (all mechanical) through cathode ray tubes to flat panel LCD devices found today in modern aircraft.

Basic flight displays found in the earliest of flying machines, such as indicators for airspeed, altitude, attitude, heading, chronometer, have now been superseded by a whole host of large format colour display data that, being flexible in terms of format, can include a multitude of permutations.

Interestingly, having worked in the industry the author has seen the 3 ATI, 4 ATI and 5 ATI standard display format (effectively 3 ATI = a 3 inch display) increase to today's large format colour displays that typically measure 10 by 15 and are replicated in 5 or 6 positions. This alone is equivalent to a 500%+ increase in cockpit display real estate!

It is not surprising that OEMs, Avionics designers and aircraft operators have been concerned at pilot overload.

The science of display formatting, often referred to as the man/machine interface, has been adopted by aircraft designers in order to avoid 'pilot overload'. Most modern Multi-function Displays can be switched to provide additional / alternative formats thereby further increasing available displayed data.

Having Multi-function displays can be a necessity in order to provide redundancy within the overall display suite in the case of a single display failure.

Modern display architectures require the consolidation of considerable amounts of mission-related data derived from multiple aircraft systems but in a common data format. This formatted data can then be used to generate symbols or graphics that can be used to drive the LED displays. Typically, therefore modern Avionic display suites include both data concentrators and graphics generators.

There is no such thing as a standard cockpit layout for display suites. However, most include a combination of the following:

- Primary Navigation Display(s) — used to show basic aircraft navigation metrics such as attitude, airspeed, altitude, heading, route, aircraft position and can be overlaid with surveillance data such as weather radar, traffic etc.
- Multi-Function Display — as above but can add or switch to provide charts, video (airport taxiing), system synoptics and health status, TCAS, WXR, EPGWS etc.
- EICAS — the Engine Indicating and Crew Alerting System display shows the status of engine thrust and other engine related parameters such as fuel status — usually a split screen to allow for both engine parameters and crew alerting prompts, system failures etc.
- ACARS — Aircraft Crew Alerting and Reporting System — not usually a stand-alone display but incorporated within an MFD noted above.
- ECAM — Electronic Centralised Aircraft Maintenance — not usually a stand-alone display but incorporated within a MFD noted above.
- Multi-function Control Display Unit (MCDU or CDU) usually provides the crew input for the FMS system e.g., route planning, alternatives etc.
- Integrated Standby Instrument — an independent back-up that, in the event of loss of primary displays, allows basic attitude, altitude and airspeed data to be generated and displayed independently.
- Mission displays (military aircraft) — these can include a multitude of options depending upon the role of the military platform including maps, charts, reconnaissance, synthetic vision for poor visibility, navigation and onboard sensor status.
- Head Up Displays (HUDS) — originally designed for military use whereby the pilot is not distracted by the suite of Head Down Displays (HDD) - they are now also being adopted on commercial aircraft in order to enhance situational awareness.
- Helmet mounted displays — almost exclusively utilised in the military field these displays have the advantage of maintaining key data in the pilot's peripheral field of vision irrespective of where his head is facing.
- Minor displays — can include radar altimeters, clocks, vertical speed indicators, pitch indicators (nose up attitude), fuel gauges, radio tuning channels etc.

A significant factor to consider is that the useful life of an airframe which can be 40, 50 or 60 years whereas the useful life of a display suite may be 10, 12 or 15 years. This results in a considerable aftermarket for retrofits and upgrades.

The main drivers for avionics display upgrades are noted within the commentary below. However, there is also a wealth of other drivers including regulatory (mandated) improvements, pilot influence, fleet commonality, cross training issues (between platforms within an operating fleet), cost of ownership, to name but a few.

A recent Avionics survey of end-users resulted in the following statement that ""40 percent of our readers are looking to acquire new cockpit displays for their current fleet of aircraft, proving that new cockpit display system technology enjoys a healthy demand for retrofitting purposes. The overwhelming majority nearly 80 percent of our readers say that reliability is their top concern when looking to replace their current displays, while another 44 percent of respondents point to size as their primary focus when upgrading. Additionally, 41 percent of readers want LCD technology, whereas 35 percent are looking to display information about nearby air traffic in their cockpit."

As aircraft move into cargo service, opportunities to update and modernise cockpit display systems when cargo conversion modifications are undertaken.

7.7 SURVEILLANCE

Surveillance is arguably a subset of a number of Avionic functions including navigation, sensors and displays. However, its overall prominence has grown within both the civil and military arenas in the last couple of decades.

For civil aircraft it is known that 90%+ of accidents relate to the take-off and landing phases of any flight. Subsequent analysis of these events has shown that a lack of 'situational awareness' by the crew was often a key contributory factor (controlled flight into terrain, mid-air collisions, missed runways, aborted landings/go arounds, 'near misses' etc).

As part of the Future Air Navigation (FANs) requirements it was deemed not appropriate to increase the burden on Air Traffic Controllers (ATC) with additional controls and monitoring, but instead to implement a system of 'autonomy' for each and every aircraft licenced to use congested airports.

This 'autonomy' is enabled by a proliferation of independent surveillance aids such as Traffic Collision Avoidance Systems, Enhanced Ground Proximity Warning Systems and Weather Radar.

In early 2000s the FAA mandated the adoption of Automatic Dependent Surveillance-Broadcast (ADS-B) as a primary technology supporting the FAA's Next Generation Air Transportation System, or NextGen. This initiative essentially shifts aircraft separation and air traffic control from ground-based radar to satellite-derived positions. Many countries have since adopted the same standards for ADS-B capability.

The ADS-B system adoption allows aircraft to be aware of each other's respective position which can be displayed on a TCAS system. Equally the aircraft can communicate position and velocity information to each other via this link. It also can be used to maintain separation minima between aircraft in congested airspace.

A further protocol, known as ADS-A, is based on a one-to-one relationship between an aircraft providing ADS information and a ground facility requiring receipt of ADS messages. For example, ADS-A reports are employed in the Future Air Navigation System (FANS) using the Aircraft Communications Addressing and Reporting System (ACARS) as the communication protocol. During flight over areas without radar coverage, e.g., oceanic and polar, reports are periodically sent by an aircraft to the controlling air traffic region.

Controlled flight into terrain (CFIT) is a further major issue surrounding situational awareness that has resulted in the generation and adoption of a number of Avionic solutions including Ground Proximity Warning Systems (GPWS), Enhanced Ground Proximity Warning Systems (EGPWS) and Terrain Awareness and Warning Systems (TAWS).

TAWS is a system meant to forecast potential danger in the aircraft's path and terrain. There are warnings systems and alerts to provide caution to the flight crew of potential danger, thereby allowing them to have sufficient time to make the necessary changes to the flight path to avoid collision.

GPWS is similar to TAWS. However, it has a number of 'modes' typically one through to five which are used to determine ever increasing levels of threat and response times required. In the 1990s Honeywell developed EGPWS which has a more refined approach to steeply rising ground for example.

These systems use topographical data to 'map' the terrain and these databases need regular updating. One famous anecdote relates to Honeywell, when flight testing EGPWS, they came across one mountain that was 1000 ft higher than that registered within the database!

Military aircraft typically have need of high performance surveillance systems that need to respond in milliseconds by identifying threats as represented by other aircraft, missiles, or enemy detection systems.

Military missions often call for very low altitude approaches in order to avoid detection. These can only be achieved if the aircraft has a precise terrain database, e.g. TERPROM, and the means by which the profile can be tracked via highly responsive primary flight controls.

A typical modern multi-role fighter such as the F-35 will likely be equipped with the following sensors which are utilised as part of its overall 'surveillance' capabilities:

- Distributed Aperture System (electro-optical) — 6 off providing 360 degree all round view of incoming threats.
- High power AESA radar system that can 'look beyond the horizon'
- Electro-optical targeting system (Forward Looking Infra-red Radar (FLIR), Infra-Red Search and Track (IRST))
- Identification Friend or Foe (IFF) Radio Frequency and microwave transmitters.
- Electro-optical targeting system

Military transport aircraft will have many of the surveillance systems fitted as described for commercial aircraft above.

7.8 COMMUNICATIONS

Aircraft communications are being expanded; in fact, in recent years a new abbreviation has surfaced. CNS ATM stands for "Communication, Navigation, and Surveillance and Air Traffic Management" which was created to support modernisation of the dated and overload-prone Air Traffic Control system.

Traditionally radios have formed the communications means between aircraft and ATC. These radios operate over VHF and HF channels ensuring, where possible, clarity and adequate levels of security.

The allocation of radio spectrum is defined by the International Telecommunications Union (ITU) and relates the use of a frequency to a specific service. The ITU has assigned frequencies for use by aircraft analogue voice dialogue in parts of the 'High Frequency' (3-30 MHz) band and in the 118-137 MHz section of the wider 'Very High Frequency' range. Aircraft can use radios operating in the HF radio band for long-range communications as the signals are reflected by the ionosphere. Unfortunately, when using HF, the link audio quality is very poor due to this long propagation of the wave. Aircraft can use radios operating in the VHF band to communicate with other radios in line-of-sight coverage. These signals do not reflect off the ionosphere or penetrate obstacles such as mountains or buildings. The advantage of VHF over HF is that the link quality is much better and there is greater reuse of the frequency channel.

Within the past two decades there has been a move to transmit both voice and data via satellites. The move to data provides for higher reliability and integrity given the potential for miscommunication and misunderstanding with analogue voice transmissions.

The addition of data link capability to HF radio is a way for aircraft operators to get additional use out of the radios they still carry in order to meet ATC rules when most communications migrate from voice to data. However, the HFDL system provides delivery of 95% of transmitted messages in three to four minutes compared to 20 to 30 seconds via satellite communications - so it is likely to be limited to providing a safety net in case of failure of satellite avionics, rather than a good alternative to satellite communications.

In the period through the 1980s and 90s ACARS (Aircraft Communications Addressing and Reporting System) was adopted as a digital datalink system for transmission of short messages between aircraft and ground stations via airband radio or satellite.

ACARS as a term refers to the complete air and ground system, consisting of equipment on board, equipment on the ground, and a service provider.

ACARS interfaces with flight management systems (FMS), acting as the communication system for flight plans and weather information to be sent from the ground to the FMS. This enables the airline to update the FMS while in flight and allows the flight crew to evaluate new weather conditions or alternative flight plans.

In addition to the legacy ACARS VHF system, ACARS over Iridium offers expanded connectivity where satellite transport of messages provides near universal coverage when beyond the range of VHF stations.

UAVs and Urban Unmanned Aircraft will not rely upon communications in traditional terms but there will still be the need for interrogation between ground control and the vehicle.

7.9 MISSION SYSTEMS

Purists may argue that military mission systems are largely distinct from avionics in general. However, we have included this sub-set as we see a number of drivers for convergence between avionics and mission systems as follows:

- Common computing resources with open architectures providing a path for affordability (COTS), upgrades, and inter-operability in both civil and military arenas.
- High speed data fusion from many sensor sources that require computations in real time.
- 'Commercial Off-The-Shelf' (COTS) developments common to both civil and military mission functions.

A military avionics system is generally divided into 5 distinct sub-systems: Navigation, Communications, Sensors, Mission Systems and Displays/Controls.

In constructing this report, we have elected to deal with both and Mission Systems and Sensors, as they relate to military platform Avionics, given that the other three categories noted above are common to both civil and military platforms and have been described earlier in this report.

We have adopted the definition of 'Mission Systems' as it relates to military platforms to typically include a number of functions or sub-systems as follows:

- Stores management
  - Weapons, payload, auxiliary fuel tanks, external pods
- Specific platform roles
  - Search and rescue
  - Transport (troops, equipment)
  - Maritime patrol
  - In-flight refuelling
  - Electronic Warfare/Electronic Counter Measures
- C4ISR (Command, Control, Communications, Computers, Intelligence, Surveillance, Reconnaissance)
- ISTAR (Intelligence, Surveillance, Target Acquisition and Reconnaissance)

Unlike commercial aircraft that have a narrow range of mission objectives (transporting people and cargo from A to B) there exists a much wider range of 'mission' functions within the military arena as noted above.

Aircraft are often dedicated to specific military missions such as Maritime Patrol (P-8A, P-3C, Atlantique 2), AEW (AWACS, EMB145 AEW), AGS (JSTARS, ASTOR). These platforms are likely to have ISTAR related mission avionics including, data gathering, data fusion, communications through SATCOM or dedicated data links (encrypted or not), tactical situational awareness, and all the supporting sensors whether it be on manned or unmanned platforms.

Military transport/payload platforms such as C-130J, C-5 Galaxy, A400M and the KC-390 will have similar 'mission avionics' to those found on civil air transport aircraft because they are both manned and they fly in civil arenas. However, these platforms will often have augmented avionics to allow for threat detection, electronic countermeasures and low altitude flying capability.

Air strike platforms, such as the F-35, will have very high-speed/high-capacity data networks to allow for both the significant amounts of data, the need for data fusion between sensors and the very high speed reaction times required to negate threats and/or exploit strike targets. The F-35 features a new 1394B serial data bus with three high-speed processors that provide the aircraft with a robust, triple-redundant mission systems management network.

Rotorcraft can cover a wide variety of mission roles including search and rescue, fire-fighting, troop carrier, gunship, medevac, border patrol and cargo/payload.

The CH-47F (Chinook), for example, is an advanced multi-mission helicopter and as such contains a fully integrated, digital cockpit management system, Common Avionics Architecture System (CAAS) Cockpit and advanced cargo handling capabilities. However, it can be utilised as part of land, sea and air operations and it has sold extensively throughout the world to many nations.

As with many military platforms that are multi-mission and/or multi-nation (e.g., CH-47K, C-130J, A400M, F-35, Typhoon, F-18, Apache AH-64) the core platform needs to be highly adaptable and this in turn requires flexible avionic architectures that can accommodate a number of diverse mission computing functions.

Hence the Open Mission Systems (OMS) initiative of the U.S. Air Force Research Laboratory "to develop industry consensus for a non-proprietary mission system architectural standard that enables affordable technical refresh and insertion, simplified mission systems integration, service reuse and interoperability, and competition across the life-cycle", focusing on the interfaces between software services and hardware subsystems, and how data is exchanged across them.

This is but one of a number of initiatives within Europe and the US to reduce costs and improve flexibility, upgrade paths, interoperability and reduce overall life cycle costs within mission computing.

A good example of a COTS approach to Mission computing was undertaken by Thales when, in 2018, they were seeking a commercial off-the-shelf (COTS) open-architecture computer for use with the company's new Elix-IR Next Generation Threat Warning System. They selected a Packaged COTS (PCOTS) pre-integrated, rugged mission computer from Curtiss-Wright's Defense Solutions division. Elix-IR is an airborne multifunction passive infrared (IR) threat warning system designed to provide enhanced mission survivability. Under the contract, Curtiss-Wright will provide Thales with a custom PCOTS rugged mission computer that combines Curtiss-Wright 3U OpenVPX single-board computers, two FPGA cards, and switches housed in a rugged chassis.

Section 14.1 of this report also looks at the positive impact that Commercial Off the Shelf (COTS) avionics is having upon the affordability of military mission equipment.

7.10 SENSOR SYSTEMS

In terms of Avionics Counterpoint has not set out to analyse avionics-related sensors in great depth in this report. However, we do recognise the significant reliance that the success of overall Avionics architectures has upon their associated sensor suite in many of the Avionics sub-systems.

We have also only given consideration to on-board sensors and not included ground-based sensors.

The following is a summary of the Avionics sub-systems and their associated sensors found in civil and military aircraft.

Avionics sub-system	Onboard Sensors	Comments
Navigation	Air data (pressure, temp)	Pitot static/Total Air Temp/Angle of Attack sensors — feed into Air Data Modules.
Inertial Reference Systems	Accelerometers, Gyroscopes	Fibre optic gyro (3 axis required)Ring laser gyrosSolid state gyros
Radio comms	Antennas, transceivers	Radio navigation DME/VHF/HF/VOR/LOC/ADF/SATCOM/GPS/ATC/TCAS (23 on a Boeing 787), TACAN
Surveillance	Multi-Mode Receivers, RadarFLIR, ATC/TCAS, WXTransponders	Used for TCAS, EGPWS, TERPROM, Weather Mapping. ADS-B autonomy
Flight Management Systems	NAV and IRS related sensors.	GPS, WAAS, GLONASS etc provided externally.

Mission related sensor systems	Wide array radar, Distributed Aperture System, Electro-optical target acquisition, Forward Looking Infrared (FLIR), Enhanced Vision Systems, Multi-Colour Infrared Alerting Sensor, Infra-red frequency detectors	Active electronically scanned radar (AESA); Infrared cameras (6 on F-35); FLIR combined with Infrared Search and Track (IRST);Cameras and video, synthetic display systems; Used on A400M; Defensive Aids

Table 5: Avionics subsystems and associated sensors

Sensors are subject to the same SWAP (Size, Weight and Performance) drivers as is the case with Avionics generally.

Evidence for this is shown with the F-35 platform where, only 8 years into service, all mission related onboard sensors either have been or are currently undergoing upgrade to next generation sensors.

Within the civil arena a similar pattern of sensor upgrades exists every 10 to 15 years often driven by regularity changes. These include:

- reduced vertical separation minima (RVSM) — 2,000 ft to 1,000ft
- TCAS mandates in EU/US — transponder equipped.
- Automatic dependence surveillance (ADS-B) — TCAS, ATC monitoring
- FANS/NEXT GEN navigation — controller/pilot data link communications, GPS navigation

Airlines/operators will upgrade avionics sensors to provide more efficient operations and thereby save fuel (e.g., MMRs for provision of GPS navigation).

7.11 DATA/DATA NETWORKS

We have elected to include data/data networks within this report as they represent a key part of the infrastructure without which Avionics could not function.

There are two distinct parts to this section which are as follows:

- Avionics data networks
- Avionics data products/services

7.11.1 AVIONIC DATA NETWORKS

Modern avionics are required to communicate data between the following areas of flight operations:

- related avionics functions (e.g., Communications, Navigation, Surveillance)
- related utility systems (e.g., Flight control, Fuel systems)
- other aircraft within certain ranges (e.g., ADS-B, TCAS)
- ground based air traffic control (FANS, Next Gen)
- ground based data services for monitoring, maintenance and support most modern civil aircraft have an on-board OMS with real time data downlink capability).

Within the aircraft itself the onboard data networks have evolved over many decades since the adoption of electronics. The number of data network protocols have increased over time to reflect the needs for higher speeds, higher bandwidth, new technologies (e.g., IMA, shared computing resources), data downlinks to ground based services etc.

Below is a list of the more common avionics databus protocols, with their primary applications, which include:

- Aircraft Data Network (ADN): Ethernet derivative for Commercial Aircraft

- Avionics Full-Duplex Switched Ethernet (AFDX): Specific implementation of ARINC 664 (ADN) for Commercial Aircraft e.g., Airbus A350.
- ACARS (an ARINC service) a digital datalink system for transmission of short, relatively simple messages between aircraft and ground stations via radio or satellite.
- ARINC 429: Generic Medium-Speed Data Sharing for Private and Commercial Aircraft. ARINC 429 is the most widely used data bus standard for aviation. The bus is capable of operating at a speed of 100 kbit/s.
- ARINC 664: defines the use of a deterministic Ethernet network as an avionic databus in aircraft like the Airbus A380, the Sukhoi Superjet 100, the A220 (formerly Bombardier CSeries), and the Boeing 787.
- ARINC 615 is a family of standards covering 'data loading', commonly used for transferring software and data to or from avionics devices. The ARINC 615 standard covers 'data loading' over ARINC 429.
- ARINC 629: Commercial Aircraft (Boeing 777). Up to 120 terminals can share the databus.
- ARINC 653 is a standard Real Time Operating System (RTOS) interface for partitioning of computer resources in the time and space domains. This standard will be found in common computing resources and IMA architectures.
- ARINC 708: Weather Radar for Commercial Aircraft
- ARINC 717: Flight Data Recorder for Commercial Aircraft
- ARINC 702A-4, a standard defining the advanced Flight Management Computer (FMC) system, was updated to add winds temperature definitions as required to support 4D trajectory operations in NextGen and Single European Sky airspace environments.
- ARINC 825: CAN bus for commercial aircraft (for example Boeing 787 and Airbus A350)
- IEEE 1394b: Military Aircraft
- MIL-STD-1553: Military Aircraft. A military standard published by the United States Department of Defense that defines the mechanical, electrical, and functional characteristics of a serial data bus.
- MIL-STD-1760: Military Aircraft. Stores Electrical Interconnection System defines a standardised electrical interface between a military aircraft and its carriage stores. High-Speed 1760 specifies a gigabit-speed interface based on Fibre Channel, operating at 1.0625 Gbit/s.
- TTP — Time-Triggered Protocol: Boeing 787, Airbus A380, Fly-By-Wire Actuation Platforms from Parker Aerospace.

It is worth noting that Aeronautical Radio Incorporated (ARINC) was founded in 1929 in order to help promote radio standards across a number of industries including Aerospace. It was acquired by Rockwell Collins in 2013. However, it continues to service the industry at large with new protocols driven by emerging technologies.

The ARINC Standards are prepared by the Airlines Electronic Engineering Committee (AEEC) where aviation suppliers such as Collins Aerospace and GE Aviation serve as contributors in support of their airline customer base.

Some of these ARINC standards are clearly geared to support Airline operations. ARINC 702A-4 according to Arinc "will enable airlines to meet Required Time of Arrival (RTA) accuracy requirements and in particular, arrival at metering point with an accuracy of ś10 seconds. This update provides a significant improvement to the accuracy of the aircraft trajectory and it will reduce airline fuel consumption"

What does these tera-bytes of data and real time data access mean to the avionics market?

Many of the leading Avionics service providers have worked with this data in order to arrive at various services designed to 'add value' to airlines and operators. A number of these commercial data service offerings, available via monthly subscription, are described as follows:

- Collins Aerospace - ARINCDirect Solution — Flight planning and Weather — allows pilots to be provided with tailor made flight plans at point of departure on laptops, mobile phones or iPads. The service is intended to allow pilots to fly optimised routes allowing for traffic, weather, local ATC rules, company practices etc.
- Honeywell's GoDirect™ Flight Bag Pro — available as an app to pilots/flight crew, via the electronic flight bag, the subscription service allows for optimised route flight planning based upon live data in real time — it can be updated en-route to allow for changes in traffic, weather etc.

- GE Aviation promotes its Air Mobility Platform service that is focused upon operators of UAVs/UTMs. The Air Mobility Platform is deployed on Amazon Web Services (AWS) GovCloud to support compliance to federal requirements. It combines Unmanned Aerial Service Supplier (USS) capabilities and compliance with CAA and ANSP rules and regulations, that provide for scalable, repeatable, and economically viable advanced UAS operations.
- Thales FlytLINK - FlytLINK operates using Iridium Certus broadband services over a network of 66 satellites that cover 100% of the globe, including poles and oceans. FlytLINK utilises this network to provide, mobile and essential voice, text and data communications for pilots, crews and business passengers.

Counterpoint sees the market for 'data service' offerings as one of significant growth given both the enabling infrastructure around data networks, real time air to ground communication links and the demand for real time inflight services.

7.11.2 AVIONIC DATA PRODUCTS

Stand-alone data products have increased in recent years in part due to the growth in infrastructure described in the previous section.

Key elements such as Cockpit Voice Recorders and Flight Data Recorders have long been mandated for civil and military aircraft in order to be able to survive a major incident (unintended landing). These devices are used post-incident to provide clear evidence of events leading up to the incident. They can more often be used to help to provide evidence as to the causes of the incident.

These data products include the following by way of examples:

- Cockpit voice recorders (CVR - post flight incident analysis)
- Flight data recorders (FDR - post flight incident analysis)
- Combined voice and data recorders.
- Data acquisition units (for downloading and/or post flight analysis)
- Data Management Units (often used to consolidate data required for MFD/NDs)
- Data concentrators (often used in conjunction with IMA architectures)
- Datalink transmitters/receivers (e.g., ACARS)
- Portable data loggers (removing data from aircraft).

Most of today's recorders are designed around solid-state electronics replacing older analogue and tape-based recorders.

A switch to solid-state architectures has allowed for a significant increase in memory capacity and high speed ethernet protocols. This together with the necessary datalink technology offered via broadband services and satellite communication allows operators to exchange data throughout the flight.

Service providers such as SwiftBroadband, an IP-based packet-switched communications network, offers a symmetric 'always-on' data connection of up to 650 kbit/s two per channel for aircraft globally except for the polar regions, using the Inmarsat satellite constellation.

The increased market demand for such in-flight services has seen the following companies all offering Swiftband-style based services:

- Cobham Antenna Systems (Chelton Satcom)
- Cobham Satcom (avionics and antennas)
- CMC (antennas)
- EMS Technologies (avionics and antennas)
- Honeywell (avionics)
- Collins Aerospace (avionics)
- TECOM Industries (antennas)

- Thales (avionics)
- Thrane & Thrane (avionics)

However, one of the significant 'threats' surrounding this increased data transmission environment is that posed by cyberspace attack. Historically much of the data that is transmitted in the civil arena is unencrypted and therefore exposed to violation or alteration by unlawful groups, terrorist action etc.

Within a more connected world that utilises satellite communications extensively, the cyber-related risks have increased exponentially in recent years.

This is no longer the case within a more connected world that utilises satellite communications extensively — the cyber-related risks have all increased exponentially in recent years.

Data transmitted via satellite internet service providers, the aircraft's onboard ADS-B transponder (a/c identification, speed, altitude, GPS position etc) and the ACARS messaging system are mostly unencrypted and there is therefore a threat in terms of nefarious intentions by 3rd parties.

All major providers of avionics have adopted various cyber security processes to minimise the risk of hacking, provide secure data exchanges and continually assess the presence of threats.

In 2007, Arinc released the ARINC 823 protocol which governs the encryption of ACARS data transmissions. However, the degree to which this has been widely implemented within avionics product offerings is not clear.

The military has long engaged in developing encryption techniques for all sensitive areas of their platform avionics. Most, if not all, modern military platforms have data encryption techniques embedded within their equipment.

Currently 'military grade' encryption is generally applied to products that utilise AES-256 encryption standards.

With the exception of mandated cockpit voice and flight data devices it remains to be seen if there will be a continued need for 'discrete' stand-alone data devices. Much of the data infrastructure is around high-speed transmission, data fusion, cloud storage devices and download/upload capabilities — data related discrete boxes will be harder to justify within common computing/IMA avionics architectures.

8 AN OVERVIEW BY MARKET SUB-SECTOR

The following section provides an overview of the various segments covered in the report, including their key considerations for avionics.

Different factors drive decision-making in the acquisition process for civil air transport, business jets, and military procurement. These differences highlight the emphasis on key operational priorities for each market. Significant factors include:

- Training costs
- Fleet commonality
- Innovation drivers
- Market appeal
- Key decision-makers

Training costs

Operational costs are a key component of the air transport market and drive decision-making. With a large cadre of pilots, any additional training to adapt to changes in avionics operations is multiplied by the costs and disruption due to scheduling and completion of training. If a new capability or change to avionics requires a training requirement, that aircraft can only be operated by the trained crews until the entire staff can complete the training and demonstrate proficiency.

The business aviation market is significantly less sensitive to this as the pilot staff is considerably smaller and training can be accomplished more rapidly.

Fleet commonality

Coincident with training costs are the advantages of fleet commonality. This allows for fewer type ratings and the option to schedule pilots to fly various aircraftfor example, the Boeing 757 and 767 share a common type rating. Most Airbus aircraft share a common type rating allowing interchangeability between A318, A319, A320, and A321 aircraft operations.

In a business aviation environment, the diversity of a company's fleet is solved by the assignment of specific pilots to specific aircraft types and where needed, the cost of additional type ratings is less of an impact as the pilot staff is significantly smaller.

Innovation Drivers

Innovative avionics capabilities are typically more appealing to business aviation operators and specialised airlines as they can more rapidly incorporate the benefits afforded by new technology due to smaller fleet sizes and smaller pilot staff. Air transport operators are less enthusiastic about incorporating new technology into their cockpits and operations unless there is a mandate or a return on investment that can be realised in a very short time. Again, this is driven by training and acquisition costs.

Market Appeal

Market appeal to an air transport operation is focused on direct operating costs above all other factors. A business aviation operator may find a newer, faster, a larger aircraft has ramp appeal and a reflection of prestige. The "latest and greatest" in this market is more significant. Air transport operators need to consider acquisition costs, training costs, infrastructure, route management in their decision making when purchasing a new fleet or retrofitting a new capability into their operations.

Key decision makers

In the air transport market, the decision is driven by specialised fleet teams that often have a strong leaning towards the financial considerations. How will this buying decision affect my operation? When will we complete the retrofit or acquisition and when can our company start realising a payback on this investment?

A business aviation operator typically relies on the chief pilot and operations manager to recommend buying decisions. Factors include acquisition costs and direct operating cost to be certain, but operational considerations such as speed, dispatch reliability and the ability to transport the VIP to their intended destination on-demand drive the decisions to acquire and incorporate new capabilities and/or aircraft.

Military Procurement

Typical military procurement of new aircraft or significant avionics upgrades are more centralised and less reliant of a single decision-maker. Military procurement is more about acquiring an entire program that includes logistics, training, maintenance and the aircraft system or aircraft. Selection of a vendor is the subject of extensive requirements development, proposals, example proposed aircraft and final selection. This is a significant departure from the civil aviation methodology.

8.1 CIVIL AIR TRANSPORT

This section is intended to provide an overview of the role that avionics play within the sector. We have defined the civil sector as including larger air transport platforms from 70 seats upwards which includes most regional jets and larger turboprops.

Airlines adopt their own strategy within the marketplace, but the common factors include:

1. Safety
2. Reliability
3. On-time departures and arrivals
4. Economics in terms of direct operating costs and the associated acquisition costs
5. Asset Utilisation (useful hours of service per day/per year)
6. Passenger experience (IFE, business services, smooth flight etc).

Low-cost carriers are typically focused upon 4 and 5 as they need a combination of low cost and maximum asset utilisation.

Long-haul international carriers are more likely focused upon 2 and 6 than other carriers.

Safety should be common to all operators.

As a key contributor to the various key performance metrics noted above, avionics has a significant role to play. Clearly gas turbine engine efficiencies and the airframe aerodynamics play by far the biggest part in an aircraft's overall economics. However, if the aircraft is unable to fly optimum routes or is regularly diverted due to a lack of the latest avionic technology, then the overall aircraft economic performance is compromised, as is its ability to arrive at the scheduled time.

Many of the FAA/CAA/EASA regulations for aircraft flying within regulated aerospace apply to civil aircraft with 20–30 seats or more. These regulatory conditions often apply to the performance of Communications, Navigation and Surveillance (CNS) avionic equipment.

Aircraft deemed to be FANS/Next Gen compliant are required to have Navigation systems that are accurate to within 0.1 nautical mile or better.

Aircraft need to have recognised 'autonomy' capability in terms of TCAS and an associated ADS-B compliant transponder for GPS position signals and aircraft messaging.

The major incentive to adopt and maintain these regulatory changes is to be able to fly more direct economic routes as permitted by ATC.

The author recalls, in the early days of FMS and FANS operations, working with Alaska Airlines to develop a 'direct' approach into Junneau airport (steep terrain, difficult approach). By adopting both FANS navigation performance of <0.1 nautical mile and terrain avoidance systems the Alaska pilots could fly a 'direct' approach and avoid a 15 - 20 minute detour around the hazardous terrain.

Given the number of flights per day and the 'costs' associated with the extra 20 minutes flight time this alone generated millions of dollars of fuel-related cost savings on an annualised basis.

The airline example noted above is one of numerous performance driven case studies that result in a significant upgrade/retrofit market within the civil transport sector. We mentioned earlier in this report that an airframe designed for 60,000 landings over say 40 years of useful operation could expect to see multiple upgrades of various components within the platform lifetime.

Many of the avionics suppliers covered within this report have developed comprehensive 'cost/benefit analysis' models that they can use as a powerful marketing tool to exploit potential airline cost savings via avionic upgrades.

The benefits associated with upgrading avionics are not only fuel cost related but include the following:

- Investing in the latest generation of avionics help to maintain the asset value of the aircraft.
- Improved reliability of latest avionics reduces maintenance costs and associated downtime (better asset utilisation)
- Improved situational awareness, reduced pilot workload in flight (TCAS, WX, EGPWS, Synthetic vision displays, larger format flexible displays)
- Insurance costs can be lower for aircraft fitted with latest generation of avionics.
- Reduce aircraft weight by 300 — 500 lbs for a complete retrofit.
- Avoid avionics obsolescence issues.

From our modelling of the overall civil market sector, it is clear that the addressable market for retrofit avionics can be equal to the market defined by the original equipment (OE) avionic supply.

Aircraft lessors have interest in maintaining cockpit avionics to the latest available standards. This can be a factor both in terms of maintaining the asset value of the platform and making the aircraft more desirable when offering it to a prospective customer.

8.2 BUSINESS JETS

Avionics specified within business jets tends to be very similar to that specified in a large commercial aircraft.

The key performance metrics for a successful business jet are typically 100% despatch reliability (a CEO/HNWI may only require a few flights a year but he does not expect a 'no-go' situation!) coupled with shortest 'door to door' timescales.

Business jets may operate between less congested hubs or more direct airfield locations. However, they still require the necessary navigation performance to avoid weather delays, congested areas, landing delays etc.

Modern business jets have therefore adopted FMS, IMA architectures, ADS-B autonomy and navigation performance in order to operate with optimised route structures.

Of growing importance is the access to the 'office in the sky' in real time which promotes the adoption of SATCOM, high bandwidth datalink service via satellite etc.

Unlike a Boeing or Airbus aircraft where the overall avionics package is specified by the OEM from several suppliers it is more likely that business jet OEMs such as Gulfstream, Bombardier, Dassault and Embraer will procure a complete 'off the shelf' integrated avionics solution from one of the big suppliers.

A number of typical examples are shown as follows:

- Bombardier Global 5000/6000 — Honeywell Primus 2000XP suite.
- Bombardier Global 7500 — Bombardier Global Vision based upon Collins ProLine Fusion suite.
- Cessna Citation CJ1/CJ2/CJ3 — Collins ProLine Fusion (upgrade offering)

- Dassault 7X/8X — EASy flight deck based upon Honeywell II Primus Epic avionics.
- Embraer Phenom 300E — Prodigy Touch flight deck based upon Garmin 3000 avionics
- Embraer Legacy 450/550 — Collins ProLine Fusion avionic suite.
- Gulfstream 280 — Collins ProLine Fusion avionic suite
- Gulfstream 650 — Honeywell Gulfstream Planeview Primus Epic suite.

Honeywell and Collins are the big two market leaders in offering integrated avionics suites within the bizjet sector. Both Thales and GE Aviation have a presence within this sector, but they do not offer a comprehensive avionics package as Honeywell or Collins.

At the smaller end of the business jet sector companies like Garmin and Universal Avionics are establishing themselves as offering a complete 'off the shelf' avionics suite at affordable levels.

As with larger civil platforms the business jet sector has significant retrofit/upgrade potential. A business jet is usually either an expensive 'business tool' or a luxury mode of transport for high net worth individuals (or both). For either case having the latest avionics helps to maintain asset value and promote saleability. Modern avionics also helps to promote 'curb-side appeal' which is not an insignificant factor when purchase decisions are made by high-net-worth individuals.

8.3 MILITARY FIGHTERS

Modern military fighter platforms are often multi-role in design which satisfies a number of roles including air to air, air to ground, support of larger aircraft, long range strike etc.

The oft applied acronym, C4ISR (Command, Control, Communications, Computers, Intelligence, surveillance and Reconnaissance) is used broadly within every field of military operation today.

Arguably one of the most significant impacts of C4ISR upon military aircraft is the increased need for 'interoperability'. This interoperability need effectively places the aircraft within a connected network of assets, whether they be land, sea or air based, all with the means to communicate in real time.

In terms of the impact upon avionics the most significant areas affected are as follows:

- High speed data networks with the means for data fusion (from multiple sources) and subsequent transmission.
- Sensors — cameras, electro-optical, infra-red required for reconnaissance, surveillance, electronic countermeasures, target acquisition and 360-degree field of view
- Helmet-mounted synthetic vision systems dramatically improving the pilot's situational awareness.
- Stores management computing required to manage the various role configurations in terms of payload etc.
- Mission computing necessary for overall mission planning, database memory and recording of mission performance for post-ops debriefing.

Advances in enhanced and synthetic vision systems in recent years have resulted in improvements to both head up displays and to helmet mounted displays. The F-35 pilot's helmet, as developed jointly by Collins Aerospace and Elbit, includes features such as helmet mounted display system, integrated communications, 'look and shoot' capabilities, night vision capabilities etc.

It is understood that this integrated helmet system costs the US DoD $400k per unit.

External stores can be added to a basic fighter configuration in order to extend range (external fuel tanks), increase payload delivery (mounted armaments), provide for EW measures (chaff/flare dispensers) and adopt more powerful radars for detection/avoidance (external POD mounted arrays).

Within the avionics suite there is need for 'stores management' computing in order to manage the array of mission specific external fitments.

It would appear to be extremely challenging, if not impossible, to achieve the needs of data fusion and interoperability, within a modern warfare environment, if the avionics were procured along the old lines of a discrete number of federated boxes from a multitude of suppliers each with their own bespoke architecture.

Both the F-22 and the F-35 have adopted 'common computing' resource which acts as host software for each of the utility or mission computing functions. Specialist software suppliers provide the signal-processing systems for the Integrated Core Processing (ICP) system, the F-35's central computer, which supports all of the embedded computing elements for several different aircraft subsystems, including digital signal processing (DSP) for the sensors and cockpit displays.

Where there is need for distributed and/or remote sensors throughout the aircraft platform then data is transmitted via the high-speed network. This F-35 has 144 information exchange requirements that specify the digital transactions that have to occur between the F-35 and all other US and allied aircraft operating within the theatre.

The associated avionic transceivers provide four channels of data transmission and reception at a data rate of 2 gigabits per second (Gb/s) over the F-35's extensive fibre optic network.

Military platform upgrades to avionics are also very prevalent given the extensive life of the airframes involved. If we take the F-16 as an example it has received two major upgrade programmes sponsored by the USAF as follows:

- 1980s - Multi Staged Improvement Programme (MSIP)
- 2010s - Combat Avionics Programme Extended Suite (CAPES)

In addition, Tier1 integrators, such as BAE Systems, can also offer the market various avionic upgrade options in addition to the prime contractor, which in this case is Lockheed Martin.

One significant factor that limits the scope for potential upgrades is the available onboard power and cooling capacities which cannot always match the addition of more power-hungry avionics.

Whilst upgrading power and cooling does arise, it is usually associated with a program to re-engine the platform which is a very significant upgrade.

The European multi-national Typhoon is a further example of the value in upgrades through the life of a platform.

Phase One Enhancement (P1E) enhancements included Air-to-Surface capability and the Litening 4 Laser Designating and Targeting Pod, integration of smart weapons, modern secure Identification Friend or Foe (IFF Mode 5), improved Radios and Direct Voice Input, Air-to-Surface Helmet Mounted Sight System, improved Air-to-Air capabilities including digital integration of Short Range Air-to-Air Missiles and updating the Multifunctional Information Distribution System (MIDS) Datalink to enhance interoperability among Coalition Forces.

Phase 3 Enhancements Package' (P3E), included improvements to the maintenance and mission systems and the integration of the MBDA Brimstone 2 precision missile.

In 2020 BAE Systems announced the contract to upgrade the Typhoon's radar to a much-enhanced AEAS radar providing far greater range, jamming capabilities and better threat detection.

The range of Typhoon upgrades have differing impact upon the aircraft's avionic suite. However, surveillance, displays, stores management and electronic warfare functionality are all improved as a result of the above upgrades.

8.4 MILITARY TRAINERS

Military trainers act as the 'feed in' aircraft to the fully fledged military fighter aircraft. They typically cost a fraction of the price of their big brothers. However, they need to replicate as much of the functionality as possible in order to serve as an effective trainer aircraft.

Many of the advanced trainers have dual cockpits/dual controls which means that, partly due to budget constraints, the cockpit avionics have to be simplified.

One of the latest trainers is The Boeing T-7A aircraft, selected in September 2018 to replace T-38 Talons, is a new, advanced pilot training system that is being offered, in partnership with Saab.

The T-7A cockpit features a large touchscreen screen display, digital up-front controller (UFC) as well as Hands On Throttle and Stick (HOTAS) and a HUD. In particular, the large single widescreen display echoes that of the F-35. Boeing has taken the avionics development of T-7A in-house to create a cockpit display aimed at the smart-phone savvy 'digital native' pilots of tomorrow. The interface, for example, features iPhone/Garmin G1000-like 'app' icons for different functions (checklist, fuel etc.), making for an extremely intuitive and user-friendly cockpit for student pilots, who can

concentrate on flying the aircraft and the mission. The avionics suite includes synthetic radar and weapons as well as datalinks to link with other T-7As (interoperability).

Whilst the avionic suite within a trainer will include mission computing, stores management, radar systems, FLIR and electro-optical sensors, low altitude TERPROM flight profiling, much like a fighter aircraft, there is not the need for the same level of mission criticality or redundancy built into the avionics architecture.

The avionics suite within a trainer aircraft is therefore estimated to cost around one quarter (25%) to one third (33%) of that for a fully equipped fighter aircraft.

8.5 MILITARY TRANSPORTS

Although this section is entitled 'military transports', we have included large military platforms some of which are utilised for advanced early warning, long range stand-off, refuelling tankers, maritime patrol, search and rescue for example, in addition to transport.

This expanded scope reflects the move in recent decades to specify and create multi role military platforms such as the A400M and KC-390.

When describing military fighters e.g., F-35, we noted interoperability as being a key requirement. These fighter role aircraft often need to be supported in the overall networked war theatre by long range early warning aircraft and refuelling tankers etc.

Many of the large military transport aircraft have to meet the relevant civil authorities' requirements (e.g. FAA, CAA, EASA) if they are to be permitted to operate within civil arenas (which covers most of the globe). Airbus as constructor for the A400M was therefore a natural choice (notwithstanding significant subsequent programme cost overruns).

The A400M was largely designed and certificated under the auspices of the Airbus commercial organisation partly to reflect the fact that a 'commercial approach' was deemed to be cost effective and, from an avionics perspective, much of the design was directly based upon the A380 aircraft.

Notwithstanding the read across from the A380 for certain of the A400M's avionics, such as the IMA computing resources and the large format cockpit displays, the mission specific computing and sensors required were all procured separately from lead avionic suppliers such as Thales/Diehl, Honeywell and Collins Aerospace.

Many military transport aircraft have been adapted from civil platforms e.g., KC-135 tanker (Boeing 707), Poseidon P-8 (Boeing 737NG), KC-46 tanker (Boeing 767), Airbus CN 235 MPA (CN235), and as a result, bring with them a suite of commercial avionics.

These platforms are then (heavily) modified to accommodate all of the mission specific avionics which will vary depending upon the role of the platform i.e., search and rescue, maritime patrol, advanced early warning (AEW), transport of troops and armaments, medevac etc.

Some of the electronic computing solutions that either interface or form part of the on-board avionics suite include:

- Flight Management Systems (e.g., A400M, Embraer C-390)
- Common computing core/IMA (e.g., A400M)
- Enhanced Vision Systems for night operations
- Hose and drogue control computer (in-flight refuelling)
- Large array long range radar (early warning)
- Stores management computer (armaments, payload, drop tanks, PODS)
- Mission computer (flight pre-planning, nav database, terrain data, post mission data downloads)
- Electronic Counter Measures (chaff, flares, radar jamming)
- Electronic Warfare (radar warning systems, laser warning systems, missile warning systems)

One of the modern military platforms, the Embraer C-390, is facilitated with an integrated avionics system and fly-by-wire flight control. Avionics includes two head-up displays (HUD), self defence systems and night-vision goggles (NVG).

The core avionics is provided by Collins Aerospace and based upon their Pro Line Fusion avionic suite.

The Embraer C-390 can be equipped with a complete self-protection package (SPS) to increase the level of survival. Detection & Control with 360 ř coverage: Radar Warning Receiver (RWR) Laser Warning System (LWS) Missile Warning System (MAWS), Chaff & Flare Directional Infrared Counter Measures (DIRCM), Infrared / Optical Optics and Enhanced Vision System (EVS)

The Embraer C-390 can also be equipped with a complete set of equipment to support the Search & Rescue mission: Removable Electro-Optical / Infrared pod (EO / IR); Removable internal fuel tank to expand the range or time at the station.

Procurement of avionics for military transports is still somewhat fragmented across many specialist suppliers. This largely reflects the specialised nature of the equipment and the limited size of the addressable market.

Again, using the Embraer C-390 Millennium platform as an example, the following is a tabulation of the avionics supplied:

Avionic — Equipment and sensors	Supplier
Flight and data management	Collins Pro Line Fusion flight deck
Mission computers	AEL Sistemas SA
Data Acquisition Systems	Curtiss Wright Defense Solutions
Radio communication equipment	Collins Aerospace
Transceivers: M3AR software VHF/UHF	Rohde & Schwarz
Weapons Countermeasures: Self-protection suite	AEL Sistemas SA
Weapons Countermeasures: Ballistics protection	Aerotron Industria e Comercio
Surveillance/Air Defense Radar: Mission radar system	Leonardo Defence Electronics
Collision Avoidance System: TCAS traffic management computer	ACSS (Thales and L3)
Inertial systems: Hybrid GPS & inertial ref system	Northrop Grumman Litef GmbH

Table 6: Embraer C-390 Millennium avionics providers

The above table reflects 10 separate supplier contracts required for the C-390 avionics suite. However, this does not include either optional equipment (e.g. in-flight refuelling computers) or specific role equipment that will result in additional contracts and suppliers.

This section would not be complete without reference to arguably the most successful military workhorse in history; the C-130 together with its many variants.

First introduced in 1954 the C130 Hercules has a total of 13 variants and has been exported to 23 nations around the world. Around 2,500 aircraft have been supplied with over 1,600 still in active service today.

The early C-130H had a cockpit that was entirely mechanical with barometric instruments throughout. Navigation was derived from multiple mechanical gyro meters supported by air data provided by pitot static tubes.

The cockpit of the C-130 has been upgraded many times within its life from barometric instruments through cathode ray displays to flat panel LCD displays.

Two of the most significant C-130 avionics upgrades are identified as follows:

- 2000 - Boeing was awarded a contract to upgrade 464 C-130Js via the Aircraft Modification Programme (AMP) budgeted at $7 million per aircraft (although it cost considerably more). The upgrade includes Communication, Navigation, Surveillance/ Air Traffic Management (CNAS/ATM) compliance, which is required in order to fly in civil airspace. It features night-vision compatible digital displays, and the 737 commercial airliner's proven flight management system. NOTE: This programme has suffered significant delays and reduction in scope as a result of cost overruns and issues surrounding the value of the enhancements.

- 2019 - Air Force Life Cycle Management awarded a $500 million contract to L-3 Platform Integration for the C-130H Avionics Modernisation Program (AMP). Increment 2. L-3 will upgrade the Air Force C-130H Combat Delivery (CD) fleet of 176 C-130H aircraft, which includes the C-130H1, C-130H2, C-130H2.5, C-130H3, and LC-130H variants of the C-130H.

Notwithstanding the issues surrounding the C130 AMP programmes, it is clear that USAF alone has budgeted a total in excess of $2.5bn for C-130 upgrades. Add to this the upgrades of C-130 fleets operating within the other 23 nations and it is not difficult to see an upgrade market potential in excess of $5bn for this one platform.

There is a significant avionics upgrade/retrofit market for military transport platforms given their very long in-service life (often 50–60 years or more).

Many of the in-service military transport platforms have benefitted from significant upgrades in recent years including:

- C-130J (AMP programme - avionics)
- C-5 Galaxy (Avionics and Engine)
- C-17 Globemaster (Block 21 upgrade to ADS-B for operations in civil airspace)
- C-27 transport (Next Generation including revised avionics)
- CN-235 (Phoenix version offered with upgraded Honeywell avionics)
- Antonov AN22 (AN22A has upgraded radio and navigation)
- Alenia G-222 transport (multiple incremental avionics upgrades to radio, radar, auto-pilot and nav systems).

Counterpoint believes that the military transport market for upgraded avionics will continue to be attractive and to grow given that the examples above represent only the major programmes. These aircraft are typically operated by many nations throughout the world each of whom have their own budgets for continuing the life of their in-service fleets (as opposed to very costly platform replacements).

8.6 HELICOPTERS

Avionics fit within rotorcraft platforms are considerably simpler than their fixed wing counterparts. helicopters operate over much shorter ranges at lower speeds and they do not exceed altitudes of around 8,000 ft. They therefore operate within a much-reduced envelope which results in simpler avionics architectures.

A rotorcraft can typically have an FMS with Autopilot and a heading and attitude reference system. It will not have the same levels of system redundancy found in large civil fixed wing platforms as the certification requirements are nowhere near as stringent.

However, the above is only a general statement. The role of the helicopter platform can determine the level of navigation performance required and the acceptable levels of avionic availability.

The CAA and EASA have introduced navigation required minima for GPS equipped rotorcraft that operate with civil passengers in the North Sea (e.g., shuttling people between oil rigs).

A further consideration that can impact avionics standards is the need for rotorcraft to utilise airports that are also used by fixed wing aircraft. As recent as 2020 SESAR (Single European Sky Aviation Research) was working to define how instrument flight rules (IFR) procedures designed specifically for rotorcraft can enable their access to airports without impacting fixed-wing commercial traffic. The flight trials were conducted by ENAV (the Italian ANSP - Air Navigation Service Provider), in collaboration with Leonardo Helicopters Division within the framework of SESAR 2020 project on enhanced runway throughput.

Rotorcraft avionics generally need to be very cost sensitive given that the platform sells for a fraction of that for a fixed wing civil air transport platform. Many OEM manufacturers list a range of avionics as ‘optional’. Equally, many avionics suppliers offer standard products that can be approved for use via the Supplemental Type Certification (STC) process.

In order to emphasise the level of activity undertaken via the STC route within the rotorcraft sector we looked at a 12-month period of airworthiness approved STCs and identified 14 approvals listed as follows:

- 12-Jun-24 - Max-Viz 2300 Camera System for Airbus H160

- 31-May-24 - L-3 Communications NGT-9000R/RD and NGT-9000/D ADS-B IN/OUT system for AB139, AS332, S-76
- 29-May-24 - Appareo Systems AIRS-400 Flight Monitoring System for Bell 206, Airbus AS350
- 01-Mar-24 - Avidyne Integrated Flight Display (IFD) Navigator(s) for Airbus AS350
- 29-Feb-24 - Garmin G500H TXi Flight Display System for Bell 212
- 15-Feb-24 - UASC CVR 120R Cockpit Voice Recorder System; AN/ARC 210 Tactical Comm System; SARSAT ELT System for Airbus AS332
- 13-Feb-24 - SKYTRAC SDL-350 Flight Following/SATCOM System for AW139c
- 07-Feb-24 - HeliSAS stability augmentation system and autopilot for Airbus AS350, EC150
- 18-Dec-23 - Garmin GRA 5500 Radar Altimeter System for Airbus AS350
- 05-Dec-23 - SKYTRAC SDL-350 Flight Following/SATCOM System (Provisions Only) for AB139
- 29-Nov-23 - Garmin GTX 345R for MBB-BK 117
- 17-Nov-23 - Garmin GTN 650 for MBB-BK 117
- 07-Nov-23 - "StableLight" 4-axis autopilot for Airbus AS350
- 03-Oct-23 - Garmin GTN 6XX/7XX Navigation System for Bell, Airbus, MD Helicopters

It is immediately apparent that this STC route is well served by suppliers including Garmin, Genesys, Max-Viz, in addition to Honeywell, Thales and Collins.

It is sometimes difficult to refer to a ‘standard fit’ for rotorcraft avionics as there is a wide range of ‘options’ and a very active Buyer Furnished Equipment market for these products.

Partly as a result of the low-cost targets mentioned above the rotorcraft avionics market benefits from ‘commercial off the shelf’ (COTS) offerings. This COTS approach to low-cost avionics is described in section 14.1 of this report.

Many avionics suppliers have therefore developed a range of avionics products, whether they be COTS or STC route, which are targeted for the rotorcraft market.

Suppliers with a strong presence in rotorcraft offering COTS/STC products include:

- Honeywell (via its Bendix king subsidiary)
- Collins Aerospace
- Meggitt
- Universal Avionics
- GE Aviation
- Avidyne
- Curtiss-Wright
- Thales/Diehl Avionics
- Garmin Avionics
- Genesys

Collins, for example, offers its ‘HeliSure’ flight Situational Awareness and Cockpit Display solutions. With 3D visualisation of high-resolution terrain data on large-format Primary Flight Displays, the HeliSure family of products feature an intuitive interface with scalability across multiple platform types and sizes, all while optimising size, weight, power and cost for a breadth of rotary-wing solutions.

Garmin offers both full cockpit updates in addition to navigation and situational awareness systems and products.

Note the emphasis in the paragraph above upon a family of scalable products for a breadth of rotary-wing solutions. Many suppliers can only make commercial sense of the rotorcraft avionic market when they develop products for numerous platforms.

In terms of military role platforms there is clearly an additional level of avionics required when compared to civil variants that is role dependent.

Military helicopters fulfil a number of roles including troop deployment, medevac, search and rescue, fire-fighting, low level support etc.

An Apache AH-64, for example, will be fitted with additional avionics and sensors, including target acquisition radar, fire and forget radar, night vision systems for displays and HUDs, enhanced vision systems (via infra-red sensors), radar jammers and electronic countermeasures (ECM).

These specialised military avionics also have a range of suppliers that develop a range of military sensitive avionic products including:

- Lockheed Martin
- Northrop Grumman
- Honeywell
- ITT Aerospace
- General Dynamics
- Raytheon
- L3 Harris
- BAE Systems
- Elbit

By way of example the Boeing Chinook CH-47, one of the largest operational military transport rotorcraft in current service, is fitted with the following avionics and sensors:

The cockpit accommodates two pilots and an observer.

- Boeing and Honeywell developed the advanced digital cockpit.
- The cockpit is equipped with multifunction liquid crystal displays and electronic flight instruments.
- The crew is equipped with ANVIS-7 night-vision goggles from Elbit and the cockpit is night-vision-goggle (NVG)-compatible.
- The communications suite includes jam-resistant HF and UHF radio systems developed and supplied by Collins Aerospace and Raytheon.
- The helicopter features AN/APX-100 identification friend or foe (IFF) interrogator from Honeywell.
- In 2008 Northrop Grumman was awarded a contract to equip the Royal Netherlands Air Force's (RNLAF) CH-47Fs with the AAR-54 missile warning system.
- The special forces MH-47E, is fitted with the ATK AN/AAR-47 missile approach warner, Northrop Grumman ALQ-162 Shadowbox jammer, ITT ALQ-136(V) pulse jammer, Raytheon APR-39A radar warner and BAE Systems Integrated Defense Solutions (formerly Tracor) M-130 chaff and flare dispenser.

Many military helicopters are also fitted with similar range of avionics, ECM and EW systems.

Yet again Counterpoint sees considerable opportunities for upgrades and retrofit relating to avionics within the overall rotorcraft sector (both civil and military)

Certification and regulatory authorities, such as EASA, provides guidance on incorporating avionics upgrades to rotorcraft (categorised as 'major' or 'minor').

This EASA list can be found at rotorcraft@easa.europa.eu and identifies 30+ test/installation requirements for a wide range of upgrades including GNSS, GPS, TCAS, TAWS, WX, XPDR Mode S, ADS-B in, Enhanced Vision Systems, Synthetic Vision Systems, Datalinks, Antenna, Radio, SATCOM, VDR, CVR, Mission Radio, Obstacle detection, Laser devices etc.

Significant avionic upgrades to rotorcraft platforms in recent years include the following:

- Chinook (1,200 built) ; 400 US Army Chinooks 'digitised' in 2003, Selex upgraded avionics on 16 Italian air force units, US Army selected Boeing to upgrade avionics on 50 Chinooks in 2011 ($24m). More recently, the Collins Common Avionics Architecture Systems (CAAS) has been adopted as the standard for CH-47F cockpit avionics.
- Apache AH-64 (2,400 built): a $1.9 billion five-year contract was signed in 1996 to upgrade 232 AH-64As into AH-64Ds (including avionics and sensors); Elbit provided Target Acquisition Designation Sight/Pilot Night Vision Sensor System and Integrated Helmet and Display Sighting System for Greek air force (19 units at a cost of $34 million) ; In 2014, it was announced that new targeting and surveillance sensors were under development to provide high-resolution colour imagery to crews, replacing older low definition black-and-white imaging systems; 2018, the Netherlands decided to upgrade all their AH-64Ds to the latest AH-64E configuration through a Foreign Military Sales contract with the US, along with 17 APG-78 fire control radar units. Additionally, AH-64E Version 6.5 (V6.5), the next version of the Apache Helicopter will include an upgraded software program to "increase its survivability on the modern battlefield".
- Sikorsky UH-60 Black Hawk (4,000 built); Upgrade to UH-60M in 2006 incorporates upgraded T700-GE-701D engines, improved rotor blades, and state of the art electronic instrumentation, Integrated Vehicle Health Management System (IVHMS) compute and aircraft navigation control — 1,227 platforms upgraded at a budgeted cost of $1.3 billion; a further upgrade in 2008 included UH-60M with fly-by-wire system and Common Avionics Architecture System (CAAS) cockpit suite.

Many of these helicopters are operated in many other countries, in addition to the US, and they have contracted their own avionics upgrades often independently of the OEM supplier. Whilst the USA is a significant market for retrofits/upgrades we believe that there are equal opportunities represented outside of the US.

8.7 UNMANNED AERIAL VEHICLES/SYSTEMS

UAVs share many technologies with traditional avionics, but often face their own sets of challenges. For example, SWaP (size, weight and power) is a common consideration for UAVs given the smaller size of the aircraft and limited power resources.

Although the two share similar challenges, Counterpoint tends to distinguish between military and commercial platforms in the UAV market. Given the fragment, long-tail nature of the UAV market, our market sizing estimates focus only on larger, military platforms. We treat urban air mobility (UAM platforms) separately in the next section.

Due to the highly fragment and long-tail nature of the UAV market, Counterpoint's market model focuses only large, military UAV platforms (mostly Group 4 and 5).

Military UAVs

Military UAVs face similar challenges to other types of military aircraft with some special considerations.

A major challenge is enabling high levels of autonomy while still allowing remote control. This involves advanced sensors, decision-making algorithms, and communication systems for seamless integration between UAVs and operators. Ensuring reliable real-time data transfer for command, control, and communication (C3) is essential, especially in contested or degraded environments.

In terms of military UAVs in operation today, special mission vehicles, such as the Global Hawk, have already seen significant operational service in the past 10 years or so. We have analysed the avionic/sensor suite on this platform and it is clear that the sensor suite predominates whilst the man/machine interface products are all redundant (no pilot, displays, voice, physical interfaces etc).

UAVs often rely heavily on advanced sensor systems for surveillance, targeting, and navigation. Efficiently processing and transmitting large amounts of data to ground stations in real-time without onboard pilots is a significant challenge. Additionally, UAVs are required to operate in environments with degraded GPS or other external signals, making robust sensor fusion and navigation systems essential.

Given the Global Hawk's need to acquire precision data for reconnaissance or target data, it follows that its own navigation systems need to be highly accurate. We understand that the Global Hawk relies upon augmented GPS for its primary navigation needs.

UAVs are heavily reliant on secure communication links for remote operations. These links are vulnerable to jamming, hacking, or spoofing by adversaries. Given the large amount of data obtained by these systems, fast data links are required to be able to transmit these systems.

Increase autonomy leveraging the latest developments in AI is a key theme for military avionics. We cover this further in Section 13.7.

Commercial UAVs

Commercial drone operations are governed by different rules depending on the size of the aircraft and nature of the operation. As an example, the table below summarises the key operating rules with the United States under the FAA:

Drone Weight	Applicable Rules	Primary Use	Key Requirements
< 0.55 pounds	Part 101 (Recreational)	Hobbyist	Registration not required, follow CBO guidelines, line of sight, stay below 400 feet.
0.55 - 55 pounds	Part 107 (Commercial)	Commercial	Remote pilot certification, line of sight, registration, 400-foot altitude limit, may apply for waivers.
> 55 pounds	Part 91	Large UAVs	Special airworthiness certification, pilot licensing, may require BVLOS operations and compliance with ATC.
Government Drones	PAO	Government	Exempt from some FAA rules, requires safe operation, often used for law enforcement and search & rescue.
Cargo Drones	Part 135	Commercial Cargo	Air carrier certification, BVLOS, airworthiness, may operate long-distance deliveries.

Table 7: Commercial UAV operating rules

UAV and commercial aircraft avionics share similar technologies. However, given their smaller size, UAVs often face special design challenges. Although size and weight are always important for aerospace, UAV avionics must be especially small and lightweight in order to enable longer flight times. Systems for flight control, navigation, and communication are often packaged into a single module. UAV avionics are often optimised for low power consumption.

Commercial UAVs also have specific requirements that differ from large commercial aircraft.

For example, smaller UAVs operating under Part 107 in the United States have requirements for identification. In September 2023, the US FAA passed the Remote ID rule, but the enforcement deadline was extended until March 2024. The Remote ID rule states that the drone must have the ability to provide identification and location information that can be received by other parties through a broadcast signal. This applies to drones weighing over 0.55 pounds operating under Part 107 rule for small commercial drones.

Another key recent development in the commercial UAV space was the first Beyond Visual Line of Sight (BVLOS) operations authorised in the United States by the FAA in June 2024. Two companies, Zipline International and Wing Aviation, were authorised for package delivery. The aircraft maintain separation using Unmanned Aircraft System Traffic Management (UTM) technology. With UTM, the primary means of communication and coordination between the FAA, drone operators, and other stakeholders is through a distributed network of highly automated systems via application programming interfaces (API), and not between pilots and air traffic controllers via voice.

Many traditional providers of Avionics also provide systems for UAVs. However, certain players have also emerged that tailor to the smaller UAV market. uAvionix, for example, specialises in low-SWaP avionics packages.

8.8 URBAN AIR MOBILITY

At the time of writing, the urban air mobility (UAM) market remains to uncertain from a production perspective to be included in our market forecast.

However, despite the challenges faced by this nascent industry, major players continue to make progress. Joby began producing aircraft in 2024, with their third aircraft produced in August. Beta Technologies is targeting 2025 for FAA certification of the CTOL version of their Alia design. Although we expect a shakeout in the market given the large number of players, the industry continues to take steps towards production and operations.

From an avionics perspective, the entire urban air mobility concept presents several key challenges, including:

- Advanced flight control systems capable of handling multi-rotor operations in dense urban environments
- Integration with air traffic management, including potential UTM systems described above; the scale of the operations described likely requires vehicle-to-infrastructure and vehicle-to-vehicle communication for coordination
- SWaP requirements, along with the ability to efficiently manage power, propulsion and energy distribution

It is equally clear that the relevant airworthiness authorities around the world need to issue airworthiness standards necessary to safely implement and control operations for UAMs in civil aerospace. This we understand is currently work in progress with bodies such as the FAA, EASA and CAA.

Some UAM companies are taking a further step of designing their vehicles for autonomous flight. Chinese OEM Ehang and Boeing-backed Wisk both have autonomous concepts. Joby, whose vehicle design is piloted, acquired Xwing in June 2024; in August that company's team demonstrated a fully autonomous Cessna 208B Grand Caravan for more than 3,900 miles of flight as part of the US Air Force 'Agile Flag 24-3' exercise

Traditional avionics players are heavily involved in this sector. A few examples of agreements include:

- May 2020; Diehl signed a contract with Volocopter for the development and production of Flight Control Computers
- June 2021; Lilium engaged with Honeywell to develop the 7-seater Lilium Jets' avionics
- April 2022; Thales have teamed up wtih Eve to conduct joint studies over a twelve-month period covering avionics, flight control, navigation, communciation and connectivity
- June 2023; Safran and Archer Aviation released additional details on their collaboration for Arhcer's Midnight eVTOL aircraft. The collaboration began in 2021 and focused on deveplopment and testing Safran's ultra-compact avionics platform

We expect the low-cost avionics developers such as Garmin, Universal Avionics, Innovative Solutions & Support and Bendix King (Honeywell) and CMC Electronics (TransDigm) could be well-positioned to offer 'off the shelf' low cost integrated avionics suites for UAMs. However, given the novelty of such platforms and the certification challenges, we expect that OEMs may rely on larger, traditional players for bespoke solutions on early generations and then transition to more COTS offerings in future iterations once the technology has been proven.

Counterpoint believes that low-cost accessible air taxi transport for the masses (UAMs) could still be some years, if not decades, away given the time it may take to design and implement the associated infrastructure.

9 MARKET SIZE AND SEGMENTATION

Counterpoint's estimates for the total avionics market size are shown in the table below which identifies the major avionic sub-system categories together with revenues split between OE, spares/repairs, retrofit/upgrades.

Our market models are based on a bottom-up assessment of the market based on major components within each of the market sub-segments. Our original equipment (OE) forecast is based on our aircraft delivery forecast. The aftermarket forecast is based on assumptions regarding replacement rates, spare allocation, retrofit/upgrades, and potential regulatory impacts that may drive activity.

2022 Avionics Market	OE	Repairs/Spares	Retrofit/Upgrade	Total
Display	1,720	1,299	517	3,536
Sensors	961	1,085	385	2,431
Navigation	791	499	248	1,539
Mission	548	537	178	1,263
Communications	511	488	140	1,138
Surveillance	491	520	119	1,131
FMS	527	437	150	1,115
IMA	651	364	83	1,097
Software	479	478	75	1,031
Data	418	434	110	962
Auto-pilot	266	124	33	423
Grand Total	**7,362**	**6,265**	**2,037**	**23,846**

Table 8: 2022 Avionics market size for OE, repairs/spares, and retrofit/upgrade

2023 Avionics Market	OE	Repairs/Spares	Retrofit/Upgrade	Total
Display	1,931	1,418	566	3,916
Sensors	1,035	1,160	405	2,601
Navigation	892	549	270	1,712
FMS	616	486	166	1,268
Mission	548	546	175	1,269
Communications	566	528	152	1,245
Surveillance	524	547	124	1,195
IMA	707	380	91	1,177
Software	526	512	80	1,118
Data	469	475	118	1,062
Auto-pilot	303	139	36	478
Grand Total	**8,119**	**6,739**	**2,183**	**17,041**

Table 9: 2023 Avionics market size for OE, repairs/spares, and retrofit/upgrade

9.1 OVERALL MARKET GROWTH TRENDS

OE vs Aftermarket

The following charts display the breakdown of OE and aftermarket activity. The aftermarket is divided in spare/repair activity and retrofit/upgrade activity.

In our forecast, retrofit upgrade activity peaks towards the end of the decade. We forecast this based on potential activity due to regulatory changes which we cover in further detail in 11.4. As a result of this activity, we forecast a small decline in the final years. This decline is caused by a lack of visibility in any regulatory changes in that horizon; it is possible that in the next ten years, technology and infrastructure changes drive further retrofit needs that are not visible at this stage.

Avionics market forecast by OE and aftermarke t
USD billions

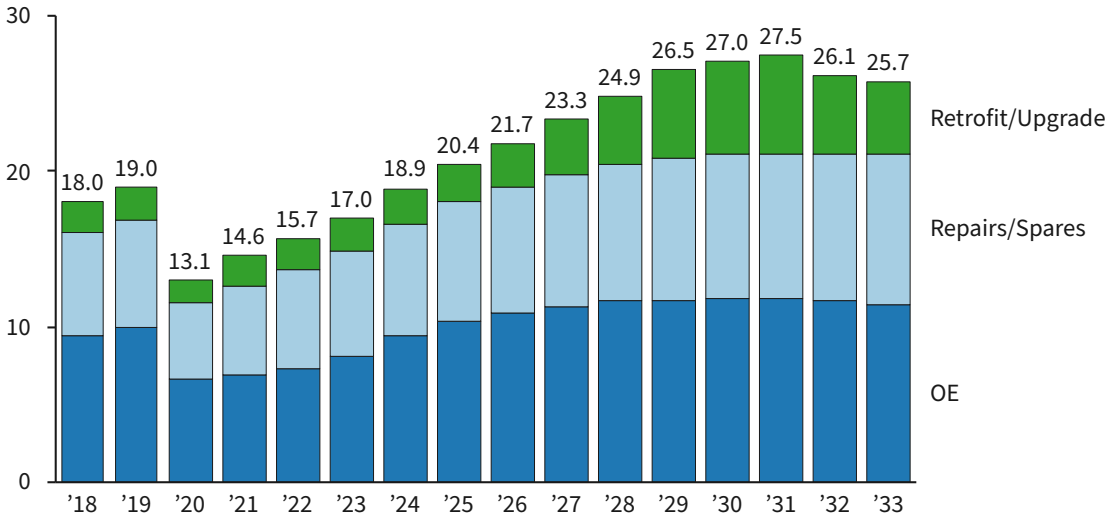


Figure 3: Avionics market forecast by OE and aftermarket

Avionics market size $ millions	2022	2023
Civil - OE	4,806	5,588
Civil - Aftermarket	4,956	5,521
Military - OE	2,557	2,531
Military - Aftermarket	3,347	3,397
Grand total	**15,665**	**17,036**

Table 10: Avionics market size for civil/military and OE/aftermarket

Civil versus military

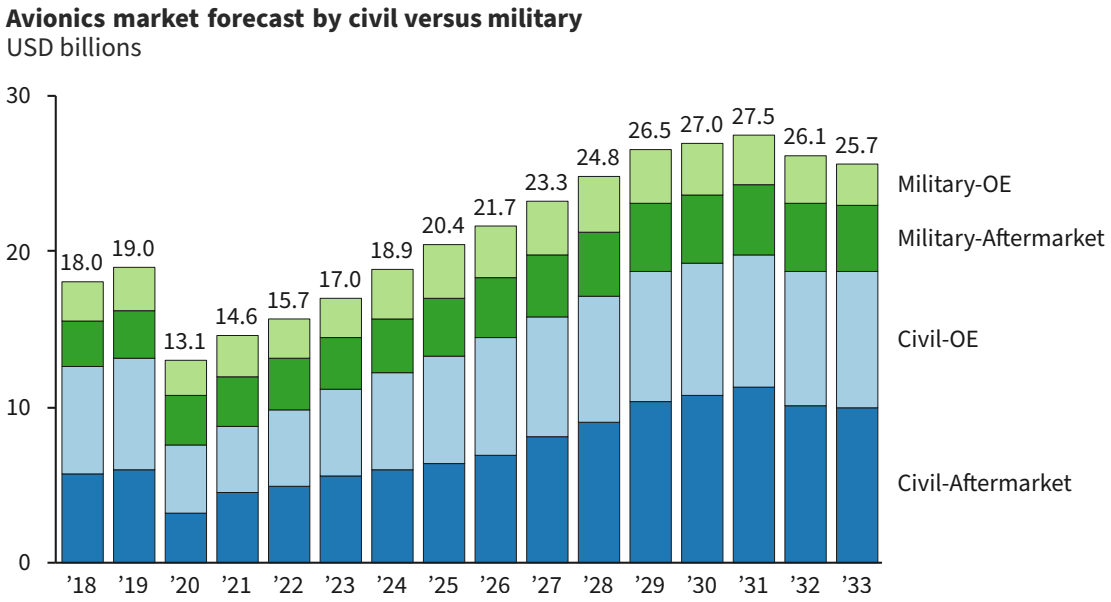


Figure 4: Avionics market forecast by civil versus military

Growth by aircraft category

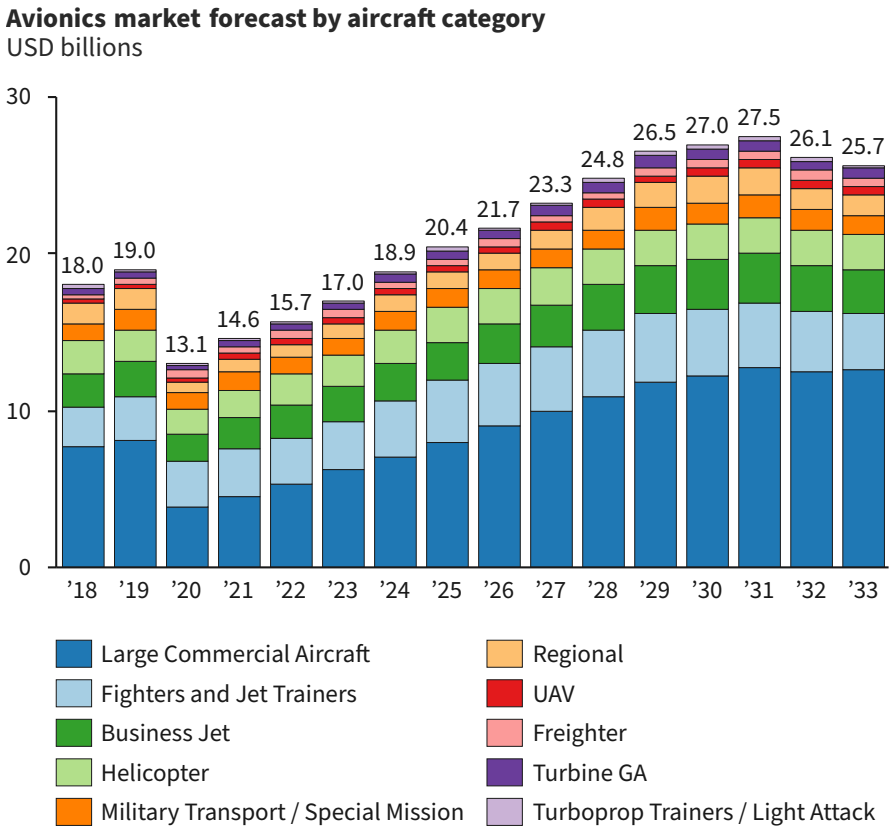


Figure 5: Avionics market forecast by aircraft category

Growth by type of equipment

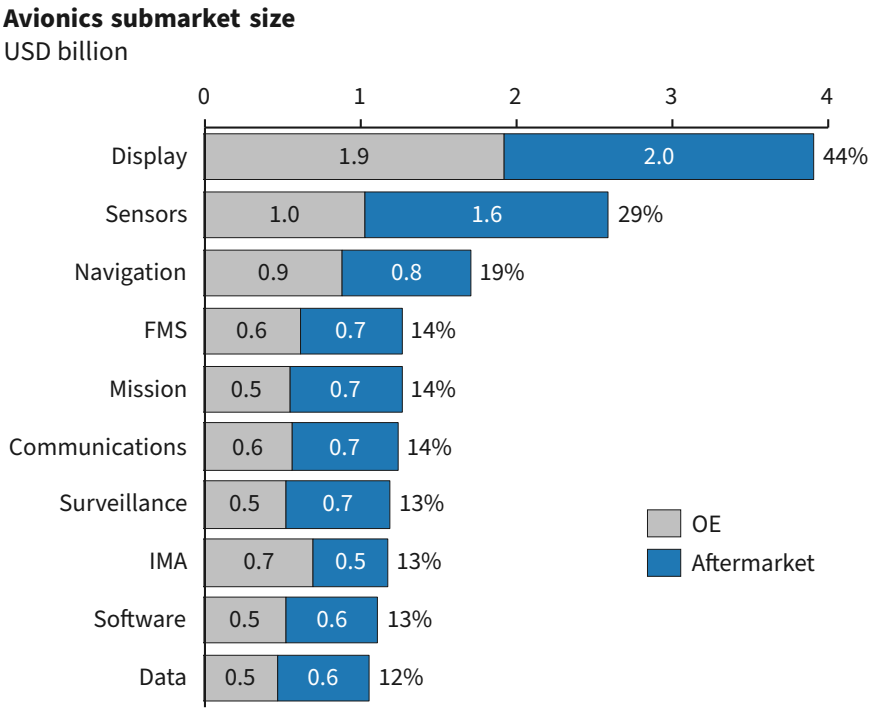


Figure 6: Avionics submarket size

9.2 SOFTWARE

Software market $ millions	2022	2023
Business Jet	134	143
Fighters and Jet Trainers	198	200
Freighter	28	29
Helicopter	145	146
Large Commercial Aircraft	354	419
Military Transport / Special Mission	57	58
Regional	41	45
Turbine GA	42	45
Turboprop Trainers / Light Attack	5	5
UAV	26	27
Grand Total	**1,031**	**1,117**

Table 11: Software market size by aircraft category

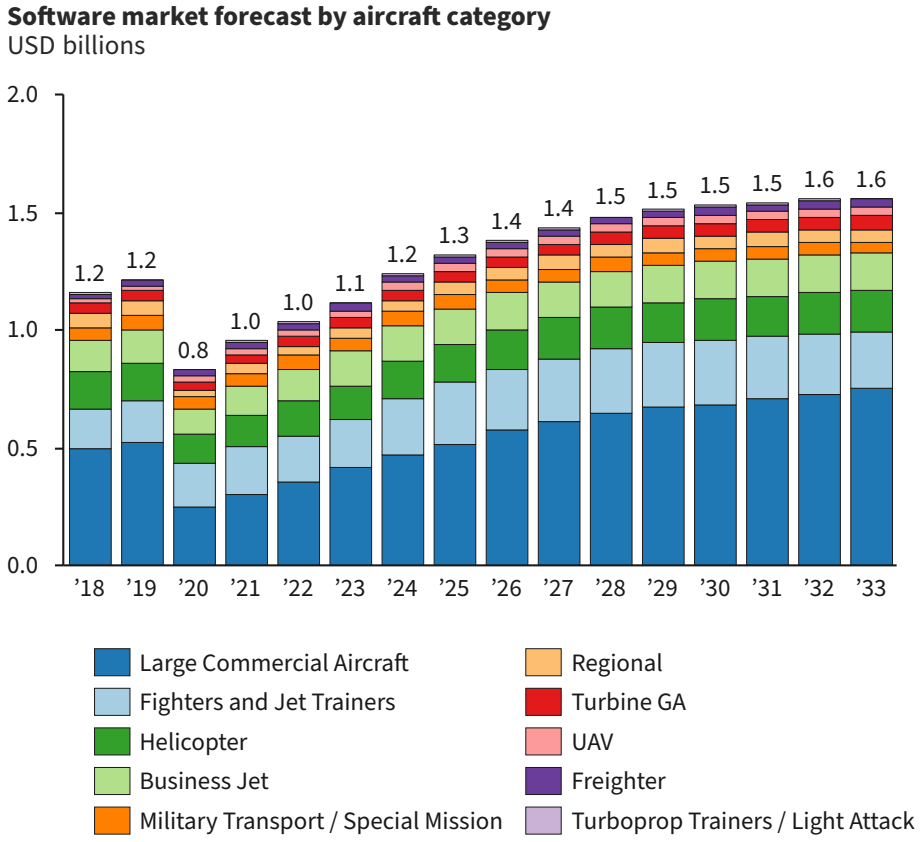


Figure 7: Software market forecast by aircraft category

9.3 IMA

IMA market $ millions	2022	2023
Business Jet	216	230
Fighters and Jet Trainers	376	375
Freighter	49	50
Helicopter	24	24
Large Commercial Aircraft	196	247
Military Transport / Special Mission	125	125
Regional	110	125
Turbine GA	>1	>1
Grand Total	**1,907**	**1,177**

Table 12: IMA market size by aircraft category

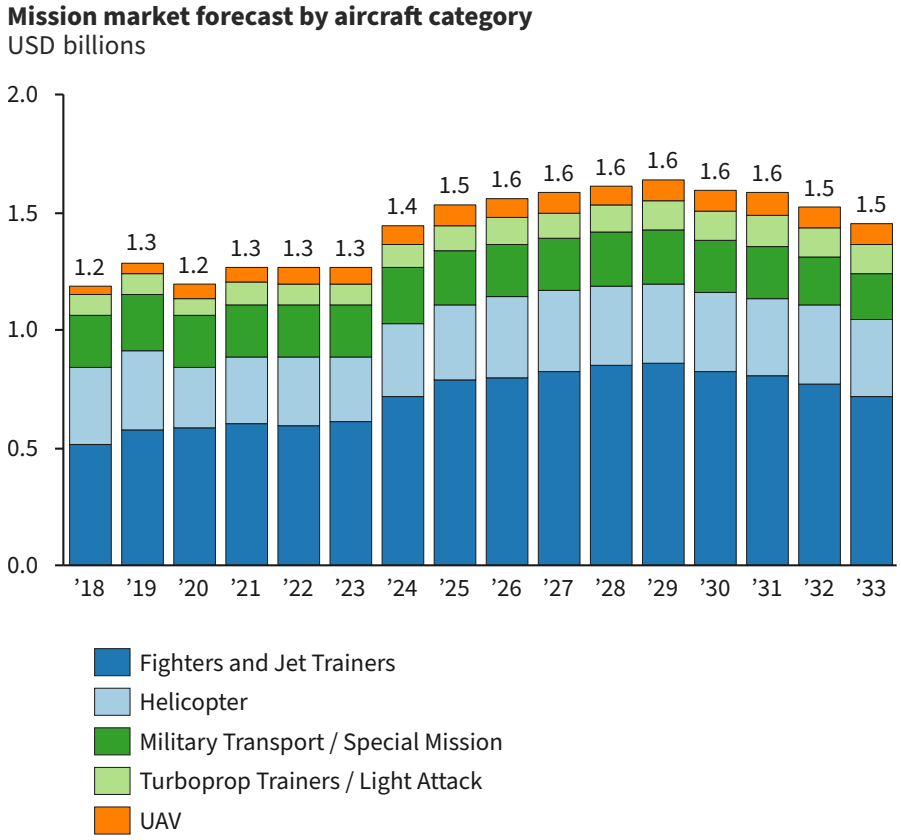


Figure 8: Mission market forecast by aircraft category

9.4 FMS

FMS market $ millions	2022	2023
Business Jet	192	203
Freighter	59	61
Large Commercial Aircraft	698	828
Military Transport / Special Mission	73	73
Regional	93	102
Turbine GA	>1	>1
Grand Total	**1,115**	**1,268**

Table 13: FMS market size by aircraft category

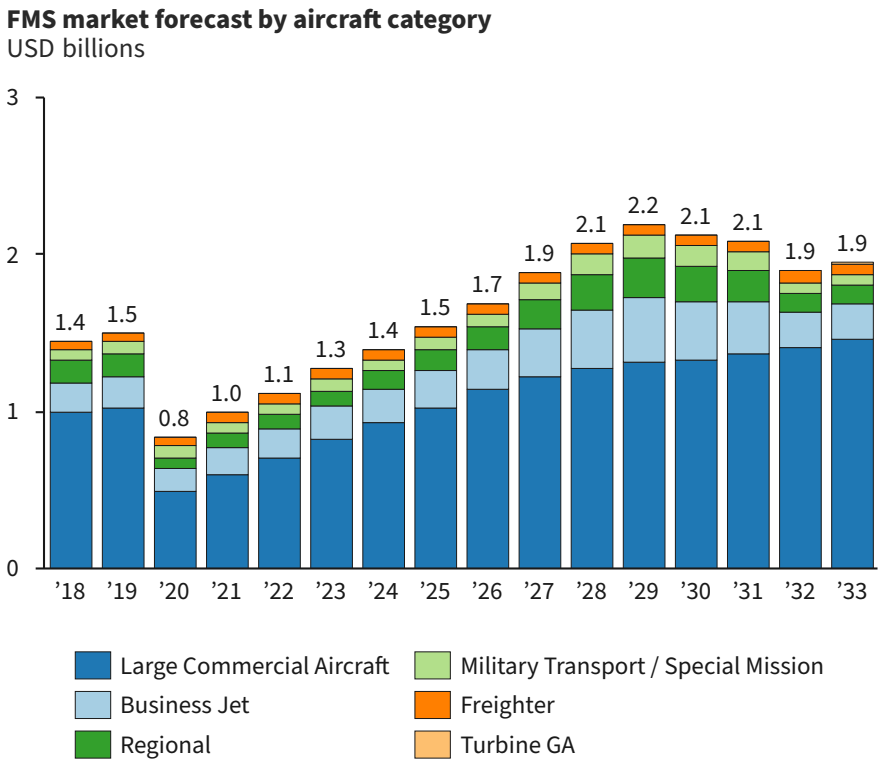


Figure 9: FMS market forecast by aircraft category

9.5 AUTO-PILOT

Auto-pilot market $ millions	2022	2023
Business Jet	50	53
Freighter	17	18
Helicopter	54	55
Large Commercial Aircraft	215	261
Military Transport / Special Mission	19	19
Regional	29	32
Turbine GA	26	28
Turboprop Trainers / Light Attack	2	2
UAV	11	15
Grand Total	**423**	**483**

Table 14: Auto-pilot market size by aircraft category

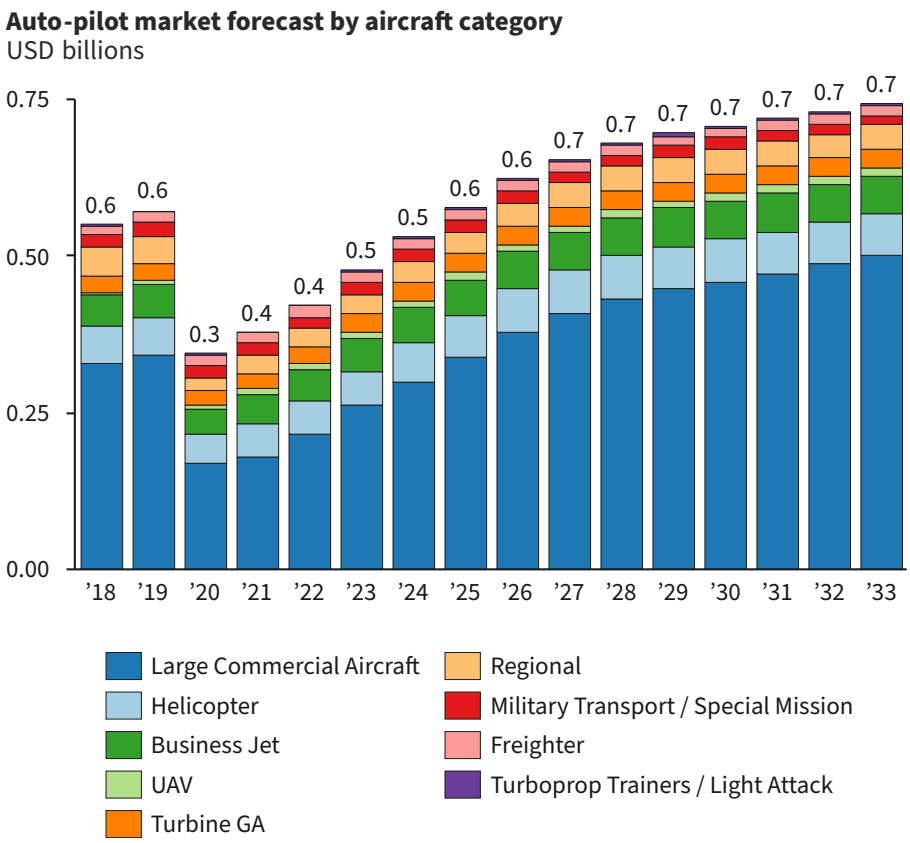


Figure 10: Auto-pilot market forecast by aircraft category

9.6 DISPLAYS

Displays market $ millions	2022	2023
Business Jet	435	461
Fighters and Jet Trainers	474	482
Freighter	110	116
Helicopter	388	398
Large Commercial Aircraft	1,438	1,723
Military Transport / Special Mission	204	206
Regional	255	283
Turbine GA	202	220
Turboprop Trainers / Light Attack	28	28
Grand Total	**3,536**	**3,916**

Table 15: Display market size by aircraft category

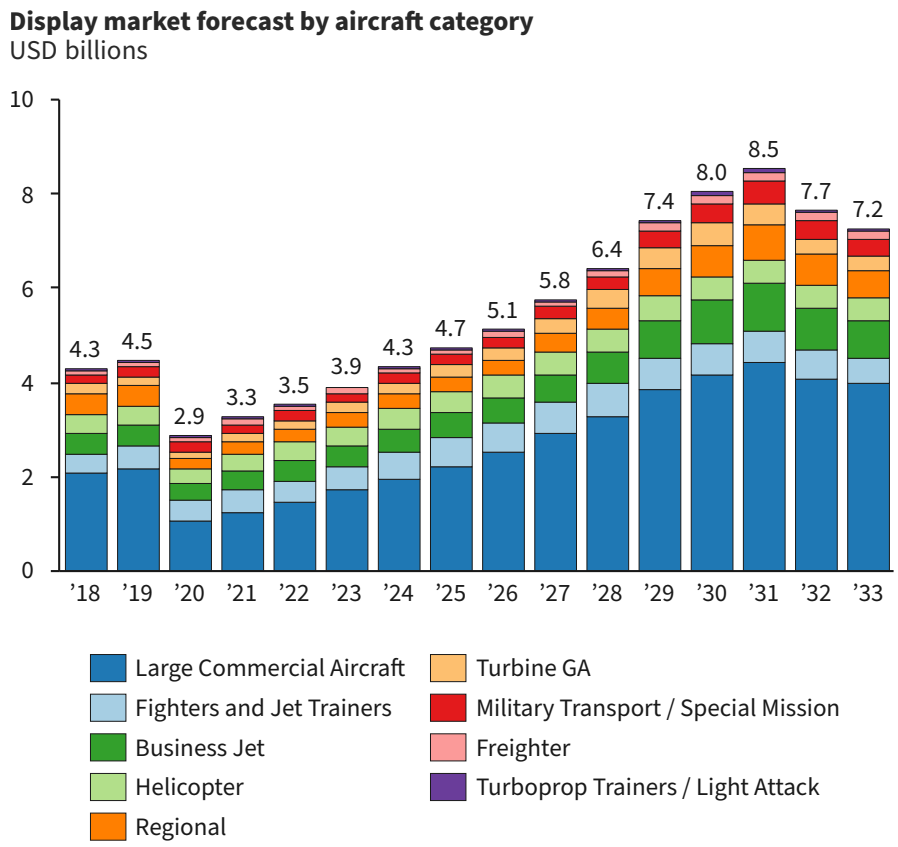


Figure 11: Display market forecast by aircraft category

9.7 NAVIGATION

Navigation market $ millions	2022	2023
Business Jet	293	311
Fighters and Jet Trainers	88	90
Freighter	50	52
Helicopter	131	135
Large Commercial Aircraft	643	769
Military Transport / Special Mission	88	89
Regional	95	104
Turbine GA	100	109
Turboprop Trainers / Light Attack	11	11
UAV	39	42
Grand Total	**1,539**	**1,711**

Table 16: Navigation market size by aircraft category

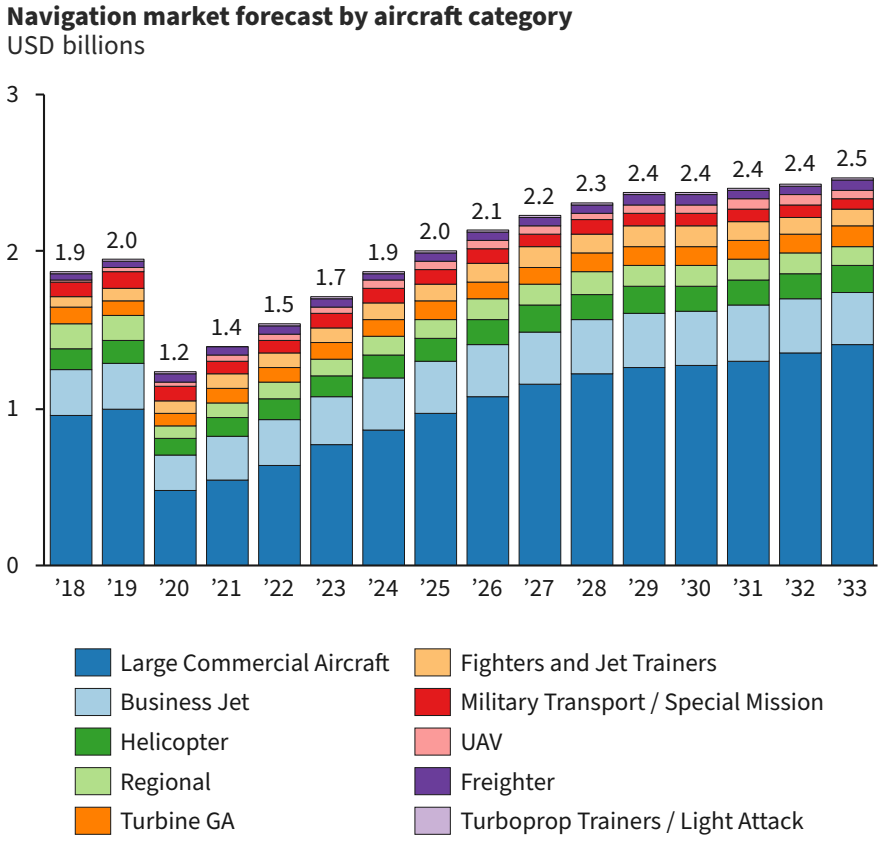


Figure 12: Navigation market forecast by aircraft category

9.8 COMMUNICATION

Communications market $ millions	2022	2023
Business Jet	306	325
Fighters and Jet Trainers	119	120
Freighter	48	50
Helicopter	56	55
Large Commercial Aircraft	414	490
Military Transport / Special Mission	47	47
Regional	74	80
Turbine GA	0	0
Turboprop Trainers / Light Attack	10	10
UAV	63	68
Grand Total	**1,138**	**1,244**

Table 17: Communications market size by aircraft category

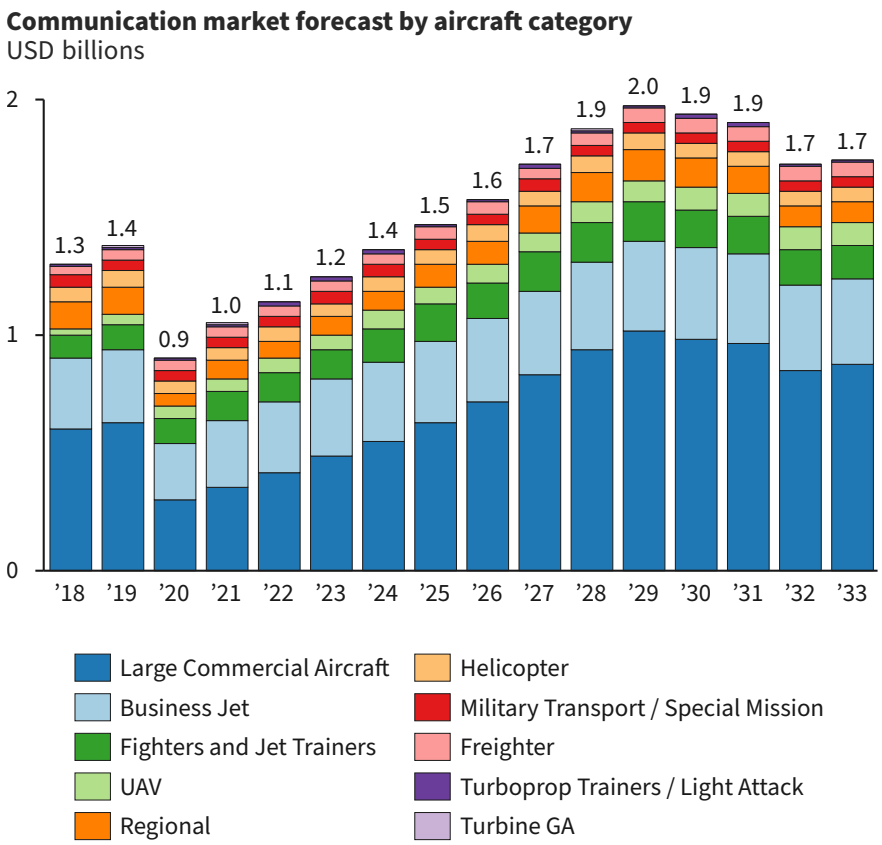


Figure 13: Communication market forecast by aircraft category

9.9 SURVEILLANCE

Surveillance market $ millions	2022	2023
Business Jet	175	185
Fighters and Jet Trainers	286	291
Freighter	16	16
Helicopter	239	236
Large Commercial Aircraft	211	253
Military Transport / Special Mission	97	98
Regional	23	25
Turbine GA	13	14
Turboprop Trainers / Light Attack	3	3
UAV	68	73
Grand Total	**1,131**	**1,195**

Table 18: Surveillance market size by aircraft category

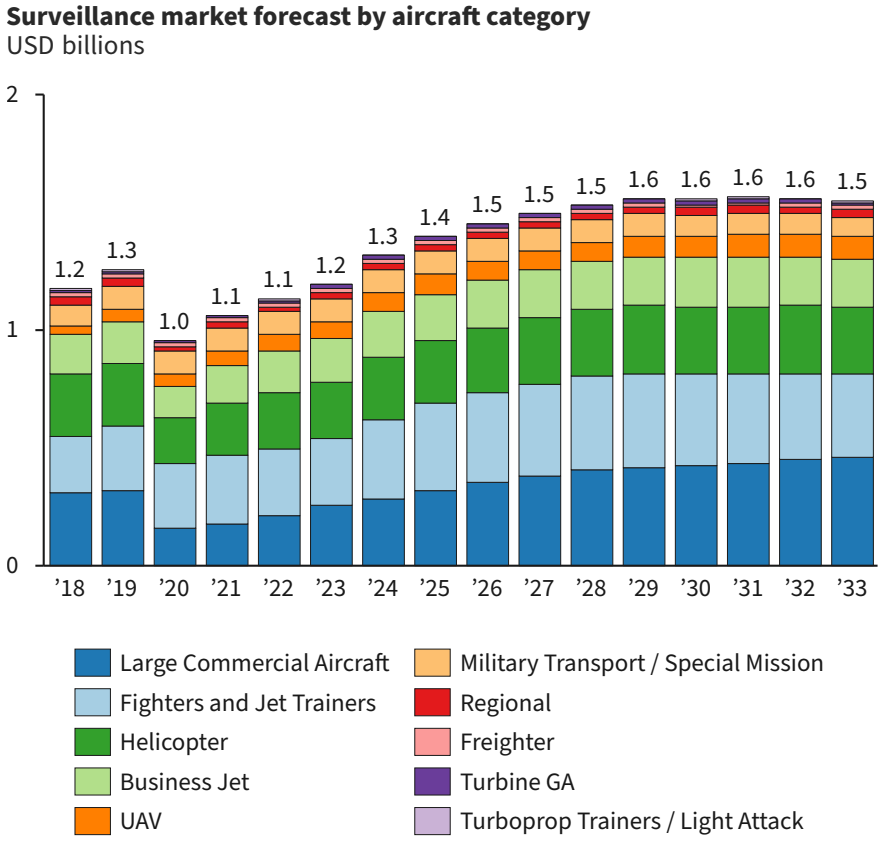


Figure 14: Surveillance market forecast by aircraft category

9.10 DATA

Data market $ millions	2022	2023
Business Jet	115	119
Fighters and Jet Trainers	138	139
Freighter	39	41
Helicopter	80	81
Large Commercial Aircraft	466	551
Military Transport / Special Mission	30	30
Regional	34	37
Turbine GA	25	27
Turboprop Trainers / Light Attack	15	15
UAV	23	32
Grand Total	**962**	**1,062**

Table 19: Data market size by aircraft category

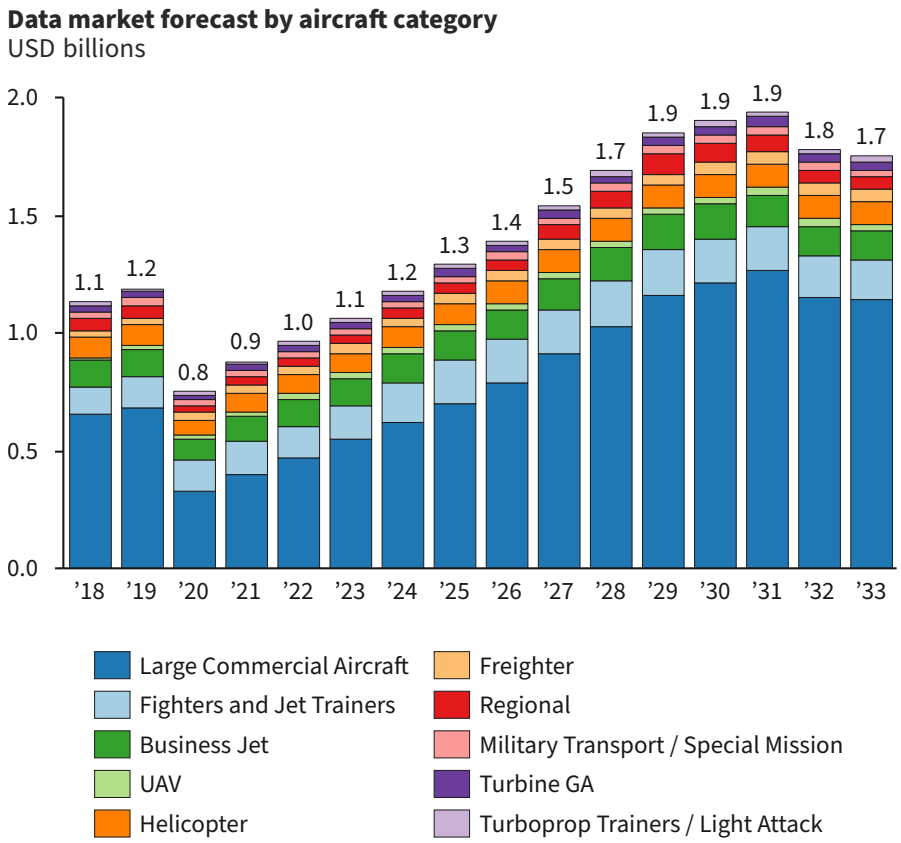


Figure 15: Data market forecast by aircraft category

9.11 MISSION

Mission market $ millions	2022	2023
Fighters and Jet Trainers	592	606
Helicopter	289	278
Military Transport / Special Mission	224	224
Turboprop Trainers / Light Attack	90	87
UAV	68	72
Grand Total	**1,263**	**1,269**

Table 20: Mission market size by aircraft category

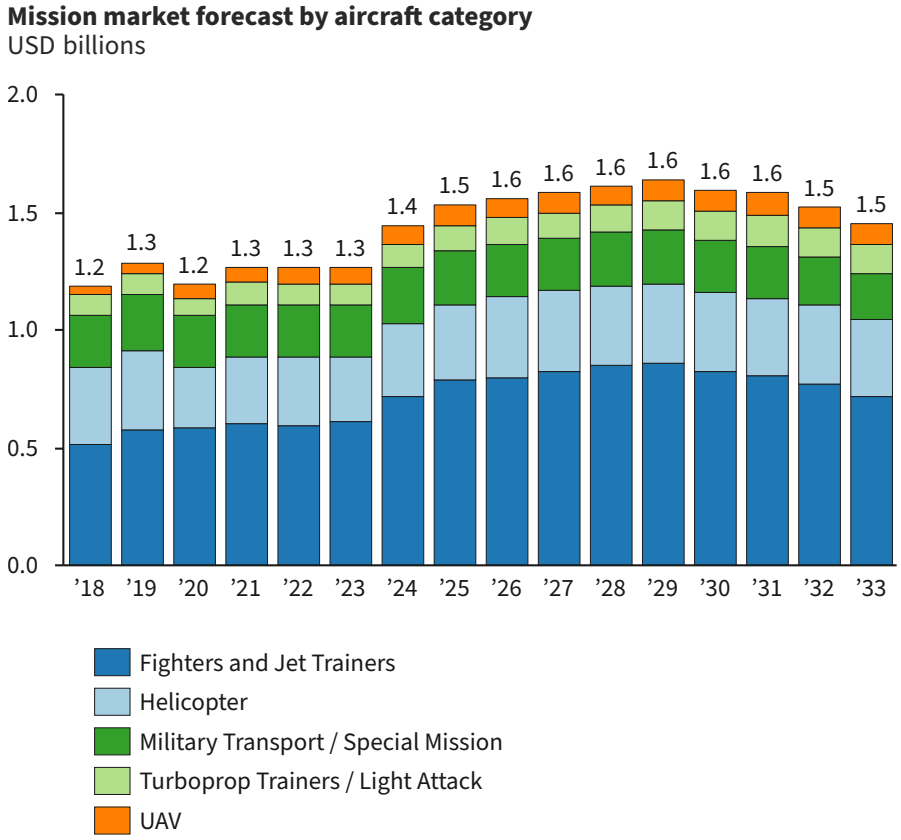


Figure 16: Mission market forecast by aircraft category

9.12 SENSORS

Sensors market $ millions	2022	2023
Business Jet	243	255
Fighters and Jet Trainers	725	733
Freighter	52	55
Helicopter	482	495
Large Commercial Aircraft	613	733
Military Transport / Special Mission	166	168
Regional	91	98
Turbine GA	1	1
UAV	58	62
Grand Total	**2,431**	**2,600**

Table 21: Sensor market size by aircraft category

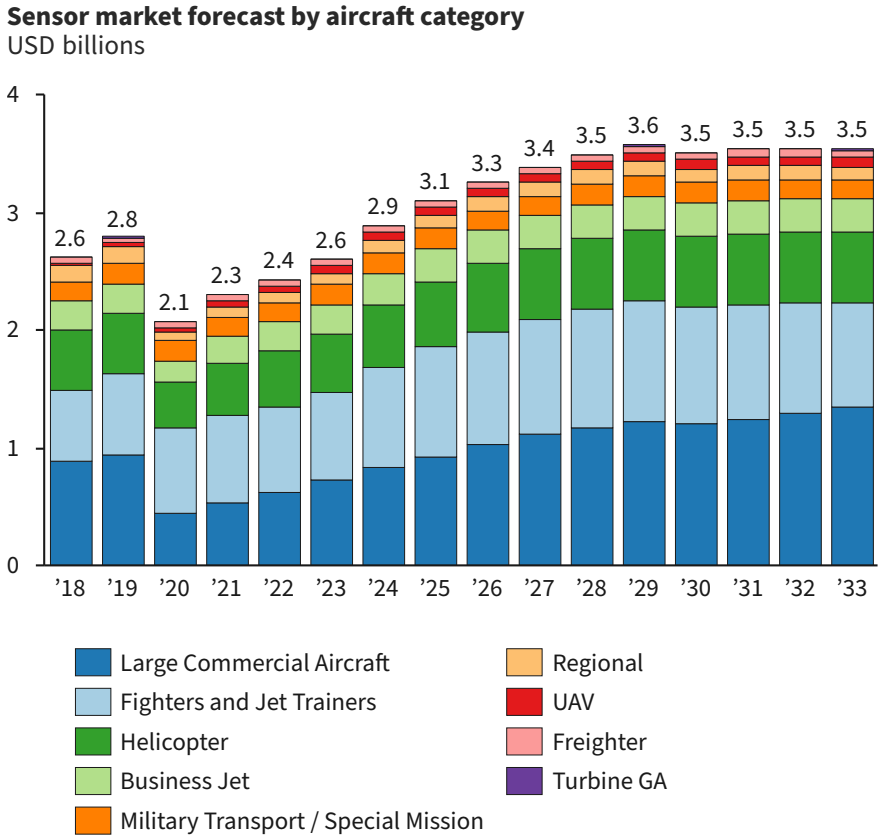


Figure 17: Sensor market forecast by aircraft category

10 MARKET SHARE ANALYSIS

The market shares in this section are calculated including both OE and aftermarket, but do not include non-production items such as funded R&D work or other services. We also add back in eliminations (sales Tier 2 to Tier 1 to Integrator) so that the sales numbers in the tables reflect actual company sales. As a result, each section has an 'intertrade' elimination so that bridge the total of company revenues to the overall market value. Without this elimination, there would be significant double-counting of revenues which would inflate the overall market size.

10.1 SUPPLIER CAPABILITY MATRIX

The table below shows the 51 suppliers that we have identified within the avionics sector. We have identified in which product sub-sectors each of these suppliers is a participant (denoted in blue).

There are a number of avionics providers that we have identified but not included within this report because they are either small or they largely operate outside of the scope as defined.

A number of these are noted as follows:

- Avidyne Corporation located in FL, USA and focused upon displays.
- Becker Avionics — located in Germany at Karlsruhe and focused upon Nav/Transponder products.
- Cuonics GmbH, Germany, provider of avionic services
- Dynon Avionics — located in WA, USA and focussed upon the GA market sector.
- Trimble — located in CA, USA provides GNSS receivers
- uAvionix — located in MT, USA, provides transponders and navigation equipment for UAS/UAVs

Manufacturer	Location	Ownership	SOFTWARE, DIGITAL	IMA	FMS	AUTO-PILOT	DISPLAYS	NAVIGATION	COMMUNICATIONS	SURVEILLANCE	DATA	MISSIONS SYSTEMS	SENSORS
ACSS	USA/France	Joint venture								■			
AEL Sistemas	Brazil	Public parent						■		■		■	
Aerosonic	USA	Public parent						■					
Astronics Corporation	USA	Public	■						■	■	■		
Aviage Systems	China	Joint venture		■	■		■				■		
BAE Systems	USA	Public	■			■				■		■	■
Bendix King	USA	Public parent			■	■	■	■	■	■	■		
Bharat Electronics	India	Public									■	■	■
Boeing Jeppesen	USA	Public parent									■		
CAES	USA	Public parent							■				
CCX Technologies	Canada	Private	■										
CMC Electronics	Canada	Public parent	■		■	■	■	■		■	■		
Cobham / Ultra	UK	Private equity											■
Cobham Aerospace Communications	USA	Public parent							■				
Collins Aerospace	USA	Public parent	■	■	■	■	■	■	■	■	■	■	■
Curtiss Wright	USA	Public						■			■		
Diehl Avionics	Germany	Joint venture		■			■						

Manufacturer	Location	Ownership	SOFTWARE, DIGITAL	IMA	FMS	AUTO-PILOT	DISPLAYS	NAVIGATION	COMMUNICATIONS	SURVEILLANCE	DATA	MISSIONS SYSTEMS	SENSORS
Elbit Systems	Israel	Public					■		■	■		■	■
Ensco Inc	USA	Private	■										
Garmin	USA	Public			■	■	■	■	■	■	■		
GE Aerospace	USA	Public	■	■	■	■	■	■			■	■	
General Dynamics	USA	Public	■								■	■	■
Genova Technologies	USA	Private	■										
Green Hills Software	USA	Venture capital	■										
HAL Hindustan Aeronautics	India	Public					■	■	■			■	■
Hensoldt GmbH	Germany	Public								■	■		■
Honeywell	USA	Public	■	■	■	■	■	■	■	■	■	■	■
Innovative Solutions and Support	USA	Public			■	■	■	■					
Jewell Instruments	USA	Private equity					■						
Kontron Inc	Austria	Public	■										
L3 Harris	USA	Public					■	■	■	■	■	■	■
Leonardo Avionics	Italy	Public						■	■	■		■	■
Lockheed Martin	USA	Public	■	■			■					■	■
Lynx Software Technologies	USA	Private equity	■										
Mannarino Systems and Software	Canada	Private equity	■										
Mercury Systems	USA	Public	■	■			■		■		■	■	■
Moog (incl Genesys Aerosystems)	USA	Public				■	■	■	■				
Northrop Grumman	USA	Public	■	■				■				■	■
Parker Meggitt	UK	Public parent					■	■					
Performance Software Corp	USA	Private	■										
Raytheon	USA	Public	■				■	■	■			■	■
Rohde and Schwarz	Germany	Private							■				
Saab	Sweden	Public	■	■	■		■		■			■	
Safran	France	Public				■		■			■		
Scio Teq	Belgium	Private equity					■						
Sierra Nevada Corporation	USA	Private						■		■		■	■
Tecnobit	Spain	Private										■	■
Teledyne Technologies (incl FLIR)	USA	Public								■			■
Thales	France	Public	■	■	■	■	■	■		■			■
Universal Avionics	USA	Public parent			■		■		■	■	■		
Wind River	USA	Public parent	■										

Table 22: Supplier capability matrix

10.2 OVERALL AVIONICS MARKET

We have analysed the avionics supply chain to provide the market leaders in each of the avionics sub-groups. The first tabulation below shows the overall avionics market leadership by market share percentage based upon their estimated revenues in 2019.

Supplier	Avionics Revenue (USD million)	Market Share (%)
Collins Aerospace	4,100	18%
Honeywell	3,200	14%
Raytheon	1,830	8%
Thales	1,750	8%
L3 Harris	1,250	6%
Northrop Grumman	1,190	5%
GE Aerospace	1,100	5%
BAE Systems	800	4%
Garmin	690	3%
Lockheed Martin	610	3%
Others	5,718	26%
Total company revenue	**22,236**	**100%**
Inter-trade eliminations	(5,195)	
Market total	**17,041**	

Table 23: 2023 Avionics overall market shares

The pandemic has caused a reordering as commercial sales have been dramatically affected by the Covid-19 pandemic. The commentary below refers to the 2019 market shares as at this stage we view 2020 as an aberration, but it is now clear that commercial sales will take some time to recover.

Collins Aerospace has been considered separately from its sister division, Raytheon Intelligence Systems, as they both tend to operate independently in the two sectors of commercial and defence.

Collins having benefitted from the combination of Rockwell Collins, B/E Aerospace and Goodrich Aerospace in recent years is now the clear market leader we believe.

Honeywell at No 2 has not benefitted from avionic related acquisitions in recent years, however, its organic growth has helped to sustain its position.

Thales believes that it is positioned as No 3 in avionics in the world today which we concur with.

A number of the large US defence contractors then take up the positions by market share.

It is interesting to note that Garmin, a relative newcomer, is now within the Top 10 avionics providers.

10.3 SOFTWARE, DIGITAL SOLUTIONS

We have estimated that the provision of avionic related software and digital services now accounts for 7% - 8% of the total avionics market.

We believe that this is an important growth sector and most of the large avionics suppliers are represented in the table below. The growth is coming from many areas but includes data analytics, data provision, flight planning, maintenance data, configuration control data, training, software upgrades and simulation support.

Supplier	Software, Digital Solutions Revenue (USD million)	Market Share (%)
Collins Aerospace	250	17%
BAE Systems	220	15%
Honeywell	210	14%
Raytheon	150	10%
Mercury Systems	100	7%
Northrop Grumman	85	6%
Lockheed Martin	80	5%
GE Aerospace	64	4%
Thales	50	3%
General Dynamics	40	3%
Others	246	16%
Total company revenue	**1,496**	**100%**
Inter-trade eliminations	(379)	
Market total	**1,118**	

Table 24: 2023 Software, digital solutions market shares

Many of the smaller software service providers fall outside of the top 10 however, many of these smaller service providers support their customers that are included above.

It is notable that there are a number of new entrants within the supplier matrix (see above) that have not traditionally been active in avionics.

Equally there are a number of major airlines who offer this level of service support to smaller fleet operators. However, these fall outside the scope of this report.

10.4 IMA/COMPUTING PLATFORMS

The tabulation below includes those providers of IMA and avionics computing platforms where 3rd party functions can be hosted.

Supplier	IMA/Computing Platforms Revenue (USD million)	Market Share (%)
Collins Aerospace	450	24%
Honeywell	410	22%
GE Aerospace	270	15%
Thales	240	13%
Northrop Grumman	155	8%
Lockheed Martin	110	6%
Diehl Avionics	90	5%
Mercury Systems	50	3%
Saab	45	2%

Aviage Systems	8	0%
Others	25	1%
Total company revenue	**1,853**	**100%**
Inter-trade eliminations	(676)	
Market total	**1,177**	

Table 25: 2023 IMA/Computing platforms market shares

We have included allowances for both Collins and Honeywell in respect to their respective ProLine Fusion and Primus Epic offerings although these have not always reflected open architecture approaches or have been designed to host 3rd party functions. They have however utilised modular avionics computing resources that lie at the heart of an integrated avionic cockpit.

The top 6 suppliers have content on Boeing 777, 787, A380, A350, Boeing 777X, F-22, F-35, A400M, G500/600 platforms which all reflect IMA style avionic architectures.

Mercury Systems is a significant supplier of common computing software offering Real Time Operating System (RTOS) partitioning for critical applications.

10.5 FLIGHT MANAGEMENT SYSTEMS

The following lists the top suppliers of Flight Management Systems which includes the Flight Management Computing system, Master Control Display Units (MCDUs), where applicable, and in certain avionics architectures there is a Flight Control interface unit.

The FMS system will also have interfaces with the aircraft navigation systems and the autopilot.

At the lower end of the market suppliers offer an “all in one” FMS unit that includes input interface, nav database, computation, links to the navigation system and auto-pilot etc.

Supplier	Flight Management Systems Revenue (USD million)	Market Share (%)
Honeywell	430	28%
Collins Aerospace	400	26%
Thales	320	21%
GE Aerospace	225	15%
CMC Electronics	51	3%
Garmin	30	2%
Saab	25	2%
Universal Avionics	13	1%
Aviage Systems	5	0%
Innovative Solutions and Support	3	0%
Others	8	1%
Total company revenue	**1,510**	**100%**
Inter-trade eliminations	(241)	
Market total	**1,268**	

Table 26: 2023 Flight management systems market shares

The top 4 FMS providers are Collins, Honeywell, Thales and GE Aviation that account for 92% of the FMS market sector.

FMS is therefore a consolidated sector which to some degree reflects the significant investment required to develop a full authority FMS and the associated barriers to entry in terms of criticality, safety and performance.

Both Collins and Honeywell benefit from packaging their FMS within their respective ProLine Fusion and Primus Epic avionics offering.

Smaller providers of FMS stand-alone products include Garmin, Universal Avionics, CMC Electronics and IS&S solutions.

10.6 AUTOPILOT SYSTEMS

Autopilot systems are typically linked to the FMS system and the Flight Control System in terms of flight guidance, and to the Engine Controls (FADEC) in terms of engine thrust control.

Supplier	Autopilot Systems Revenue (USD million)	Market Share (%)
Collins Aerospace	220	35%
Honeywell	130	21%
Thales	100	16%
GE Aerospace	60	10%
Safran	35	6%
Garmin	30	5%
BAE Systems	20	3%
CMC Electronics	13	2%
Moog (incl Genesys Aerosystems)	5	1%
Innovative Solutions and Support	3	0%
Others	13	2%
Total company revenue	**628**	**100%**
Inter-trade eliminations	(150)	
Market total	**478**	

Table 27: 2023 Autopilot systems market shares

The top four suppliers, Collins, Honeywell, GE Aviation and Thales account for 76% of the Autopilot sub-sector within avionics.

Thales has developed a strong position in recent years based upon its position both at Airbus and within the EU military market.

Safran has also developed capability within its Electronic Systems division and arguably benefits from having a strong position within Engine Controls.

Whilst BAE systems divested its avionics business some years ago it retained its auto-pilot capabilities for military applications. BAE also has a strong market position with Engine related FADEC control systems.

10.7 DISPLAYS

Displays represents one of the largest avionics sub-sectors and is a much more fragmented sector in terms of number of suppliers.

Supplier	Displays Revenue (USD million)	Market Share (%)
Collins Aerospace	1,200	26%
Honeywell	830	18%
Thales	590	13%
Garmin	320	7%
L3 Harris	250	5%
Raytheon	210	4%
GE Aerospace	210	4%
Elbit Systems	180	4%
CMC Electronics	160	3%
Diehl Avionics	135	3%
Others	596	13%
Total company revenue	**4,681**	**100%**
Inter-trade eliminations	(765)	
Market total	**3,916**	

Table 28: 2023 Displays market shares

Displays includes a wide range of product functions including multi-function displays, primary navigation, electronic flight instrumentation, engine and fuel displays, standby displays and surveillance displays.

Modern cockpits tend to have a much higher level of integration within avionics resulting in fewer large format flat panel displays. As product reliability associated with flat panel LCD technology has improved OEM constructors can rely on fewer larger multi-function formats.

The top 3 suppliers, Collins, Honeywell and Thales represent a combined 53% market share of the display sub-sector.

The display sector has grown in recent years given the need for greater surveillance/situational awareness and the application of HUDs within commercial platforms.

However, in the medium/long-term increasing autonomy and less dependence upon pilots may reverse this trend.

10.8 NAVIGATION

Navigation is one of the major avionic functions requiring a significant level of redundancy and incorporating a number of differing technologies.

Navigation has to encompass a range of needs from inter-continental long haul flights to landing a military platform on a moving surface such as an aircraft carrier.

Consequently, there are a significant number of suppliers within this avionic sub-sector many of whom represent only a fraction of the market.

Supplier	Navigation Revenue (USD million)	Market Share (%)
Collins Aerospace	350	18%
Honeywell	330	17%
Northrop Grumman	250	13%

L3 Harris	225	11%
Safran	150	8%
Thales	150	8%
GE Aerospace	93	5%
Garmin	75	4%
CMC Electronics	51	3%
Raytheon	50	3%
Others	249	13%
Total company revenue	**1,973**	**100%**
Inter-trade eliminations	(261)	
Market total	**1,712**	

Table 29: 2023 Navigation market shares

The top 4 suppliers, Collins, Honeywell, Northrop Grumman and L3Harris account for 64% of the navigation sub-sector in terms of market share.

Northrop Grumman achieved the No 3 position largely due to its acquisition of Litton Industries in 2001.

Navigation technology has evolved in recent decades from mechanical gyros (including RLGs, FOGs) to solid state devices which currently do not always meet the strict performance criteria necessary for primary navigation needs. However, it has allowed new entrants to offer solid state inertial reference units for platforms such as missiles, UAVs, rotorcraft and smaller aircraft.

10.9 COMMUNICATIONS

Radio based communication systems have been around for a century or more and still today are utilised for use in many aircraft.

Software defined radios together with a range of security and encryption means have recently been developed in order to allow safer, more reliable communications.

Data exchange communications systems, such as the industry wide ACARS system, have also been developed by suppliers.

Supplier	Communications Revenue (USD million)	Market Share (%)
Collins Aerospace	410	22%
CAES	350	19%
Cobham Aerospace Communications	225	12%
Honeywell	160	9%
Raytheon	150	8%
L3 Harris	95	5%
Garmin	75	4%
Rohde and Schwarz	70	4%
Saab	65	3%

Astronics Corporation	40	2%
Others	228	12%
Total company revenue	**1,868**	**100%**
Inter-trade eliminations	(623)	
Market total	**1,245**	

Table 30: 2023 Communications market shares

Collins Aerospace (Rockwell Collins) can trace its roots back 80 or more years to early airborne radios. Honeywell, via its Bendix King subsidiary, also has a long history within airborne radio communications.

Raytheon, Cobham and L3Harris have developed satellite-based security encrypted communications solutions for the defence market. Securitising transmitted data has taken on greater importance in recent decades within the military arena in order to avoid terrorist interference. These 3 companies also support commercial platforms where the threat of terrorist interference has increased in recent years.

Specialist communications providers such as Rohde and Schwarz and RET continue to develop software based digital communications solutions.

10.10 SURVEILLANCE

We elected early on in the design of this report to include Surveillance as a significant sub-sector given that it represents a significant growth path for suppliers. The emphasis upon improving situational awareness and reducing pilot workload all ties back to safety and survivability.

Within the past two decades there has been a number of airworthiness mandates directly related to surveillance (i.e. RVSM, TCAS, EGPWS). Operational efficiencies require that operators can complete a mission in reduced visibility and poor environments hence the proliferation of Enhanced Visual Systems (EVS) and Weather Radar systems.

Supplier	Surveillance Revenue (USD million)	Market Share (%)
Collins Aerospace	300	18%
Honeywell	290	17%
L3 Harris	180	11%
Thales	180	11%
Hensoldt GmbH	110	6%
Garmin	110	6%
Leonardo Avionics	100	6%
BAE Systems	90	5%
ACSS	82	5%
Elbit Systems	60	4%
Others	207	12%
Total company revenue	**1,708**	**100%**
Inter-trade eliminations	(513)	
Market total	**1,195**	

Table 31: 2023 Surveillance market shares

Given the note above many suppliers have developed a range of avionic product solutions to help operators improve efficiencies, safety and mission reliability.

This sub-sector is more fragmented as it has spawned a number of discrete solutions many of which can be retrofitted to existing aircraft.

We believe that the ratio of retrofit to OE forward fit revenues is in the order of 55%/45% in recent years.

The top four suppliers, Collins, Honeywell, Thales and L3Harris represented 55% of the surveillance sub-sector in 2019.

10.11 DATA

Data is a sub-sector that can be difficult to define in terms of hardware and software (i.e. data service providers).

Airborne data can be navigation based, communication based, maintenance based and analytically based in terms of say aircraft operating efficiencies.

Within the military field multiple data sources result in “data fusion” which is required as part of an effective network-centric operating arena.

Within this report we have included airborne avionic related data loaders, avionic data networks, data recorders, Quick Access Recorders (QARS) and data concentrators to fall within scope.

Supplier	Data Revenue (USD million)	Market Share (%)
Boeing Jeppesen	380	26%
Collins Aerospace	220	15%
Honeywell	170	12%
Curtiss Wright	150	10%
L3 Harris	120	8%
GE Aerospace	94	7%
Garmin	50	3%
Hensoldt GmbH	45	3%
Astronics Corporation	30	2%
General Dynamics	30	2%
Others	146	10%
Total company revenue	**1,435**	**100%**
Inter-trade eliminations	(373)	
Market total	**1,062**	

Table 32: 2023 Data market shares

The inclusion of Boeing Jeppesen, as a data service provider, can be debated however we note that a number of FMS/NAV providers including Collins, Honeywell and GE Aviation all provide data services necessary to support their hardware.

This one exception aside all of the suppliers identified within the table above provide avionic data hardware in its many forms (e.g. voice data recorders, flight data recorders, data loggers, data transfer terminals, data storage, data concentrators, quick access recorders etc).

If we look at the top four data hardware suppliers, Collins, Honeywell, Curtiss-Wright and L3Harris they account for 47% of the revenues in 2019, which suggests that this is a relatively fragmented sub-sector. Additional third-party suppliers of flight data recorder data analysis and reporting include Avionica, Flight Data Systems and KGB.

10.12 MISSION SYSTEMS

In compiling this report, we have adopted a broad definition of mission systems to include mission (command and control), stores management, electronic warfare, threat detection, countermeasures, and surveillance.

Supplier	Mission Systems Revenue (USD million)	Market Share (%)
Raytheon	350	17%
Northrop Grumman	300	15%
BAE Systems	250	12%
Lockheed Martin	200	10%
L3 Harris	150	7%
General Dynamics	110	5%
Collins Aerospace	90	4%
GE Aerospace	81	4%
Saab	80	4%
Elbit Systems	80	4%
Others	311	16%
Total company revenue	**2,002**	**100%**
Inter-trade eliminations	(732)	
Market total	**1,269**	

Table 33: 2023 Mission systems market shares

The top four suppliers account for 53% of revenues in 2019, which we would expect within the military sector where one might expect greater national fragmentation.

Notwithstanding this we note that the above suppliers appear regularly as main suppliers on platforms that are either multi-national or enjoy significant foreign military sales (e.g., F-35, F-18, F-15, F-16, C-130J, Apache AH-64, A400M, Chinook, Blackhawk).

Raytheon Intelligence Systems does not have the distraction of being a platform constructor which we believe helps it to be the No 1 supplier within mission systems.

BAE Systems has a strong presence in the US and therefore ranks 2nd in this sub-sector.

Both Honeywell and Collins, who dominate many of the commercial sub-sectors, appear much lower in the military rankings.

Northrop Grumman, Lockheed Martin, L3Harris and General Dynamics are all strongly positioned as US defence contractors within mission systems.

10.13 SENSORS

We believe that the lines that differentiate sensors from avionics are becoming heavily blurred and that sensor development is a key enabler of avionics performance.

Communications, Navigation and Surveillance are able to deliver improved performance and reliability thru the advancement of sensor technologies. Equally we see sensor technology becoming digitised (solid state) and smart (e.g., AESA radar, Air data modules).

Within this report we have defined sensors to include air data, radar, infra-red, electro-optical, inertial, lasers, and cameras/videos. We have not included basic generic sensors for position, pressure, temperature, etc.

Supplier	Sensors Revenue (USD million)	Market Share (%)
Raytheon	920	30%
Northrop Grumman	400	13%
L3 Harris	230	7%
BAE Systems	220	7%
Collins Aerospace	210	7%
Honeywell	170	6%
Lockheed Martin	160	5%
General Dynamics	120	4%
Thales	120	4%
Mercury Systems	105	3%
Others	427	14%
Total company revenue	**3,082**	**100%**
Inter-trade eliminations	(481)	
Market total	**2,601**	

Table 34: 2023 Sensors market shares

The top four suppliers Raytheon, Northrop Grumman, L3Harris and Collins accounted for 57% of total revenues generated within this sub-sector in 2019.

Raytheon is a clear market leader with sensors developed for all sectors of the military market including missiles, UAVs, rotorcraft, fighters, trainers and military transport.

Collins benefitted from the acquisition of Goodrich which had a market leading position in air data sensors.

Mercury Systems is a provider of software solutions that further emphasises the fact that sensors are becoming digitally controlled and often encapsulate ‘smart’ peripheral capabilities.

11 MARKET DYNAMICS

11.1 EFFECTS OF THE COVID-19 PANDEMIC ON THE AEROSPACE SUPPLY CHAIN

While the world-wide COVID-19 pandemic has passed, the effects on the aerospace industry linger, and will likely be felt for the next five years. During the pandemic, airlines were faced with sharply reduced passenger volumes, OEM constructors reduced their manufacturing tempo and avionics OEMs paused production. This disruption in both the labour supply and to the supply chain overall has had far-reaching effects on the industry.

As passenger volumes have largely returned to pre-pandemic levels, OEM constructors are faced with shortages due to these ongoing supply chain issues. This has delayed the delivery of new aircraft, disrupted the supply of material needed for MRO and repair activities and has impacted the ability of the industry to meet pent-up demand for air travel and transport of commercial goods. In addition, the normal demand for parcel and freight carriage in the absence of the usual capacity for passenger aircraft to carry a significant portion of this freight has caused unplanned demand for freight aircraft, primarily met with passenger aircraft conversions.

The result of this perturbation in the aerospace supply chain has been felt across the board, but is evident in its impact on the civil aviation market, particularly in terms of supply of new passenger aircraft. Backlogs are steadily increasing for all passenger airframe OEMs, while at the same time, 1st and 2nd tier suppliers to these OEMs appear to be second-guessing the airframers ability to ramp up production to meet publicly stated goals, leading to unexpected shortages of raw materials exacerbating already expected delays in delivery of aircraft. As of early 2024, the Airbus backlog stands at just over 8,500 aircraft, while the Boeing backlog stands at just over 5,600 aircraft. Assuming that suppliers can continue to meet the demands of Boeing and Airbus, this leads to a backlog of over 7 years to receive a new commercial aircraft ordered in mid-2024.

As a result, production rates for many major aircraft programmes still fall below pre-pandemic rates. We estimate that the OE market remains 17% below pre-pandemic levels across all aircraft (both civil and military) in constant dollar terms.

The aftermath and recovery from the COVID-19 pandemic also affects the aftermarket and MRO market segments. The supply chain capacity problems confront suppliers with satisfying OEM constructors while also servicing the demands of the aftermarket. The limitations of delivering to a predictable schedule impacts the return-to-service of aircraft as significantly as delivery of new aircraft.

One headwind for the avionics aftermarket is the trend of airlines delaying retirement. As many airlines grapple with a lack of new aircraft, several are holding onto to older aircraft longer than planned. This presents opportunities for avionics providers to issue upgrades and retrofits to keep these aircraft in service longer.

11.2 OEM AIRFRAME MANUFACTURER MARKET DYNAMICS

Airframe manufacturers clearly have a vested interest in ensuring that their platforms, designed for 60,000 landings or 30, 40, or 50 years of in-service operation, can be maintained throughout the life cycle. Within avionics, where computing resources can become obsolete every 5–10 years, the challenge for the OEM becomes significant. Equally, the OEM has to deal with the ever changing regulatory environment, which is largely concerned with maintaining safety in ever more congested airspace.

Thus, the airframe manufacturers need to take into account all of the above factors when designing and certificating their chosen avionics architecture at the outset (as the componentry and products will likely change several times through the life cycle value of the asset).

Airframe manufacturers' approaches to the sourcing and development of Avionics varies greatly depending upon the role of the platform, performance requirements and affordability issues.

Some 'common threads' facing airframe manufacturers that we see across most sectors are summarised as follows:

- The role of the OEM specifier vs that of the Avionic provider: OEMs have overall responsibility for 'integration and certification' of the platform. However, they are highly dependent upon the Avionic integrator. We see OEMs 'branding' their cockpits, but the avionics remain ProLine Fusion (Collins), Primus Epic (Honeywell) or similar derivatives.

- The drive to reduce cost of ownership via the adoption of 'open computing' architectures. This allows for modifications and upgrades in service by customers without incurring significant 3rd party costs.
- Avoidance of built-in obsolescence issues at the avionics design stage — i.e., life cycle ownership issues.
- Greater drive for the adoption of common industry standards/COTS approach to sourcing Avionic-related software and firmware e.g., rotorcraft, business jets, GA, small regional aircraft.
- Commercial OEMs limiting the amount of Buyer Furnished Equipment (BFE) associated with cockpit avionics (which results in dual certification costs) — i.e., affordability issues.
- Concerns over security, cyber-attacks and data abuse within an increasingly networked digital operating environment — i.e., safety, security.
- Provision for greater overall autonomy of the platform operating within a networked environment (e.g., independence from ATC, data fusion within battlefields, office in the sky, health and usage monitoring in real time)
- 'Cockpit connectivity', which covers a wide range of communications, networks and data linkers via satellite, ATC etc. allowing OEMs to plan for the necessary infrastructure to support increased demands for In Flight Entertainment (IFE), 'office in the sky' services, exchange of real time maintenance data and autonomous data for decision making purposes.

11.2.1 OEM ROLE IN SUPPORT OF THE OPERATING FLEET

Civil OEM airframe constructors also have a role to play in maintaining/upgrading their in-service and forward fit avionics throughout the respective platform life cycles. Much of this is through necessity i.e., mandated and/or regulatory changes and partly it is to ensure that they maintain sales through offering a competitive product that is not limited by avionics obsolescence issues.

Boeing for example offers an Avionics upgrade service as part of Boeing Services. Boeing delivers more than 600 avionics Service Bulletin (SB) solutions every year, which it claims, are preferred by regulators over more restrictive supplemental type certificate (STC) solutions. Boeing SB solutions also integrate technical publications, maintenance-related documents, and airworthiness artefacts in a manger that minimises additional recurring maintenance tasks.

Boeing claims the following benefits are available via its Boeing Avionic Support Services business:

- Gain efficiency by navigating the best route from airport to airport in all weather conditions.
- Increase awareness and satisfy regulatory requirements with surveillance solutions that include ADS-B Out, TCAS, and MMR.
- Increase pilot effectiveness with the same heads-up and large-display systems used on the 787 Dreamliner.
- Meet emerging needs with our world-class, 24/7 customer and technical support.
- Asset value retention with Boeing solutions for leased aircraft.

Airbus similarly offers Avionics support services that are geared to maintaining airworthiness, type approval etc. They focus upon 'air traffic management' services with the following specific examples on offer:

- Communication: data link & SATCOM needs with FANS A+/B+, Iridium or Inmarsat solutions
- Navigation: optimised flight paths with RNP-AR
- Surveillance: collision avoidance and automatic data broadcasting with the ADS-B Out.

Like Airbus and Boeing other commercial OEMs, including business jet and regional manufacturers, also have a vested interest in maintaining their avionic suites to current standards.

The asset value of an aircraft is dictated by a number of factors including usage but also by having the latest standard of avionics fitted. All leaseholders and financial institutions that deal with second-hand aircraft place significant emphasis upon the standard of avionics fit having been maintained to current industry standards.

Equally many leaseholders, operators and end-users have a preference for aircraft that have avionics upgrades designed and approved by the OEM provider as holder of the original certification approvals (as opposed to an upgrade via an STC or 3rd party product installer).

The OEM constructor may undertake the installation of the new avionics themselves or, as is often the case, will work with an approved 3rd party such as Honeywell, Collins Aerospace, Lufthansa Technik etc.

Within the military arena, the emphasis for OEM constructors is often driven by the national budget process that dictates the success or otherwise of platforms that are expected to operate for decades in service. Budget reviews can increase, decrease or discontinue platform budget allocations.

11.2.2 MILITARY OEM AIRFRAME MANUFACTURER MARKET DYNAMICS

Military programmes can be summarily cancelled at differing stages of development or heavily curtailed in production as has happened in recent decades (e.g., Nimrod, CAH66 Commanche, IAI Lavi, Grumman XP50, F-20 Tigershark, General Dynamics F111-B).

OEM constructors within the military sector find it necessary to actively participate within the prevailing geo-political arenas that can have a significant impact upon their YoY investment needs.

The larger military OEMs will typically spend considerable time and resources canvassing local government bodies regarding R&D needs, local employment needs, security of Intellectual Property, investment needs, national security needs etc.

Equally the same OEMs will need to look beyond their national boundaries to locate risk-sharing partners in seeking to develop new platforms.

Recently Boeing teamed with Saab to offer the USAF a new trainer, now designated T-7A, which resulted in the award of a $10 billion contract for up to 2,000 aircraft. Embraer elected to partner with Boeing in 2012 in order to develop its C-390 Millennium military transport plane although in 2019 Boeing pulled out of this partnership due to internal issues. The Airbus-led consortium for the A400M involves 8 national partners all of whom are risk sharing and are committed to purchasing varying numbers of the aircraft.

Military OEM constructors will often take an active role in upgrading their initial fit avionics computing and sensor suite in order to maintain performance and to continue to attract Foreign Military Sales (FMS). This is clearly the case with, for example, F-35, C-130J, Apache AH-64, Typhoon, which all have significant sales potential outside of their countries of origin.

One aspect of large defence OEM constructors, both at the airframe and the avionic/electronics level, is the degree to which we found similar levels of profitability across many of the suppliers. This level of profitability was consistently within the 10% — 12% range and we believe that this may well reflect the 'open book' accounting policies dictated by the large defence consumers e.g., US DoD, USAF, USN, US Army. This open book cost-plus policy applies to suppliers at Tier 1 and Tier 2 levels and can constrain levels of profits that can be realised from military contracts.

Both civil and military OEM constructors work very closely with major avionic providers such as Honeywell, Collins Aerospace, Thales, GE Aviation, L3 Harris, Northrop Grumman, General Dynamics, Raytheon Intelligent Systems. This largely reflects the fact that the major providers have a vast pool of experience to draw from and that the performance of today's modern avionics and sensors have a significant impact upon the overall performance of the platform.

11.2.3 AIRCRAFT OEM IN-SOURCING VS OUT-SOURCING

In 2017 Boeing announced its investment in creating a facility that would operate to develop in-house avionics solutions to meet Boeing's future needs.

This we believe was partly a response to its experience with the 787 whereby it placed much greater reliance upon its key suppliers to develop larger integrated systems solutions. One result of this initiative was to place greater power and control in the hands of its supply chain.

Many suppliers, including avionics providers, were provided an opportunity to leverage improved commercial conditions not only with Boeing but also with the airline end-user community.

Boeing has subsequently sought to bring a number of equipment-related design and development capabilities in-house.

Boeing stood up its AvionX division in July 2018 with the focus on development and production of avionics systems for navigation, flight controls and information systems. It was widely expected that the target was the New Mid-market

Aircraft (NMA) slated for EIS around 2025.

Both in-production and aftermarket opportunities are being researched by AvionX. The new subsidiary is located in Plano, Texas, the headquarters for Boeing Global Services, which will oversee AvionX.

Clearly the combination of the 737 MAX issues, the pandemic and the demise of the NMA may well have set this initiative back some years.

The barriers to entry to avionics are very high and it remains to be seen if Boeing can offer the market avionics products at competitive or attractive levels or if the Airlines/end-users will accept these products from an OEM constructor (previous moves have met with considerable resistance).

We note that all of the subsequent Boeing press articles have indicated that reviewing 'aftermarket services' is the priority for AvioniX as opposed to developing OEM avionic products.

Airbus also has an 'avionic"' division. However, this sits within its spacecraft business unit and it is entirely focussed upon developing and sourcing avionics products for satellite launches and EU-funded space programmes.

Airbus does include 'upgrades' within the list of commercial services provided to the commercial aftermarket and these include the following options:

- Communication: data link & SATCOM needs with FANS A+/B+, Iridium or Inmarsat solutions
- Navigation: optimised flight paths with RNP-AR
- Surveillance: collision avoidance and automatic data broadcasting with the ADS-B Out.

We are not aware of any similar moves by Embraer, Bombardier, Gulfstream or ATR to create in-house avionics design and development capabilities.

Within the military arena there are likely to be fewer commercial reasons for bringing avionics in-house. However, there may be sourcing or security reasons for generating capabilities 'in-house' where IP can be better protected.

BAE Systems, as an OEM constructor, sold its avionics business to Finmeccanica (now Leonardo) some years ago and, whilst it retains capabilities in commercial flight controls, FADECs and military EW, we do not see any moves to move back into mainstream commercial or military avionics.

Lockheed Martin, as an OEM constructor for the F-35 platform, has developed a number of key avionic/sensor capabilities in-house. These include Auto Ground Collision Avoidance, Electro-Optical Targeting System (EOTS) and mission computers.

The Auto GCAS, has been developed jointly by Lockheed Martin Skunk Works® , the Air Force Research Laboratory and NASA, is designed to reduce incidents of what is known as controlled flight into terrain, or CFIT. According to U.S. Air Force statistics, CFIT incidents account for 26% of aircraft losses and a staggering 75% of all F-16 pilot fatalities.

The Auto-GCAS development was therefore driven by national safety needs within a specific application for a specific mission role.

Within the military rotorcraft sector, Leonardo owns Selex as an avionics subsidiary. Selex Inc. provides navigation and precision landing equipment vital for successful mission execution in all weather conditions. Selex offers VOR, DME and TACAN as part of its precision landing capabilities. Leonardo Inc. describes its avionics capabilities as communication, navigation, identification, and surveillance (CNIS) avionics systems. They specialise in High Frequency (HF), Very High Frequency and Ultra High Frequency (V/UHF) radio systems for commercial and military application as well as Identification Friend or Foe (IFF) transponders for military use.

However, it is equally clear that the range of mainstream rotorcraft within Leonardo's portfolio, be they military or civil, rely upon avionics providers such as Honeywell, Collins, Meggitt, and Thales for the vast majority of their avionic suites. Selex does not appear to materially benefit from being a favoured 'in-house' provider.

In summary we do not foresee any significant or emerging threat posed by the OEM constructors to the avionics suppliers in terms of a change to in-sourcing. There will always be exceptions especially in the military sector driven by national sensitivities, need to protect IP etc.

We see the biggest attraction within the civil sector is for the OEM Constructors to achieve a greater market share of the lucrative upgrade and retrofit market. Arguably the jury is still out as to whether Airlines and end-users will view this as a better service proposition relative to the current status quo.

11.2.4 SUPPLIER INVESTMENT IN OEM CONSTRUCTOR PROGRAMS

Another trend is the increasing demand by OEM constructors to require a greater investment by key suppliers in the development and evolution of aircraft programs. Significant investment, buy-in, or risk sharing by these key partners result in a lengthier payback period for the suppliers. Where prior aircraft programs allowed for a payback period that spanned the first several hundred aircraft, the payback period is now extended, perhaps, by 10-fold.

While suppliers benefit from an entrenched position, OEM constructors capitalize on these positions by demanding greater investments, de-escalation in prices and expectations of "free" upgrades to existing products in exchange for production continuity for the suppliers.

11.3 AVIONICS AFTERMARKET DYNAMICS

11.3.1 THE NATURE OF THE AFTERMARKET

This section will consider the aftermarket in terms of sustaining the in-service avionic equipment over its life cycle by way of traditional repairs, spares, MRO and support logistics.

Avionics related computers do not suffer traditional 'wear and tear' although they are subject to vibration and environmental effects. Equally software, once verified and installed, does not typically wear or break in service.

Frequent thermal cycling can adversely affect electronic equipment and over time componentry and boards can fail, however, significant improvements with the design of componentry and improved mounting techniques (anti-vibration) has improved the reliability of electronics significantly.

The adoption by avionics designers of 'active' as opposed to 'passive' cooling has also had a beneficial effect upon premature failure rates of electronic equipment (especially around notorious hotspots).

In reviewing avionic equipment failure rates, it is clear that many of the issues that arise within the cockpit on the systems synoptic pages are often defects and/or bugs as opposed to hard failures. These defects or bugs can often be resolved by a soft or hard reset or, upon further investigation, they can relate to false sensor related signals.

Nevertheless, many elements of an avionic suite are considered mission critical or safety critical and avionics designers have achieved the requisite levels of reliability by incorporating redundancy (e.g., multi-cockpit displays, triple inertial reference systems, dual FMS, dual air data systems etc).

11.3.1.1 THE TREND TOWARD LONGER IN-SERVICE LIVES FOR OLDER AIRCRAFT

Commercial airline operators respond to world events and changing passenger demand to reshape their operations and fleets. During the economic downturn of 2008 and the COVID-19 pandemic, operators altered their aircraft fleet mix, in both cases, parking, returning to lessors, or selling segments of their fleets.

The timing of these moves has had interesting follow-on effects. For example, one of the unforeseen effects of the COVID-19 pandemic, its long-term impact on the supply chain, has substantially reduced the industry's ability to ramp-up production of new aircraft to pre-COVID levels. As passenger volumes have returned to normal levels, the demand for new aircraft has outpaced the production capability of Airbus, Boeing and Embraer. As a result, airlines are keeping older aircraft in service longer than previously planned.

With more of these older airframes remaining in service than had been planned, these near-legacy aircraft are less likely to be equipped with capabilities meeting current airspace operational requirements or maintaining interoperability with the newest aircraft in the fleet. Additionally, these aircraft may have avionics that are nearing the end of their useful economic life, with maintenance becoming ever more expensive. This means that the industry will need to respond to aftermarket demand for retrofitting these aircraft with more modern technology.

11.3.1.2 THE ROLE OF MAINTENANCE AND REPAIR ORGANISATIONS

One common factor amongst most, if not all avionics, is their modular design and common interface connectors. This means that rack-mounted (avionics bay) or cockpit-mounted products are easily removed and replaced. Unlike certain systems and structures parts that are much more inaccessible a faulty avionic LRU can often be replaced in the time take to turn the aircraft around between flights (assuming that a replacement unit is available locally).

This in turn generates a significant market for the number of loaners or exchange units required within avionics.

A quick look at 3rd party service providers will show that they carry significant inventory in terms of loaner and exchange units. The service provider usually carries a significant number of OEM or manufacturers approvals necessary to offer exchange unit and repair services. All of these 3rd party service providers need to have repair station approval such as FAR 145 or EASA 145 certification in order to operate.

Faulty or failed avionics units cannot usually be repaired 'on the spot'. Unlike mechanical products, where a seal or bearing can often be changed locally with minimum equipment, avionic LRUs require specialised tools, diagnosis sets, electronic test equipment and clean or 'white room' assembly conditions.

There is a significant investment required to set up such a repair and overhaul shop to support avionics. Again, if you look at many of the major avionic suppliers, they will often have many 'support centres' or 'technical support centres', but far fewer actual repair and overhaul stations.

Hence the need for OEMs and manufacturers to approve local 3rd party avionic repair houses (which have sprung up all around the globe).

Some of the significant 3rd party avionic support centres, many of which operate via approvals from the OEM manufacturers, include the following:

- Haeco Group (Avionics division)
- Standard Aero (Avionics)
- Lufthansa Technik Avionics
- TAP maintenance and engineering (supports Embraer)
- OGMA Aviation services
- LOT Aircraft maintenance services
- TAG maintenance services
- Cincinnati Avionics (US)
- Flite electronics
- Scandinavian Avionics (SA Group)
- British Airways Avionics Engineering
- Aero Dienst Germany
- Aerospace Maintenance Solutions (OH)
- Ontic Services
- Commander Instruments and Avionics (US)

The avionics aftermarket, as defined by repairs and overhauls, represents a significant proportion of the overall avionics market and is estimated to be $16.0 billion in 2019, falling to $11.5 billion in 2020 It will be interesting to note if and how the traditional electronics repair houses will include software services given the growing proportion of software within avionics.

11.3.2 RETROFIT AND AFTERMARKET DRIVERS

Within this report we identify a number of key drivers for the need to retrofit or upgrade avionics within both commercial and military aircraft over time. These can be summarised as follows:

- Technology improvements (e.g., Flat panel LCD displays replacing CRT displays)
- Obsolescence avoidance (e.g., production of older qualified computing components ceases)
- Reduced pilot workload (e.g., FMS, Integrated functions, data fusion)
- Improved situational awareness (e.g., TCAS, Weather radar, EGPWS, EVS)
- Future Air Navigation performance requirements (e.g., MMRs, FMS, GPS Navigation)
- Mandatory/regulatory changes from Airworthiness authorities (e.g., RVSM, TCAS, ADS-B, FANS etc)
- Improved operating efficiencies (e.g. Data analytics, onboard services, improved Nav performance)

It is clear that many avionics suppliers have developed products and services necessary to support this attractive market sector, which operates somewhat independently of the forward fit OEM cycle.

We say 'attractive' market sector because the retrofit/upgrade market is fragmented and presents many access points (opportunities). Airline operators can come under time pressures to comply with airworthiness requirements, and they will also need to minimise downtime associated with the retrofit so 'price' may not always be the key determinant in the supplier selection process.

Example: The adoption of multi-mode receivers

One example of these changes is the adoption of Multi-Mode Receivers (MMRs) in the past decade or so. Installation of an MMR can help an aircraft overcome problems associated with multipath interference, and support advanced navigation standards, such as GLS CAT II/III and WAAS LPV. The MMR combines the previously separate modes of VOR, DME, AFD and introduces satellite-based GPS into one receiver to cover all primary navigation needs for the aircraft.

The MMR thus saves weight, cost and should result in reduced maintenance costs compared with a number of older discrete Nav systems.

We estimate that about 50% of MMRs are sold to the OEM constructor and 50% are supplied to the retrofit market.

In 2019, Collins said it has sold approximately 10,000 MMRs, more than 7,000 of which have been delivered. Honeywell says it has sold about 3,000 MMRs and delivered 1,600 units; and Thales says it's won more than 3,000 MMR orders from 40 airlines.

This report sets out a number of forecast scenarios that continue to unfold as the world continues to deal with the Covid-19 pandemic. It is becoming increasingly clear that airlines and operators are having to retire aircraft, in some cases prematurely, in order to reflect significantly reduced capacity demand and the need for newer aircraft with improved operating efficiencies.

Many of these aircraft would have been prime candidates for improvements to their avionics over time. The aircraft most affected by these early retirements (as opposed to just storage which will reverse once demand improves) include Boeing 747-400s, A340s, A380s, Boeing 777-200s, early versions of Boeing 737NGs and A320s.

Example: Avionics aftermarket support organisations

In the previous section we noted that OEM constructors have a vested interest in maintaining avionics standards through the life cycle of their respective platform offerings. OEM constructors therefore offer a range of in-service support for their products once the warranty period has expired.

However, these services can vary (size of fleet, location of fleet, stock availability, urgency, timing etc) and whilst the OEM constructors will typically offer regulatory, mandatory, advisory notes, service bulletins, technical publications, recommended performance upgrades etc, they do not always include sourcing of parts, associated installation services and aircraft re-commissioning services.

Much of this work needs to be performed in the field at airline depots or at line 1 maintenance depots — the OEM constructors simply do not have the infrastructure to support this level of aftermarket service.

Aside from OEM constructor services, the avionics market is supported by many avionics providers who offer their own upgraded products via the Supplemental Type Certificate (STC) route.

Also, the OEM constructor is unlikely to invest significant sums in updating 'out of production' series aircraft platforms. Often the only option available to operators of out of production aircraft is via 3rd party aftermarket service providers.

The STC approval route allows 3rd party providers to offer customers of a certain 'type' an additional or upgraded avionic product, and once approved, can offer the STC product to all operators of the particular platform type.

Whilst it is difficult to quantify the market specifically for STC products it is supported by most avionics providers (i.e. they nearly all offer a range of STC solutions) and these STC products are available for hundreds of in-service platforms.

Many smaller business jets, GA aircraft and rotorcraft are offered by the OEM constructor with a 'minimum fit' of avionics necessary to achieve aircraft certification. However, owners/operators can enhance their basic avionics suite via the STC route.

We have analysed the STC market in order to provide examples of how prolific this sector can be.

In the following example we selected the older Boeing 737 classic and 737NG (500/600/700/800) to see what STCs are on offer from various vendors by way of upgrades.

Service Provider	Product upgrade offerings (STC)	OEM/STC holder
ASM Inc	TAWS, Next Gen Nav, MFD, EGPWS, DADC, DFDR, GPS	Honeywell, Universal Avionics, ASCC, GE Aviation, IS&S
Avionics Support Group (ASG)	EFB, SATCOM, ELS/EHS Transponder, SSCVR with ACARS.	Honeywell, Cobham, Collins,
Honeywell	FMS, Flight recorders, Weather radar system, High speed SAT comms, Comms management Unit, Runway Awareness Advisory System	Honeywell
HS Aviation	GNSS/SBAS is an independent GPS system that allows aircraft to meet the RNP requirements for en-route and terminal approach. Other upgrades include CPLDC, SSCVR DATALINK, VHF/VDL-2 Datalink, SATCOM, FANS 1A, WIFI and IFE upgrades.	CMC (TransDigm)
Standard Aero	Flight data recorders, UNS-1C FMS, TCAS, High speed internet and Comms router	Triumph (ex-Fairchild Controls business), Universal Avionics, Honeywell, Aircell.
Teledyne	E - Airborne Data Loader (nav data base loader).	Teledyne
SEA Aerospace	RDR 4B Weather Radar, SATCOM system, Cockpit Door Surveillance System (CDSS)	Honeywell, Cobham, Collins
Mid Canada	4 Display EFI-890R Large Panel Smart Displays, Dual UNS-1FW WAAS LPV FMS, Class A TAWS, Vision 1 Synthetic Vision System, Automatic Dependent Surveillance, Electronic Passenger Briefing System	Universal
IS&S (offeror and installer).	FAA Certifies Flat Panel Display System (FPDS) For Classic Boeing 737. STC Covers Installation on -300, -400, and -500 Models.	Innovative Solutions & Support
KF Aerospace	EFIS displays, Head Up Displays,	Collins, Universal

Table 35: Boeing 737 Classic/500/600/700/800 avionics upgrades

The above is only a small sample of the number of service providers that offer avionic upgrades and retrofits to older Boeing 737s. Most other legacy platforms still in service will have a similar range of STC product offerings.

The service providers noted in the table above will usually specify the STC type approval together with the equipment

needed, any rewiring or structural modifications required and the total number of hours necessary to install the upgrade.

Most of the national airworthiness authorities publish a list of approved STCs usually identifying the platform type, product function and STC holder.

11.3.2.1 THE POSITIVE AFTERMARKET EFFECTS OF COVID-19

One further note of caution relates to the effects of the current Covid-19 pandemic. The impact upon OEM build rate recovery is not yet entirely clear. However, consensus is growing around both narrow body and wide body recovery rates.

What is less certain is the degree to which the parked/stored fleet returns to service. Many airlines faced with reduced capacity and the higher operating costs associated with older platforms may not return all of their stored fleet to service.

This could have a significant impact upon the retrofit/upgrade market in reducing the size of the addressable market.

We have analysed the parked stored fleet at end of 2020, and we have identified those aircraft platforms with >50% of the fleet in storage and > average age of 15 years.

We note the following platforms fall within this category:

A300-600, A310-200/300, A330-200, A321ceo, A380, A340-300-500-600, Boeing 757-200, 747-8, 747-400, 767-300, 737—200/300/400/500/600, 777-300, 767-400ER, ATR72, ATR42.

Many of these aircraft may re-enter service and these typically represent the target market for retrofit/upgrade avionic providers.

Within the military sector the STC approach is very similar with avionics suppliers often engineering the STC approval (as the Holder) and then utilising 3rd parties to install the upgraded equipment together with any necessary mods to the existing wiring, airframe etc.

Requests for military upgrades can come from the operators which in this case is usually the relevant services arm e.g., US DoD, USAF, MoD, Luftwaffe etc. This is certainly the case for older aircraft and out of production aircraft.

This report does not include the GA market in any detail. However, it is a very fertile market for upgrades. Many suppliers including Aspen, Garmin, Gensys and Avidyne offer a wide range of STC type approved products including ADS-B, flat panel displays, autopilots, basic FMS navigation, engine monitors etc. These products can be purchased for as little as $2,000 for a simple ADS-B transponder through to $10,000 - $35,000 for an integrated display suite. Installation by a 3rd party provider will add to these costs.

Counterpoint believes that the upgrade market is significant, in terms of revenues, relative to the OEM forward fit. However, it operates over a different timing cycle and it is therefore attractive to many avionics suppliers. All of the evidence from suppliers' financial reports indicates that the upgrade market generates higher profit margins than the equivalent OEM forward fit supply, adding to its attractiveness.

Further we do not see any significant impact from the pandemic upon the military upgrade market. However, the civil market sector for upgrades/retrofits will likely reduce owing to earlier than planned retirements of legacy platforms.

11.3.3 AVIONICS SERVICE AND SUPPORT MODELS

Support services associated with avionic products, as distinct from both mid-life upgrades and spares/repairs, is a relatively new and growing market. It has grown largely as a result of the need for the following:

- Primary navigation databases, as part of an FMS, that require updating on a monthly basis
- Terrain, weather and ground data for EGPWS/TERPROM/WX systems.
- Download and analysis of onboard generated avionic system data (health monitoring, predictive maintenance, trouble-shooting etc).
- Broadband wi-fi and internet services via SATCOM and satellite systems for mobiles, video on demand, 'office in the sky' services.

- Software upgrades for debugging, performance upgrades, new regulations (think Apple iPhone!)

Honeywell Avionics, for example, offers its range of 'connected services' as part of its avionic portal. Within this connected service are seven offerings, all of which can be purchased via monthly subscription, including:

- Navigation database loading
- Maintenance support and planning
- Cabin services (wi-fi, SATCOM etc)
- Configuration maintenance (firmware/software upgrades to avionic equipment)
- Camp trending (statistical analyses of on-board generated data)
- Forge billing and subscriptions (data used for optimisation, cyber-security and maintenance)
- Sky Connect (digital mapping for displays and aircraft tracking in real time via Iridium satellite)

Each of the main avionics suppliers offer similar in service support packages that allow equipment configuration, optimisation, data-bases, maintenance and in-flight support services to be realised in real time via a periodic subscription.

The OEM constructors have equally played a role in developing support service offerings. When Boeing developed the Boeing 787 it offered customers its 'Goldcare' package which essentially is a 'fly by the hour' price agreement taking into consideration maintenance, spares, repairs, overhaul, technical support etc.

Suppliers selected to provide the main systems and equipment on the Boeing 787 were also required to commit to 'fly by the hour' pricing as part of the Goldcare offering.

More recently Boeing has offered the market 'MyBoeingFleet' which covers parts, maintenance, flight operations, analytics, consulting and training.

Airbus offers an equivalent to Boeing's Goldcare with its 'Total Support Package' as part of its commitment to costed Flight Hour Agreements.

Further down the avionics supply chain there are many providers of in-flight avionic service support.

- Cobham SATCOM's core portfolio of SwiftBroadband solutions, ranging from the AVIATOR 200, 300 and 350 to the AVIATOR 700 and 700D and the new AVIATOR S series, provides in-flight connectivity to support a host of advanced applications including cockpit voice dialling in addition to in-flight calling, email and internet browsing for passengers.
- Thales offers its "Avio" range of support services that extends to include:
  - Avio hardware and software support/upgrades
  - Avio cyber security software
  - Avio data for maintenance and optimisation needs
  - Avio EFB solutions
- Collins Aerospace's ARINCDirect flight support services offer a single, comprehensive suite of services and support for flight operations — from take-off to landing. The ARINCDirect flight support services provide flight planning, international trip support, cabin connectivity and flight operations management.

There are fewer examples of service subscription offerings within the military sector. For many years military OEM constructors and their associated suppliers have offered 'Performance Based logistics' (PBL) support contracts which largely extends to costed flight hour support including spares, repairs, overhauls, exchange units etc.

Two significant service provisions, offered on a periodic basis, within the military arena include TERPROM updates, or ground terrain mapping, for low altitude missions and the availability of software upgrades associated with mission and stores computing.

11.4 AREAS FOR GROWTH IN THE AVIONICS AFTERMARKET

Continual evolution of equipage and operational capabilities in commercial and business aircraft has been the norm from the early days of civil aviation. This evolution process can be triggered for a number of reasons, outlined previously.

Obsolescence, technology evolution and efficiency updates are driven by the operator to address solutions to these issue. In general though, mandates are the most reliable aftermarket growth predictor and the least difficult for decision-makers, since all users of regulated airspace must play by the same rules. The other stimuli for aircraft upgrades tend to be basically economically driven, so these types of changes need to be cost-effective and cost-justifiable.

Currently, there are several market and operational drivers, which while not equipage mandates, are anticipated to drive aftermarket changes over the next ten years, primarily the following:

1. Performance Based Navigation (PBN)
2. Controller Pilot Data Link Communication (CPDLC)
3. Head-Up Displays

11.4.1 PERFORMANCE BASED NAVIGATION (PBN)

Performance Based Navigation, according to ICAO Doc 9613, the Performance-based Navigation (PBN) Manual, issued in 2008, "ICAO performance-based navigation (PBN) specifies that aircraft required navigation performance (RNP) and area navigation (RNAV) systems performance requirements be defined in terms of accuracy, integrity, availability, continuity, and functionality required for the proposed operations in the context of a particular airspace, when supported by the appropriate navigation infrastructure".

Simply stated, this means that an aircraft must be able to successfully navigate, and most importantly, successfully avoid conflict with other aircraft operating in the same airspace. The world's Air Navigation Service Providers (ANSPs) have been advancing the technical state of the art on this subject for decades, steadily reducing allowed separation minima between aircraft as sensor, guidance, display and flight control technology has advanced. This has allowed ANSPs to move, in a stepwise manner, away from a static sensor-based airspace management strategy toward a more dynamic use of available airspace, in order to support more traffic in the same physical volume while adapting to changes in the volumes and needs of traffic on an ongoing basis. The enabler for this evolution has been the deployment of global navigation satellite system (GNSS) equipment supporting position determination independent of ground-based sensors such as radar.

The original GNSS, the US Global Positioning System (GPS), was thus the first essential technology for development of PBN. GNSS systems are now evolving with deployment of satellite-based augmentation systems (SBAS), ground-based augmentation systems (GBAS) and ground-based regional augmentation systems (GBAS), while the introduction of Galileo and the modernization of the US GPS and the Russian Global Navigation Satellite System (GLONASS) will further improve GNSS performance. Similarly capable GNSS constellations are now being deployed in other parts of the world, including China (BIEDOU) and India (IRNSS).

Apart from the GNSS sensors themselves, a number of aircraft avionics systems are involved in PBN upgrades, including navigational sensors, flight displays, flight management and guidance computers and related avionics systems. Recently manufactured aircraft, both commercial air transport and business aircraft, are generally well equipped for PBN operations, however, a significant upgrade strategy is expected for unplanned older aircraft that are now being retained in service.

A navigation specification that requires on-board navigation performance monitoring and alerting is referred to as a Required Navigation Performance (RNP) specification. If RNP is not imposed, aircraft operate under area navigation (RNAV) specifications.

In this context, an RNP of 10 means that a navigation system must be able to maintain its position to within a radius of 10 nautical miles. An RNP of 0.3 means the aircraft navigation system must be able to maintain its position to within a radius of 0.3 nautical miles. An RNAV specification, on the other hand, is designated as RNAV X, e.g. RNAV 1. The RNAV rating refers to lateral navigation accuracy in nautical miles, which is expected to be achieved at least 95 percent of the flight time by the population of aircraft operating within the airspace, route or procedure. RNAV operations have been historically associated with regions for which ATC ground-based surveillance systems, e.g. radar systems, are in place

to survey the covered airspace region to monitor for flights which are not conforming to navigation requirements for that region. Where ground-based independent surveillance is not present, for example in oceanic regions or continental regions not having radar coverage, RNP procedures allow an increased flight density without compromise to safety. These RNP procedures can comprise both straight and curved flight segments, to optimize use of the available airspace.

RNP operations impose stringent requirements on a number of aircraft systems, including flight management systems (FMS), position sensor systems and display systems, particularly where curved paths are part of the RNP procedures. Thus, the key elements in required in making PBN upgrades to older aircraft include all of these types of systems, which has led to increasing demand for FMS, sensor and primary flight display (PFD) upgrades. These upgrades have been increasingly demanded in the post COVID era for older aircraft now planned for retention in the fleets, and this demand is expected to continue to grow for some time to come.

11.4.2 CPDLC

Controllerpilot data link communication (CPDLC) provides data link communication between controller and pilot, supplementing and eventually replacing controller/pilot voice communication. This service comprises the exchange of clearance, information and request message elements derived from the voice-based practices currently employed by air traffic control procedures. The controller can issue level assignments, crossing constraints, lateral deviations, route changes and clearances, speed assignments, radio frequency assignments, and various requests for information. The pilot can then in turn respond to messages digitally, to request clearances and information, to report information, and to declare or revoke an emergency. The pilot can also request conditional clearances and information from a downstream air traffic service unit (ATSU). A "texting" capability (resembling that of smartphones) is also provided to exchange information not conforming to defined formats. The controlling Air Traffic Services Unit can forward a CPDLC message to another Air Traffic Services Unit, typically the downstream ATSU that is expected to receive the flight after handover.

CPDLC has been planned for implementation for several decades, but has so far seen operational deployment primarily in the oceanic airspaces. Broad scale acceptance has been limited by a number of factors, most notably due to the complexity, cost and overall difficulty of installing and/or upgrading the necessary ground-based information technology infrastructure. The cost and complexity of training of controllers and pilots in the new procedures has also been a limiting factor, and there has been a certain level of resistance to the loss of the so-called "party-line". This refers to the fact that with voice communications by all pilots in communication with a controller responsible for a particular airspace sector on a single voice frequency, all pilots are able to monitor what other aircraft in their vicinity are requesting and what instructions they are receiving.

However, CPDLC has finally begun to see operational deployment in continental airspaces as well, with operational deployment underway in Europe for the past several years, and with the FAA announcing in mid-2024 that CPDLC service would now be provided operationally for coast-to-coast flights that transit equipped FAA area control centers (ACCs). This imposes new requirements on various avionics systems, including flight management systems, communication systems, navigation sensor systems, display systems, and human interface systems. In addition, as data link communication replaces voice communication, upgrades will be required to provide data recording of data link exchanges between pilots and controllers, as has been accomplished in the voice communication environment by the cockpit voice recorder system. Thus, the operational implementation of data link will necessarily lead to aftermarket growth, as with the implementation of PBN, to equip older aircraft now being retained in the fleet post-COVID.

11.4.3 HEAD-UP DISPLAYS

A Head-Up Display (HUD) presents flight data and information to the pilot which is viewed in the pilot's normal exterior line-of-sight, allowing the pilot to view important flight information without taking his/her eyes off the view forward from the aircraft. This is accomplished by projecting this information onto a transparent screen positioned just in front of the pilot.

While HUDs were pioneered in military application several decades ago, this technology has been used in civil aviation since 1993, where initial installations tended to be single-sided. Today, HUDs are widely available for both airline and general aviation aircraft, and usually feature two-sided displays, allowing ease of transition between Pilot-Flying (PF) responsibilities between two pilots. HUDs use holographic technology to project the image well in front of the pilot, to avoid the need for the pilot to refocus to view the HUD information.

As guiding principles for HUD development, Airbus characterised the key objectives for a head-up display as follows (*source: Head-Up Display System, Airbus, January 2004*):

"As a part of the Airbus continuous effort to enhance the flight safety, HUD is considered as a tool to

- Increase the pilot situational awareness.
- Increase approach stability in NPA (Non-Precision Approach) or VMC (Visual Meteorological Conditions).
- Increase landing accuracy
- Enable seamless IMC (Instrument Meteorological Conditions) / VMC transition.
- Provide a flexible platform for growth using new technologies such as EVS (Enhanced Vision Systems) and SVS (Synthetic Vision Systems) to enhance surface operation and obstacle awareness."

Early HUD installations essentially replicated existing head-down Primary Flight Display (PFD) systems. However, with the development of Electronic Flight Instrument System (EFIS) technology during ensuing decades, the amount of information on cockpit displays has continued to proliferate. Thus, one of the primary challenges in HUD design is ensure that the HUD actually decreases the pilot's workload while ensuring that the pilot is presented with pertinent, accurate and in combination, non-misleading information.

As HUD information content increased, two problems have been identified:

- Attention capture, also known as tunnelling, where pilots focus on the HUD while not paying satisfactory attention to head-down instrumentation, warnings, and the view outside the aircraft
- HUD imagery obscuring the view outside the aircraft.

This has led to the challenge of choosing what information could effectively be displayed on a HUD screen in the pilot's view and in what configuration, without overwhelming the line-of-sight view and in effect, actually distracting the pilot from the task of flying the aircraft.

The most compelling benefits of a HUD in the context of transport aircraft flight safety have been seen mainly as the enhancement ofăsituational awarenessăfor flights in reduced visibility in the vicinity of visible terrain, water, ground-based obstacles or in the clear visibility of other aircraft. This applies to initial climb after departure but is particularly relevant for the approach and landing phases of flight, where the majority of aircraft accidents occur.

Even given the substantial safety benefits of HUD installations, as of 2024, there are very few regulatory authorities who have mandated HUD equipage for transport aircraft. One notable example is China, where commercial operators are required to equip 100 percent of their aircraft fleet with HUDs beginning in 2025. Apart from this exception, HUD equipage is voluntary, although rapidly expanding throughout the world due to the obvious safety advantages.

As of 2024, most transport aircraft have HUD options on offer. In the case of Airbus, HUD SFE (Seller Furnished Equipment) options are available for most aircraft families, including the A320, A330, A340, A350 and A380 aircraft types. For older aircraft in service without HUD installations, Service Bulletin options give those operators a means to upgrade their aircraft to modern Airbus standards. HUDs are available for most Boeing aircraft, including the ubiquitous B737 family (737-600/700/800/900 series), and are standard equipage on the B787. In addition to Airbus and Boeing, the majority of long-range business aircraft and regional aircraft can also be equipped with HUDs, both as line-fit options for new aircraft and as retrofit options for existing aircraft.

Given this commercial landscape and the clear safety advantages of HUD equipage, HUD deployment is likely to continue to advance in the coming decade, from an aftermarket perspective as well as in the context of original equipment on new aircraft, whether mandated or not. From the aftermarket perspective, the demand is likely to be significant, since many older aircraft with a decade or more of useful passenger service are not yet equipped. And from the business aircraft and freighter perspectives, the drive to retrofit will be equally compelling, given that these aircraft types are often required to operate from airports and in weather and night-visibility conditions that present navigation and safety challenges.

11.5 CHALLENGES IN THE AVIONICS MARKET

In addition to the normal evolution of equipage and operational capabilities in commercial and business aircraft, there are a number of critical issues/problems facing the aviation industry which will likely affect avionics market growth,

particularly in the aftermarket. The most critical of these issues are:

1. GPS Spoofing
2. Clear Air Turbulence Detection
3. Boeing 737 MAX Incident Influence on Certification
4. Single-Pilot Operations & Extended Minimum-Crew Operations

11.5.1 GPS SPOOFING

While the technology for GPS spoofing was first demonstrated in 2015 based on a low-cost system built from commercially available components, a significant threat to the safety of air navigation has emerged in late 2023, affecting a wide range of aircraft traversing airspace in which deviations would lead to intrusions into unauthorised airspace without a clearance. The culprit appears to be counterfeit GPS signals which are causing navigation failure.

OpsGroup, a membership organization specializing in international flight operations, has collected data on this phenomenon since September 2023. The number of incidents and the geographic focus of these recent incidents make this more than a mere coincidence.

The number of flights affected has risen from an average of 200 daily in the period January-March, to around 900 daily for the second quarter of 2024. On some days, as many as 1,350 flights have encountered spoofing. Flight crews also report that the intensity of the spoofing is increasing. Figure 18 on GPS spoofing presents observed spoofing activity from January to July 2024 as recorded by Zurich University of Applied Sciences and SkAI Data Services (credit OpsGroup).

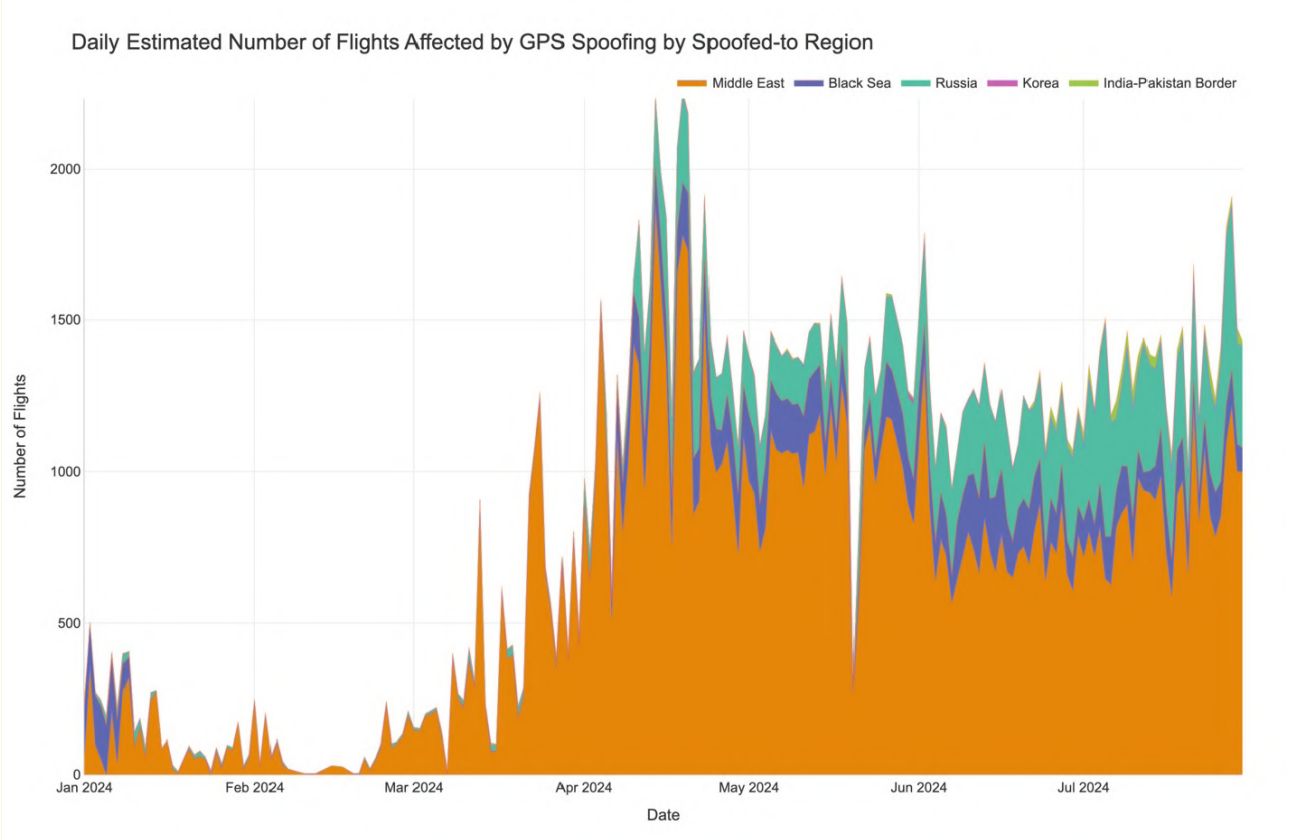


Figure 18: Flights affected by GPS spoofing

The consequences of this interference with air navigation could create an international crisis and possibly the loss of civilian aircraft. This phenomenon is referred to as “GPS Spoofing”, as distinguished from GPS jamming, where aircraft

sensors are simply unable to receive GPS signals and the aircraft's navigation system must consequently fall back on other means of position identification. Aircraft equipped with Inertial Reference Systems (IRS) are able to continue operating when GPS signals are lost, but GPS Spoofing is a new threat which can compromise the entire navigation system.

According to the OpsGroup, these latest incidents involve "spoofing" in which the counterfeit GPS signals cause the FMS to conclude that the aircraft is more than 60 nm off-track, which then disables the aircraft Inertia Reference System (IRS). Since the IRS utilizes GPS signals for real-time corrections during flight, the navigation system software assumes that the counterfeit GPS is correct, which leads the IRS to disengage. When the navigation system compares the false GPS signals to other navigation inputs such as those acquired from ground-based NAVAIDs, the software is unable to process an error of this magnitude, and in turn, on-board navigation is essentially disabled.

Most of the incidents to-date have occurred in regions of conflict or crisis, such as the Middle East, or in areas where bad actors can easily operate. However, the OpsGroup also reports that GPS spoofing events have occurred near regions of entry into oceanic airspace, such as that of the North Atlantic. When an aircraft is attacked in this manner just prior to entry into an oceanic region lacking independent surveillance, e.g. radar, the aircraft must fall back from RNP4 to RNAV10, which seriously degrades the capacity of the oceanic airspace, as intermediate tracks can no longer be used.

Also, based on evidence collected by the OpsGroup, a number of other aircraft systems have been directly affected include TCAS, ADS-B, HUD guidance, and transponders. The aircraft clock is often one of the first victims of a spoofing encounter, and has collateral effects which include making CPDLC unusable. Eurocontrol reports now seeing this on a daily basis. Even the aircraft Enhanced Ground Proximity Warning System (EGPWS) can be compromised, leading to false proximity warnings and unnecessary go-arounds.

A number of industry groups are urgently studying the problem of GPS spoofing, as this has now become a critical problem, leading to daily events compromising air navigation worldwide. It seems quite likely that solving this problem will present solutions which will drive both OEM and aftermarket technology solutions for the foreseeable future.

11.5.2 CLEAR AIR TURBULENCE DETECTION

Within the commercial aviation sector, clear air turbulence (CAT) events represent the single largest source of injury and claims exclusive of takeoff and landing incidents. Avoidance of airspace where CAT has been reported results in non-optimal flight altitudes, speeds, and routing resulting in additional direct operating costs.

The development of a reliable CAT sensor could provide an airborne indication and mapping of CAT regions allowing minimum diversion trajectories and rapid resumption of the planned flight path once the region of CAT is no longer a concern to the flight crew.

Several technologies offer possible paths of inquiry including lidar, infrared radar, RF detection of electromagnetic signatures in areas of convective activity, and ground-mounted microphones that pick up ultralow-frequency sound waves produced by clear-air turbulence, among others.

A viable solution could lead to fitment requirement for airborne solutions or ground-based sensor for terrestrial system.

11.5.3 B737 MAX INFLUENCE ON CERTIFICATION

The MCAS issues with the Boeing 737 MAX program have illuminated significant issues with the FAA oversight of aircraft certification. The FAA delegates significant authority to entities such as engineering organisations, certification consultants and manufacturers.

The B737 MAX problems illustrate the risks when there is insufficient oversight by the FAA of the manufacturer's self-certification processes. However, the FAA lacks sufficient human resources to fulfill the certification needs for OEM constructors, avionics certification, and STC development. In order to remedy this situation, the US Congress has enacted the Aircraft Certification, Safety, and Accountability Act (ACSAA), which covers the entirety of the certification delegation problem, but has also specifically mandated a significant increase in the number of FAA technical and certification specialists on staff at the FAA to supervise safety aspects of operations that have been previously been delegated to industry. As of June 2024, more than 300 new specialists have been hired by the FAA under this legislation.

Some level of external certification delegation to industry will certainly continue, but it is clear that certification schedules for both new aircraft construction (type certification, or TC) and for modification to existing aircraft (supplemental type certification, or STC) will both be impacted for the foreseeable future. This will have a negative impact in particular on schedules of aftermarket modification projects.

11.5.4 SINGLE-PILOT OPERATIONS & EXTENDED MINIMUM-CREW OPERATIONS

One of the more challenging areas of operational and technical evolution in air traffic operations is related to the desire on the part of operators to reduce crewing costs in civil aviation. Aviation has always been linked to technological advancements, and the introduction of technology over the decades of development of civil aviation has largely been accompanied by improvements in safety and measurable decreases in the rate of accidents. This is due in part to the maturity of introduced technological advances but is also inextricably tied to improvements in crew training and performance. In general, the basic principle of technological advancements in aviation is that the level of safety following introduction of new technology or procedures must leave the system at least as safe as it was before their introduction, and preferably should improve levels of safety.

Airliners from the 1950s were operated with four crew onboard, a pilot, a co-pilot, a flight engineer and a navigator. The crew count evolution since then has been reduced first to three, by eliminating the navigator as cockpit systems reduced navigational workload, and then to two, by eliminating the flight engineer as technical workload was in turn reduced by advances in cockpit automation. Maintaining two crew in the cockpit has been the norm ever since, where accepted rules and guidance world-wide currently mandate two pilots on the flight deck during all routine flight operations of civil airliners and freight carriers. Rules for smaller aircraft in some cases allow one pilot operations, but typically all aircraft that fly on commercial flight routes, whether passenger, freight or business aircraft, continue to require two pilots on active duty in the cockpit.

The implication of this practice is that for long flights, additional crew must be on board to allow active pilots to take rest breaks, being replaced on active duty in the cockpit by a 3rd or 4th crew member on board for that purpose. The cost implications to the operators are thus significant.

For this reason, Single-Pilot Operations (SiPO) & Extended Minimum-Crew Operations (eMCO) have been under study for several decades, under research by manufacturers, regulators, airline associations and pilot associations. In this context, SiPO means that there is only one pilot onboard the aircraft, while eMCO means that there are two pilots on board, but with a requirement for only one active pilot during routine/cruise phases of flight. With eMCO, for example, one of the two pilots on a long-haul flight of seven hours might be absent from the cockpit for five of the seven hours. SiPO, on the other hand, would mean that even approach and departure procedures would be carried out by one pilot. SiPO could apply to longer flight trajectories if a second resting pilot was onboard to exchange with the active pilot during the flight.

SiPO, although technologically feasible, would require substantial changes to aircraft, procedures and crew training, and is not expected to be realized in the foreseeable future. eMCO, on the other hand is currently being actively researched by manufacturers and is under evaluation in regulatory environments.

In 2022, the International Civil Aviation Organization published its report on this topic, A41-WP/101, "AN APPROACH TO NEW OPERATIONAL CONCEPTS INVOLVING EXTENDED MINIMUM CREW OPERATIONS AND SINGLE-PILOT OPERATIONS", in which ICAO observed that "These proposals are not simply a change from two crew members to one, it is a paradigm shift toward a pilot flying alone at the controls of large commercial aircraft. This inevitably involves a change to the role of the pilot, towards becoming a systems manager, over a physical flyer, and may introduce increased risk, particularly during the introductory phase of the new technology."

In Europe, the European Union Aviation Safety Agency (EASA) published a report in 2022 on pilot fatigue and human performance (EMCO SIPO EASA.2022.C17, D-6 REPORT ON PILOT FATIGUE AND HUMAN PERFORMANCE), addressing the human issues related to both SiPO and eMCO, noting that prior to authorizing either SiPO or eMCO, further research was required. EASA noted that "the available scientific knowledge about long-haul operations and its effect on fatigue and alertness cannot be translated to minimum crew operations, and these should be further investigated first. In addition, the most optimal rest/wake ratio for reduced crew operations is not clear. Future studies should therefore also incorporate multiple realistic rest/wake ratio scenarios, taking into account specific eMCO related factors such as noise of the pilot flying (PF) engaged in flying tasks, timing, and personal characteristics." In the United States, the Federal Aviation Administration (FAA) Administrator announced to the Air Line Pilots Safety Forum on 11 September 2024 that "FAA leadership has no intention of changing the agency's longstanding position that reduced crew opera-

tions (RCO) will not be permitted in updates to rules and guidance that currently mandate two pilots on the flight deck during all routine flight operations."

From the regulatory point of view, much work still remains to support authorization of either SiPO or eMCO in civil aviation airspaces. In late 2023, EASA issued a rulemaking task on extended minimum crew operations, to investigate authorizing a single active pilot during routine segments of a flight's cruise phase, the task's summary explained. EASA has already received at least one formal manufacturer's application for concept approval. According to Aviation Week, the FAA's most definitive step to date has been to agree with a Research, Engineering and Development Advisory Committee (REDAC) recommendation to develop a research plan to "be prepared with scientific data to support the processes for aircraft design and operational approvals for concepts such as eMCO," the agency wrote in a formal response to REDAC in 2024.

These actions have motivated pilots' group, including the Air Line Pilots Association (ALPA), the European Cockpit Association (ECA) and International Federation of Air Line Pilots Associations (IFALPA), to join forces to oppose such regulatory changes. From the pilots' perspectives, safety is a key issue, which is certainly supported by the numerous identified needs for human factors and systems redundancy safety research. But it is fair to say that eliminating one pilot per aircraft certainly poses economic and health risk issues for the pilots themselves.

From the manufacturer's point of view, both Airbus and Dassault have programs in progress to advance the state of the art in cockpit automation and human factors toward certification of at least eMCO for passenger aircraft, and perhaps eventually SiPO. FedEx and Airbus have also advanced operational concepts for SiPO for future freighters. At Airbus, research into autonomous flight systems has recently been expanded with the Dragonfly program, launched in January 2024 to expand on progress made in the Autonomous Taxi, Take-off and Landing (ATTOL) project. The objective of Dragonfly is to be capable of automatically selecting an emergency diversion airport and planning a route to that airport, where vision systems will guide the aircraft to a landing on the selected runway.

Advances in eMCO and SiPO for passenger aircraft and flight route application will clearly some time to develop, prove and certify, as will freighter applications, where the freighters interact with passenger aircraft in dense airspaces and on common flight routes. However, due to continued commercial pressure, it is expected that these procedures, both SiPO and eMCO will continue to advance over the coming decade. In this area, it is essential to follow the various lines of research and regulatory activity in progress, from the perspective of the manufacturers, the regulators, the pilots and of course, the passengers.

12 MARKET STRUCTURE

12.1 THE ROLE OF THE AIRCRAFT OEMS

In Section 11.2 we reviewed the role of the aircraft OEMs in terms of forward fit of avionics and the need to be proactive in upgrading their products and capabilities over the life cycle.

From a market structure perspective, it is clear that recent consolidation and M&A activity has resulted in there now being a number of avionics providers whose parent companies are equal or larger in size than many aircraft OEMs.

Raytheon (Collins Aerospace), GE Aviation, BAE Systems, Northrop Grumman, Honeywell, General Dynamics and L3 Harris all have market capitalisations measured in the 10s of $ billions.

The examples above all provide avionics solutions to the aircraft OEMs and arguably wield significant 'supplier power especially where they also offer key equipment such as engines, sensitive electronics and critical infrastructure (e.g. software, sensors).

The aircraft OEMs' approach to these structural challenges varies but some have sought to strike 'strategic relationships' where key technologies are concerned.

Boeing's approach on the 787 was to select far fewer key systems suppliers (i.e. bigger packages) who shared in the investment to develop the 787 platform.

For the 787 avionics suite Boeing selected GE Aviation (Smiths), Collins Aerospace (Rockwell Collins) and Honeywell with each being responsible for significant parts of the entire avionics package.

Airbus arguably has a leaning towards Thales as a primary source of cockpit avionics. However, on A350 both Honeywell and Collins Aerospace were selected for avionics sub-systems.

Military aircraft OEMs need to recognise national security interests when it comes to sourcing sensitive defence-related products such as avionics, electronics and sensors. The real degree to which this is a factor in source selection can be hard to identify. However, a quick review of the F-35s avionics, electronics and sensors will show that whilst the majority of the equipment is US-sourced, offshore companies such as BAE Systems, UK (electronic warfare suite) and Elbit, Israel (jointly with Collins Aerospace for the helmet mounted display) have been selected to supply very sensitive equipment.

The F-35 is a multi-national programme with eight international partners all of whom need to be provided with a proportionate amount of workshare usually related to purchase commitments (interestingly BAE Systems is a partner in F-35, but Israel is not).

Notwithstanding procurement strategies for avionics as outlined above, all aircraft OEMs appear to have one thing in common when it comes to specifying new platforms — they all adopt a process that allows for significant input from their respective end-user groups — usually the pilots and operators.

This process of engagement between aircraft OEMs and airline groups, lease companies and operators, (potential purchasers) at the outset of a new platform development, is an established process.

This aircraft OEMs/customer engagement process reflects the degree to which the avionic suite is recognised as the critical man/machine interface for the entire operation of the aircraft platform. It also reflects the fact that pilots are still a very powerful voice within the industry — ignore them at your peril!

The other major focus for all OEM constructors, civil and military, is the need to work with the recognised bodies within the industry that have influence and control over the entire operational life cycle of their product.

There are many national and industrial bodies that have influence and control over areas of research, development, certification, regulatory, operational and environmental issues.

The major bodies that exercise particular influence over the avionics aspects of the airframe are identified as follows:

- Airworthiness authorities (e.g., FAA, EASA, CAA)
  - These National Airworthiness Authorities control the issuance of airframe certifications for airworthiness as well as Supplemental Type Certificates.

- International Civil Aviation Organisation — defining the needs of Future Air Navigation (FANS)
  - See Global Air Navigation Plan 2013 — 2028
- EUROCONTROL — responsible for Air Traffic Control within Europe (41 member states)
- Radio Telecommunications Control Authority — sets RTCA standards across the industry
  - Sets industry wide standards for IMA, common computing and software.
- Many national research projects that will dictate future technology needs
- EU 'Clean sky' project focussed upon emissions
  - NASA's funded Advanced Air Transport Technology (AATT) programme includes Electrical Aircraft Propulsion project (EAP)
- Airlines Electronic Engineering Committee (AEEC) undertaking the development of an industry roadmap for the use of Internet Protocol v6 in air-to-ground data communications
- Defense Advanced Research Projects Agency (DARPA)'s Aircrew Labour In-Cockpit Automation System (ALIAS) program — using Robots as back-up pilots.
- Jan 2020: The US Air Force (USAF) launched three studies on future communications, innovation in space, and the unintended consequences of using autonomous systems, the results of which will shape the service's research investments.

The role of aircraft OEMs, from an avionics perspective, can therefore be summarised as maintaining engagement with the very many stakeholders in both the civil and military sectors in which electronic/digital technology can advance very much more quickly than other more mature technologies.

12.2 BUYER FURNISHED EQUIPMENT (BFE) VS SUPPLIER FURNISHED EQUIPMENT (SFE)

The concept of Buyer Furnished Equipment, that is providing the customer with an option relating to supplier source allowing for a level of 'customisation', has been around for many decades.

A method used by OEM constructors to reduce costs and to streamline supply chain complexity is to reduce the number of options available to aircraft purchasers. This has led to an increase in the relative percentage of Seller Furnished Equipment (SFE) supplied with aircraft on delivery

Previously, operators were given options to furnish avionics sourced directly from the operator's supply chain. "Buyer Furnished Equipment" (BFE) options are becoming less prevalent as OEM constructors look to reduce the costs of certification and management of providing these options.

Pilots, crew and passengers do not usually have any engagement with 80% - 90% of an aircraft's systems. However, in both the cockpit and the cabin this is not the case where man/machine engagement is much higher.

For those avionics where there is usually a high level of pilot or crew interaction or operational influence there will inevitably be preferences. Similar to the computing world, in which we are either Windows or Mac users, you will hear pilots having a preference for either Honeywell or Collins.

Airlines can have a strong operational preference based upon issues around pilot/crew training, spares stocking, cross fleet cockpit commonality.

Typical avionic equipment for which there is a BFE option are listed as follows:

- Radio communications
- HF communications
- SATCOM
- Cockpit Voice recorder
- Flight Data Recorder

- Digital Data Acquisition Units
- Flight Management Systems (reducing in prevalence)
- Standby Attitude Indicator
- Multi-mode receiver
- Weather Radar
- TCAS
- Radio Altimeter System
- Automatic Direction finder

The main flight displays, auto-pilot, common computing services, primary navigation and data-buses all tend to be SFE as they represent the essential part of the aircraft operation.

Usually, the aircraft OEM will sell an 'SFE' aircraft at a price and will have negotiated all of the BFE options with the suppliers. The airline/end-user can then specify these BFE items from the list at a pre-agreed price for inclusion in order to arrive at an overall customised aircraft price i.e., SFE plus BFE.

There are more BFE options within the cabin in IFE, seats and galleys where airlines and passengers can have stronger preferences.

In terms of overall platform costs we estimate the following for SFE vs BFE

- Assuming a $50m flyaway price for a narrow-body aircraft, the BFE-costed equipment will typically range from $1m to $2.5m, (2% - 5%) and of this total approximately 60% - 65% will represent cabin customisation.
- For a $100m wide-body aircraft, customisation costs will range from $8.0m - $12.0m (8% - 12%), and of this total approximately 70% - 80% will be represented by cabin customisation costs.

A major issue for the aircraft OEM is the very high costs associated with certificating and maintaining two separate options.

Many within the industry refer to BFE as either being 'brand' oriented (i.e., cabin, IFE, seats) or 'operations' oriented (i.e., data recorders, FMS, radio communications).

We see the OEM market as offering fewer avionic BFE options going forward due to the prohibitive costs associated with the development of software based avionic products.

Both Airbus and Boeing continue to offer the market an option of either a Thales or Honeywell FMS for their commercial platforms. However, we see the trend for offering two FMS systems (expensive to certificate) as reducing.

For other avionics-related products where there is an option offered such as TCAS, Weather Radar, ADS-B, Displays, multi-mode transceivers, much of the development and certification costs have often already been borne by the supplier (often via a COTS approach that spreads the investment over many platforms).

The suppliers can also pursue the STC route, independent of the aircraft OEM, in order to have their equipment certified for a specific platform or family of aircraft.

BFE has even less of a presence within the military field although multi-national platforms tend to experience end-user or national preferences.

12.3 ROLE OF AIRLINES (END-USERS)

Section 13.2 discussed one significant role of the airline within the area of BFE equipment preferences and selection.

At the outset of a completely new airframe development, it is normal practice for the aircraft OEM to seek early engagement with a range of airlines and seek their inputs as a representative user group that will effectively influence the avionics architecture and overall cockpit layout.

Many of these user groups will typically have 20 or 30 different airline'/end-users representatives involved at the development phase.

Equally, these user groups may also involve personnel drawn from the airline representing pilots, crew, maintenance personnel, financiers and engineers.

This, in part, reflects the differing needs of, for example, the narrow body market (e.g., Boeing 737, A320) where the market can be segmented into:

- Low-cost carrier/single airframe
- Feed in for international network operators/fleet operators
- Aircraft lessors
- Short haul/high route density
- Medium haul/low route density
- Transnational vs domestic

The aircraft OEM has to ensure that the tens of billions of dollars of investment that is required to develop an aircraft is 'right first time' and that it has mass market appeal — getting it wrong can be very costly once the platform is certificated and in service.

There is therefore a strong ongoing bond and relationship forged between OEM constructors and airlines that typically pervades throughout the entire product life cycle.

The significance of this interface between OEMs and Airlines is that avionics today acts both as the 'hub' for many airline 'operational' issues such crew training (expensive), efficient route structures, reporting, data, maintenance and safety as well as providing infrastructure for passenger 'brand related functions such as IFE, Cabin comms and SATCOM.

The major airlines also play a significant role in the upgrade and retrofit market when avionics require changes whether it be for mandated airworthiness reasons or for improved operational efficiencies. Major airlines typically invest in engineering resources, maintenance shops, repair and overhaul facilities which means that they are well equipped to undertake retrofit/upgrade work.

They work both with the aircraft OEMs and the suppliers to facilitate the upgrade work both to their own fleets of aircraft. This can also involve the airline in obtaining Supplemental Type Certificate (STC) approval from the national airworthiness bodies that control equipment modifications.

Many of the larger airlines such as Lufthansa, United Airlines and British Airways will offer these services to the smaller airlines that cannot afford to invest in the facilities necessary to undertake retrofit/upgrade work.

12.4 SYSTEMS INTEGRATORS/TIER 1/TIER 2

Avionic suppliers have been at the forefront of avionic related technology advances taking place every few years which is juxtaposed with the development cycle of a typical airframe which typically needs to 'evolve' over its 30, 40 or 50-year life cycle.

This apparent technology/platform 'disconnect' has to be managed in part by suppliers who work to bridge the void between frequent avionic developments and long cycle airframes that operate in a heavily regulated industry requiring the very highest level of safety standards.

In terms of avionics some of the technology advances that have impacted the overall supply chain are noted as follows:

- Barometric > Cathode ray tube > LED flat panel > Synthetic Vision Systems
- Analogue to digital based avionic implementation.
- Data bandwidths have grown exponentially from 100KBs to GBs/TBs in 20 years.
- Real Time Operating Systems for e.g., partitioning in IMA
- ASICs to FPGAs (flexible programming)
- Lines of software code typically increased 100-fold in 20 - 30 years.
- Solid state sensors replacing mechanical analogue devices.

- Fibre optic data transmissions replacing copper wiring.
- Development of satellite-based GPS navigation systems
- Development of autonomous systems for enhanced situational awareness
- Software-based radio communications.

This is not an exhaustive list, but it does represent the extent of the technology related challenges that have been confronting Avionic suppliers in recent decades.

A significant mechanism adopted by OEMs, suppliers and airlines is the design of avionics architectures that allow for 'technology insertion' upgrades over time as product technology evolves.

Technology insertion can be at many different levels. A complete cockpit upgrade typically includes replacing the old analogue multi-instrumented flight decks with a digital flat panel suite comprising integrated functions (LED displays, FMS, Nav, Comms, Surveillance).

A simple technology insertion may be limited to a new 'box' that can be introduced as a 'plug and play' upgrade where, from an aircraft perspective, all of the interfaces, e.g. I/O, connectors, wiring, sensors, mechanical interfaces etc., are entirely compatible with the existing avionic architecture.

Cockpit 'real estate', as represented by the total viewing area, will often need freeing up in order to accommodate new or additional functions such as TCAS, EGPWS or Weather radar. Suppliers have proved themselves adept at consolidating and/or integrating multiple display formats in a single unit.

Suppliers have had to adopt a number of avionic-derived processes in order to successfully compete within the avionics sector. These processes which often form part of the suppliers 'core competences' include the following:

- Understanding of man/machine interface sciences
- Design for product/component obsolescence
- Commercial Off -The-Shelf (COTS) design capabilities
- Software code design, verification, validation and certification processes
- Data fusion/integration from multiple sources (e.g., synthetic imaging).
- Multiple avionic/utility functions operating in 'real time' within a software partitioned environment.
- Supplemental Type Certification process (approved engineering and test facilities)
- 'Life-time buy' procurement processes
- Legacy product support processes

A quick review of the major avionics integrators (e.g. Honeywell, Collins Aerospace, Thales, GE Aviation) shows a similar approach in that they all promote avionics around a number of themes with equal emphasis as follows:

- Avionics as providers of integrated cockpit suites
- Avionics by individual function e.g., FMS, NAV, Comms, Surveillance
- Avionics by way of retrofit and upgrade (Technology Insertion, STC, COTS)
- Avionics by way of life cycle support in service.

This, we believe, supports the evidence outlined within this report that avionic suppliers are required to focus on more than just forward fit OEM potential with technology insertions, upgrades, major retrofits, data services and through life cycle support, all representing important revenue generating sub-sectors within the overall avionic market.

12.5 SUPPLEMENTAL TYPE CERTIFICATE (STC) PROVIDERS

A supplemental type certificate (STC) is a national aviation authority-approved major modification to an existing type-certified aircraft. In the United States issuance of such certificates is under the purview of the Federal Aviation Administration (FAA) and in Europe it is controlled by the European equivalent, EASA. The STC applicant must show compliance to the same regulations as the original type design, for the area affected by the modification.

From a supplier's perspective, the STC route is often the only affordable and practical means to bring a new product to market. With major new platforms only coming along every 10 or 20 years the means for many suppliers to generate revenues is by offering products directly to the end-users.

Often these 'regulatory' or 'optional' product offerings fall outside of the focus of the OEM constructor. Plainly speaking they can become an unnecessary distraction for the OEM constructor who would otherwise have to devote valuable engineering resources to develop discrete product solutions, market them accordingly and facilitate their installation.

This has, in effect, spawned a whole range of discrete product offerings provided by many avionic suppliers.

A further consideration is the affordability of these discrete product functions which, at the less regulated end of the aviation market, can be provided via an STC certificate at a much lower cost than a bespoke solution.

A quick look at any National Airworthiness register will usually reveal hundreds of approved STCs by product function that apply to those aircraft operating within that nation's airworthiness jurisdiction.

Globally today there are thousands of STC products available at any one time.

The FAA alone lists 1000s of STCs and it is apparent that a majority of these STCs apply to GA, smaller business jets, rotorcraft and military trainers.

Within the avionics supply chain most providers of engineered avionics (both small and large) will have a range of STC products available.

The STC market is attractive to many suppliers because it is largely de-coupled from the OEM forward fit market and it therefore acts as a cyclical counter to OE build rates.

12.6 3RD PARTY SERVICE PROVIDERS (SOFTWARE/DATA)

Third party service providers represent a growing element within the avionics market. Clearly both availability of aircraft systems related data and greater reliance upon software-based functions has increased significantly in the past decade or so.

As often the case with a paradigm shift within an industry there is an opportunity or requirement for new players with different skill sets.

This is to some degree the case within avionics. Within the supplier matrix there are now a number of software providers who are actively engaged in developing avionics solutions often in partnership with OEM constructors or suppliers.

Some of these software base providers are listed as follows:

- Ensco Inc
- Green Hill Software
- Genova Technologies
- Lynx Software Technologies
- Mercury Systems
- Performance Software Corp
- Mannarino systems and software
- Wind River systems

These companies provide a range of software services with the largest consumers of software by avionic function include:

- Integrated modular avionics or common computing resources requiring partitioned software.
- Graphics generation (data fusion) for flat panel displays
- Flight management systems

Many of these software companies also offer related services to the Aerospace & Defence sector including cloud-based storage (for analysis), cyber security and certified software for COTS use in military applications.

In section XX we referred to providers of data services having commercialised their offerings by way of monthly subscription from end-users.

These service providers include offerings such as the following:

- Navigation database updates for FMS systems (typically every month)
- Download, storage and analysis of aircraft system derived data for trends, predictive maintenance action.
  - This is often a 'real time' service given the availability of high speed data connections via satellite
- Satellite data connections for cabin services e.g. mobiles, e-mails, video on demand etc.
- Terrain mapping databases for EPGWS/TERPROM.

Equally there are a similar number of service offerings from the OEM suppliers in addition to 3rd party providers. Many of the major avionics suppliers typically offer the above services to the airlines and end-users.

OEM constructors can also offer similar services e.g., Boeing acquired Jeppesen which provides many airlines with monthly navigation updates. Airbus also offers an equivalent navigation database service via its NAVBLUE distributor.

From a market perspective we observe that all players, from the OEM constructor through to the Tier 3 specialist provider, have recognised both the potential growth and value associated with digital/data services. They are all increasing their offerings to the relevant market sectors accordingly.

13 TECHNOLOGY TRENDS

13.1 GREATER STANDARDISATION IN THE COCKPIT AND AVIONICS SYSTEMS ACROSS PLATFORMS

OEM constructors are moving to greater standardisation of avionics. This is driven by both supply chain and inventory savings and the greater integration of avionics by the system suppliers. The avionics OEMs have increased integration of their own products to increase their share of avionics real estate and to further enhance their own positions by warding off the availability of avionics component options for other sub-tier suppliers. If an avionic OEM tightly integrates, say, a radio function with the complete cockpit system, opportunities to supply an alternative radio function by different supplier vanishes.

13.2 TIGHTLY COUPLED AVIONICS AND OTHER SYSTEMS AND COMPONENTS

Greater integration of avionics into complete cockpit system increases the span of products provided by single avionics suppliers. For example, autopilot functions are now supplied by the cockpit system supplier rather than being part of the basic aircraft. This simplifies the job of the avionics OEM and further solidifies their supply chain position. At the other end, sensors (pitot static, inertial, radio) functions are in-drawn by the avionics OEM to complete their system.

This is clearly seen in the business aircraft segment as exemplified by the Garmin G1000, G3000 and G5000 systems, and the trend extends to commercial aircraft and helicopters as well, with Honeywell, Thales, Collins Aerospace and other OEMS offering integrated cockpits bound to particular aircraft types. This is a way for avionics OEMs to increase their content and to spread their risk-sharing across a greater number of individual components.

13.3 COMMERCIAL OFF-THE-SHELF (COTS) AVIONICS

“A bespoke hand cut tailor made suit for $750 or one off the peg for $250?”

The above is analogous to the Avionics market where, since around 2000, a significant number of Avionics suppliers have offered customers ‘commercial off-the-shelf’ (COTS) avionics products and packages.

A commercial off the shelf product is defined as one that has not been designed and certificated for a specific customer platform i.e., it is potentially suitable for a multitude of customers and platforms.

A further definition of COTS is provided by EASA/Thales as “Component, integrated circuit, or subsystem developed by a supplier for multiple customers, whose design and configuration are controlled by the supplier’s or an industry specification”.

RTCA DO-178B defines COTS as “Commercially available applications sold by vendors through public catalogue listings”.

The primary driver for this approach has been cost and affordability issues. This is particularly the case for low volume OEM manufacturers (e.g., helicopters, business jets, GA) that cannot afford to invest in a bespoke avionics solutions.

Equally, operators of aircraft requiring retrofit/upgrade of avionics cannot afford to invest in a bespoke solution and they are therefore reliant upon COTS providers.

The military sector was the first to consider the application of COTS products developed for commercial applications and adapted/adopted for military applications. This is especially the case for rotorcraft, trainers, military transport and UAVs.

For example, the FMS utilised by Boeing as part of major upgrade programmes for both the C-130J and the Poseidon P-8 is essentially the same FMS as developed by GE Aviation for the Boeing 737. This approach allows GE to avoid having to recover a large tranche of development costs already consumed by the 737 development.

Another good COTS example is the application of both Voice and Flight Data Recorders. These devices operate in a similar way irrespective of the platform in which they are located. Most suppliers of these products offer them within many different market sectors as essentially a ‘COTS’ product.

However, there are other issues to consider in terms of traceability, integrity, certification and safety when adopting a COTS approach. The regulatory authorities are concerned at just how rigorous a process has been followed in sourcing, developing and testing COTS products (at component level) especially in regard to the approvals for the appropriate levels of software criticality (defined by RTCA DO-178 as A, B, C or D).

The cost benefit can be seen if we consider the likely total recurring cost of a bespoke avionic suite (for a mid-size commercial jet) that typically falls within the range of $1m to $1.5m whereas Avionics suppliers can offer an 'off the shelf' integrated COTS based avionics package for $300K to $800k.

The increasing cost of bespoke avionics suites has largely been driven by the increased software content that brings with it very high validation and certification costs. This problem is further exacerbated when the associated market volume expectations, for a single platform, are relatively low and development costs have to be amortised over a small base.

It is therefore understandable that airframe manufacturers, both civil and military, are attracted to COTS offerings.

The FAA, EASA and one of the industry governing bodies, RTCA DO-178B (software standards), has identified issues surrounding COTS which include:

- Clear certification path for COTS products relating to the correct level of software for application criticality (level D is the lowest with level A being the most critical).
- Transparency of product source and software codification for commercially based products (e.g. Microsoft, Windows NT, LinuX etc).
- Lack of evidence for compliance to RTCA DO-178B for COTS products

It is unlikely that large civil airframe manufacturers would adopt a COTS approach to sourcing Avionics for their next generation aircraft, however, it is possible that lower level D criticality functions could be COTS sourced.

Smaller aircraft and military platforms that do not require certification to the same levels of criticality as large commercial aircraft are more able to adopt a COTS approach.

Notwithstanding the ongoing issues noted above with certification standards the market for off the shelf COTS solutions has increased significantly within the past decade or so.

There are a number of suppliers who offer a wide range of off the shelf COTS products that are designed to meet a significant part of a market sub-sector or a fleet wide retrofit/upgrade need.

In early 2000, Honeywell was offering its Versatile Integrated Avionics (VIA) as a mature, flexible, general purpose processor developed for the commercial airline market. VIA also has direct applications for military aircraft and offers a commercial-off-the-shelf (COTS) solution. The VIA offering has been developed from Honeywell's Aircraft Information Management system (AIMs) used on the Boeing 777.

Offering the market a COTS-based avionics computing platform allows for open architectures and upgrade paths for future utility applications that do not require the airliner or operator to have to revert to the original Airframe manufacturer (thereby avoiding significant costs).

We have included a tabulation of a sample of COTS suppliers with products and end applications noted where known:

Supplier	COTS offering	Typical sectors/platforms/upgrades
Honeywell (Bendix King)	AeroNav GPS/Nav/Com/MFD combined unit	General Aviation, Business jets, Rotorcraft
	AeroVue™ Touch display	Cessna family of aircraft
Collins	Special Mission Processor (in development). Open architecture utility host computer incorporating compatibility with COTS	Military/C-130 upgrades
	FCS 7000 Flight Control system (FMS, Nav, Displays, A/P etc)	C-130, KC-135, E-3, E-8, CN235

Thales	Deployable ILS for USAF airfields (COTS)	The Thales D-ILS is a COTS system based on Thales ILS 420
	FlytX Avionics	H160, Rotorcraft, VRT500
GE Aviation	Displays, IRUs, Recorders	All platforms
	Flight Deck upgrade	C130 AMP (based on 737 avionics)
Garmin	G5000 integrated flight deck	Beechjet 400, Citation XLS
	Garmin Autoland	Cirrus, Piper, Daher
	Garmin GTS 8000 TCAS	Cessna Citation
Universal Avionics	Integrated Flight Deck (FMS, NAV, Displays, Comms)	Airbus Super Puma
	EFI 890R flight displays	C130-J
Curtiss Wright	Mission Computers (COTS)	Military rotorcraft, trainers
	Flight Data Recorders	Multiple platforms
IS&S	Next Gen FMS system	GA, business jets, cargo
	Displays (various)	Retrofits, upgrades
Meggitt	3 ATI LCD Displays, ADAHRU	Civil & Military platforms
	ADAHRU	Civil & Military platforms
L3 Harris	Displays, Recorders, Nav	All platforms

Table 36: Commercial off-the-shelf avionics offerings

The list above is NOT exhaustive and is only a small sample of both suppliers and their products that are offered to the market via catalogues, brochures and via distributors — hence defined as COTS products.

Although not identified within the table above another sector that draws heavily upon the use of COTS avionics is the space sector. Single platform space programmes do not have the funds available to design and build a bespoke Avionics solution for each and every mission.

OEM airframe manufacturers are not always focussed upon replacing or upgrading obsolete cockpit Avionics which has resulted in many suppliers, 3rd parties and Airlines investing in COTS products.

In summary, we see the COTS approach to Avionics as a means to achieve much greater market penetration within low volume sectors. In terms of Avionic functionality, it also means that small business jets, GA, Rotorcraft and military platforms can be provided with Next Gen navigation performance, similar to that found on a modern airliner say, but at affordable levels.

13.4 ELECTRONIC FLIGHT BAGS

Electronic Flight Bags (EFBs) provide a platform to add information and functionality to aid the flight crew without altering the avionics and certification of the aircraft. Initially, EFBs were contemplated as a way of reducing the amount of paper required in the cockpit. Approach charts (Jepp Charts), flight manuals, weather data and other information.

EFBs are divided into two broad categories: personal electronic devices (PEDs) such as iPads or tablets, and devices that can receive information from the aircraft avionics. The later are fixed installations (B787 for example) and the former are placed in mounts that allow for easy installation and removal.

13.5 INTEGRATED AVIONICS

The potential benefits associated with an integrated avionics approach have been discussed in recent decades. Reducing the number of individual avionics computers by exploiting as many common features as possible, and stan-

dardisation can result in significant cost savings, reduced maintenance and spares holdings and reductions in both weight and volume.

Examples of an integrated approach to avionics were developed in the 1990s by Collins Aerospace and Honeywell with their ProLine Fusion and Primus Epic offerings respectively.

These integrated avionics offerings were largely targeted at OEMs within the business jet, GA and rotorcraft sectors where there is much greater pricing pressure. However, these integrated offerings contained proprietary software and were considered to be 'closed architectures' by all 3rd parties (including the OEM customer).

Thus updates, additional functionality, changes to databases etc all required approval and installation by the original manufacturer usually at considerable cost.

Large commercial aircraft and military platforms

Increasing pressures from constructors, owners and operators, resulted in Boeing, amongst others, pursuing more open architectures. Boeing adopted the Boeing 777 Aircraft Information management System (AIMS) developed by Honeywell which hosts the following avionic functions:

- Cockpit displays system
- Flight management system
- Thrust management system (Autothrottle)
- Aircraft condition monitoring system
- Data communication management (Datalink)
- Flight deck communication
- Central maintenance system
- Flight data acquisition system

However, the Boeing 777 AIMS is still a closed architecture that is proprietary to Honeywell and can only be modified with the OEMs approval.

With the Boeing 787 Boeing contracted Smiths (now GE Aviation) in order to develop a more open architecture 'common core processing' (CCS) system. This is essentially an extension to the Boeing 777 AIMS system with greater flexibility in adding additional utility functions and to date it hosts around 60 utility functions in total all operating on a common backplane with common I/O etc.

Boeing claims that by adopting the CCS approach on the 787 they have saved 2,000 lbs of weigh and have eliminated 100 LRUs.

These benefits also derive from the approach taken at the outset of the platform design. The 787 also adopted Remote Data Concentrators located at strategic points throughout the aircraft. By consolidating all of the utility data gathering via common concentrators (which connect via a standard databus to the CCS) further savings are realised in terms of reduced wiring and connectors throughout the aircraft.

Within the military field both the F-22 and the F-35 have adopted an integrated approach to avionics. This integrated approach, whilst driven by weight and volume considerations, is also required in order to minimise cooling requirements associated with high power military electronics and the integrated approach also generates benefits in terms of high-speed data fusion. This latter factor is key in terms of fulfilling the F-35's interoperability needs within a complex war theatre supported by land, sea and air.

Other recent examples of IMA architectures include the A380, A400M and the A350.

In the last 10 years, the mainstream IMA definition has incorporated time and space partitioned software environments based on the ARINC 653 standard. During this period, software complexity has increased significantly. The ARINC 653 extended IMA definition has enabled the development of common software infrastructure to enhance complex systems management and enable greater software reuse.

In terms of the future many believe that a significant goal should be to realise IMA as a 'platform', much as a PC or laptop today is a computing platform, which hosts different software functions all operating in segmented space and partitioned time. Data is packaged and sent over a standard network between the functions that require it.

A key benefit of this approach has to be to allow the 'end-user' ease of access in terms of adding functionality whether that be utility software functions, apps or 3rd party developed software — much as you can today with your laptop computer.

Within the IMA world 3rd party software developers are playing an increasing role in providing both the core software platforms and the associated utility functions (see section 11.6).

Counterpoint expects to see significantly increased adoption of IMA concepts not only to save weight and cost at the outset but also to avoid obsolescence and to significantly improve life cycle cost of ownership.

In the past 20+ years or so there has been an 'integrated avionic package' offering from two of the market leaders; Collins Aerospace (Rockwell Collins) and Honeywell.

Business jet, GA and helicopters

Similar to the commercial aircraft constructors, business aircraft OEMs are requiring similar risk-sharing partnerships from their avionics supply chain. These demands coincide with a goal of reducing the certification risk of offering multiple avionics options and to shift this burden to a single supplier for each given aircraft program.

The tempo of business aircraft programs is considerably faster than the development of commercial aircraft programs. As commercial OEM constructors strive to maintain commonality with prior aircraft series to assist operators in managing training costs, business aircraft OEMs are less burdened by this requirement. For example, Gulfstream has launched significant new aircraft programs (G600, G700, G800) in the last ten years. Textron Aerospace (Cessna, Beechcraft) have unveiled a number of new aircraft programs (Latitude, Longitude, Denali, SkyCourier)

Avionics systems commonality across aircraft models reduces costs for the OEM constructor, but differentiation of features and benefits distinguishes the capabilities of specific aircraft types. So, often capability differentiation occurs between aircraft models rather than options within a particular aircraft type.

In the business aircraft models then, bespoke interiors, enhanced passenger connectivity and passenger amenities are options available to the purchaser without changing cockpit avionics standardisation.

The market for integrated avionics offerings, which can be both forward fit and retrofit/upgrade, is typically limited to the business jet, GA and rotorcraft sectors. There are a few notable exceptions, which are highlighted later in this section.

For the first 10 years or so both Collins and Honeywell offered the market their ProLine Fusion cockpits and Primus Epic cockpits respectively and they both quickly benefited from gaining considerable market share.

In around 2010 Garmin stepped into this sector with its G1000 offering which was targeted at replacing the older CRT displays embedded in the earlier ProLine and Primus cockpits.

A key market driver for this approach to offer a complete one stop shop integrated cockpit was affordability. Many of the business jet/GA OEMs cannot afford a bespoke avionic suite for each of their platforms — the development and certification costs are prohibitively high.

Equally, many of these airframe OEMs do not have the depth of engineering resources and capabilities necessary to procure a set of modern avionics functions that require integration within the airframe and subsequent certification.

A further consideration evolves around life cycle ownership and maintenance. Digital electronic avionics carries with them obsolescence issues whereby commercial electronic components can cease to be produced any number of times during the life of a typical airframe. This can bring with it a major headache for operators/owners.

A cost-effective solution is to allow the avionics provider/integrator to manage the avionic supply chain and ensure that there is an adequate upgrade path both for future functionality improvements and to avoid costly obsolescence problems.

Many of these integrated avionic offerings have a common core but are tailored to their end platform applications. The certification route adopted is often via Supplemental Type Certificate (STC) which is a very cost-effective approach. The

offeror will be spreading these STC costs across a multiple range of platforms, a family of aircraft derivatives and any number of operators.

Given the above issues it is not surprising that both Collins and Honeywell quickly established themselves as market leaders with their integrated offerings.

These offerings are very competitively priced given that they have evolved over 20 years and incorporate all of the regulatory requirements, newer technologies and considerably greater functionality than was available in 2000.

These integrated avionic offerings have evolved over the past 20 years to now include TCAS, Weather Radar, GPWS, flat panel LCD displays, Enhanced/Synthetic Vision Systems, Head Up Displays, ease of route planning (via FMS) and data reporting/downloading.

Garmin entered the market around 2010 with its G1000/G3000 offerings aimed at FAR Part 23 aircraft which weight less than 25,000 lbs. More recently they have certified their G5000 offering which is FAR Part 25 compliant (i.e. 25,000 lbs+).

In terms of upgrade or retrofit both Collins and Honeywell offer their latest Proline and Primus Epic suites at prices upwards of $500k to $1,200K whereas Garmin has priced its fully loaded G5000, with its extensive range of functions, very competitively at around $500K.

On top of this, an operator seeking to upgrade or retrofit will need to consider installation costs. Service providers such as Elliott Aviation will install a G5000 cockpit into a Cessna Citation for around $80K.

The avionics OEM supplier base is dominated by fewer major players. Often, the popularity of the supplier base goes through cycles where the dominance of one OEM changes.

Whilst these three providers have established themselves as leaders there are others who also offer an integrated avionics package as follows:

- Thales offers its FlytX package, but this does not appear to include the same range of functionality on offer from others.
- Universal Avionics offers a 'flight deck' package for platforms including King Air 90/100/200/300/350, Bombardier Challenger CL-600/601, Cessna Citation I/SP 501, II 550, II/SP551, III 650, VII, Dassault Falcon 900, Gulfstream GII - GV, Learjet 45, 55, 60.

We list the following avionics functions as being typical of what is contained within the latest offering for each of the main suppliers:

- Collins Aerospace Pro Line Fusion (King Air 360 ER)
  - Intuitive graphical touch-screen flight planning
  - High-resolution Synthetic Vision System (SVS) with patented airport dome graphics
  - Convenient pre-sets to reconfigure all three displays with a single touch
  - Full multi-sensor flight management system
  - Integrated touch screen checklists
  - Available automatic wireless database and chart uploads
  - Open and scalable architecture for future upgrades and mandates
  - NextGen and precision GPS capabilities: DO-260B compliant ADS-B, SBAS-capable GNSS, localiser performance with vertical guidance (LPV) approaches, radius-to-fix (RF) legs
- Honeywell Primus Epic 2 (for the Pilatus PC-24)
  - Advanced navigation and situational awareness. Honeywell's SmartView synthetic vision, Interactive Navigation and Airport Moving Maps optimise safety by increasing situational awareness, reducing pilot workload regardless of outside visibility.
  - Four 12-inch colour LCD displays. The integrated cockpit system features two Primary Flight Displays and two Multifunction Displays that are user friendly and lessen pilot workload. These displays also offer scalable window views, charts, maps and aircraft system details that make glancing across controls effortless.

  - Primus Epic 2.0 includes the latest communication systems, providing operators with an easy path to the mandated Automatic Dependent Surveillance-Broadcast Out system. The system also supports Cockpit Display of Traffic Information, which combines a map view with location information on other aircraft in a plane's vicinity, while in the air or on the ground.

- Garmin G5000
  - Engineered to reduce workload, improve situational awareness and give flight crews the tools to enhance safety and efficiency
  - Large, high-resolution colour screens depict aircraft performance, navigation, weather, terrain and traffic information with easy-to-interpret displays.
  - A proven, digital attitude and heading reference system delivers high-precision data for the instruments on the Primary Flight Displays (PFD).
  - Moving-map graphics on the Multi-Function Display (MFD) show the aircraft's current position relative to navigational aids, airways, flight plan routings.
  - Plus, with the addition of optional Garmin SVT™ synthetic vision technology, pilots see a realistic 3-D view of topographic features surrounding their aircraft.
- Universal Avionics "Flight Deck"
  - Flight Management; 2 - UNS-1Fw FMSs with 5" CDUs
  - Display Suite; 3 - EFI-890R 8.9" flat panel displays
  - Situational Awareness; 1 - Vision-1™ Synthetic Vision System, 1 - Terrain Awareness and Warning System (TAWS), 2 - Application Server Units (ASU)
  - Radio Tuning and Communications; 2 - Radio Control Units (RCU), 1 - UniLink™ 701 Communications Management Unit

When considering a retrofit or upgrade the newer more modern equipment will typically deliver lower power requirements, lower operating costs, improved service support and weight savings. Garmin claims to save 150lbs of weight by upgrading a Cessna citation to the G5000 cockpit in terms of wiring and hardware.

Currently, Garmin (G1000, G3000, G5000), Collins (Pro Line, Pro Line Fusion), Honeywell (Epic, PlaneView, EASy) are the major suppliers, as outlined Table 37.

In terms of the range of platforms that have been fitted with integrated avionic offerings from the three key suppliers we have tabulated the following, which is not an exhaustive list, but it does cover many of the major applicable platforms:

- Collins Pro Line Fusion (all variants)
  - Beechcraft King Air 350
  - Beechcraft B200GT
  - Dassault Falcon 50
  - Dassault Falcon 2000
  - Global Express 5000
  - Global Express 7500
  - Global Express 6000
  - Learjet 60XR
  - Airbus A220 family
  - Embraer C-390 Millennium transport
  - CL515 Firefighter (de Havilland)
  - Airbus CN295 military transport

Very Light Jets	Cockpit System
Cessna Citation Mustang	Garmin G1000
HondaJet HA-420	Garmin G3000
Cirrus G2+ Vision Jet	Garmin Perspective Touch™
Light Jets	
Cessna Citation M2 Gen2	Garmin G3000
Cessna Citation CJ4+	Collins Pro Line 21
Embraer Phenom 300E	Garmin Prodigy Touch®
Pilatus PC-24	Honeywell Epic 2.0 ACE
Midsize Jets	
Embraer Praetor 500	Collins Pro Line Fusion®
Citation Latitude	Garmin G5000
Super-Midsize Jets	
Cessna Citation Longitude	Garmin G5000
Bombardier Challenger 3500	Collins Pro Line Fusion®
Dassault Falcon 2000LXS	Dassault (Honeywell Primus Epic) EASy
Heavy Jets	
Dassault Falcon 8x	Dassault (Honeywell Primus Epic) EASy IV
Gulfstream G700	Gulfstream (Honeywell) Symmetry Flight Deck

Table 37: Business jet cockpit system providers

  - TRJ728 Turboprop (Turkey)
- Honeywell Primus Epic(all variants)
  - Learjet 40
  - Hawker 800
  - Dassault Falcon 900
  - Dassault Falcon 7X
  - Pilatus PC-24
  - AW-139 rotorcraft
  - Embraer 2Gen E-Jet family
  - Gulfstream G300/350
  - Gulfstream G500/G550
  - Gulfstream G600/G650
  - Cessna Citation Hemisphere
  - Cessna Citation XUPS A300s
  - Dornier SeaWings
- Garmin G500, G600, G1000, G3000, G5000

- Daher TBM 700
- Cessna Citation Mustang
- Cessna Citation XLS
- Embraer Phenom 100/300
- HondaJet
- Beechcraft C90 King Air
- Piperjet
- Bell 505 rotorcraft
- TacAir F-5 military fighter
- BO 105 rotorcraft
- Diamond DA42
- Beech 1900DS
- horts SD360
- Dash 6 Twin Otter

Whilst the main market for 'off the shelf' integrated avionics offerings is business jets, GA and rotorcraft there are exceptions. Above we note that there are regional and large commercial jets (Gen2 E jets, A220 family), military transports (C-390 Millennium, CN295) and legacy fleets such as UPS's A300 fleet.

13.6 DATA FUSION

Data fusion is not a new concept and has been researched by a number of industry and academic bodies for the past 10 - 15 years or so.

Equally, real world applications exist in modern day fighters, e.g., F-35, where common computing processing and high-speed data networks allow much greater levels of data fusion derived from multiple sensor sources.

There are essentially separate growth paths to be considered from the different perspective of military and commercial sectors each of which has its own set of distinct needs.

More recently, military developments with common processing, high speed networks and continuing demands for interoperability within the theatre of war have increased the emphasis upon the need for more data fusion.

Data are largely derived from sensors and the U.S. defence industry have been pursuing several major programs that depend on enabling radar, infrared systems, and other sensors to work together such that they combine their strengths and mitigate their weaknesses to create a sensor network that is greater than the sum of its parts.

With these kinds of dynamics in mind, Raytheon weapons developers are currently testing an emerging technology called Common Open Secure Mission Computer (COSMC). The concept is to replace federated functional computer systems with a data-fusion architecture to handle multi-function needs, by bringing them together.

Increased automation and AI-enabled computing can ease the 'cognitive' burden upon military crews by performing time and energy consuming procedural functions autonomously, all while leaving human decision makers in the irreplaceable role of command and control. This way, dynamic, capable human problem solving can be more fully and effectively leveraged in combat. In summary, pilots will be able to make faster and better decisions.

Also, another parallel can be found with the F-35's computer-enabled 'sensor-fusion' process wherein otherwise disaggregated feeds of time-sensitive sensor data are organised into a single, integrated screen for pilots. Navigational, sensor and targeting data can be analysed in relation to one another to offer pilots more complete, structured information.

Within commercial platform operations Multi-Sensor Data Fusion concepts can be used to maximise the meaningful information extracted from disparate data sources to obtain enhanced diagnostic and prognostic information regarding the health and condition of airframe systems and, perhaps most importantly, the gas turbine engine.

Onboard Maintenance Systems are a growing feature of many commercial platforms which allow diagnostic and prognostic analysis to be conducted in real time with potential action items downloaded to service centres ahead of landing.

Airlines have long been somewhat critical of the tera-bytes of data now available that costs in terms of data download and storage - so where is the value generated, they ask?

Data fusion models are now being developed to generate a 'digital double' that is in effect a simulation of the physical asset (component/LRU) in digitised terms. Artificial intelligence can be utilised to allow for a more accurate predictive model that 'learns' from in-service experience (defects, wear rates, collateral damage etc).

Counterpoint believes that a combination of smart sensors, data fusion in real time and the application of artificial intelligence will be utilised to both alleviate pilot workload and aid decision making as well as help with health and usage monitoring/predictive maintenance.

13.7 AUTONOMOUS FLIGHT/'PILOTLESS' COCKPIT

Starting with a parallel industry, current autonomous car programmes expect to have to test, drive and simulate millions of miles of driving under a wide range of test conditions (traffic congestion, motorway, climate extremes, hazardous snow, ice and fog, mixed vehicle types etc).

As with autonomous automobiles, or any vehicles that transport a human cargo, there is a very high degree (and associated cost) of software development, validation, verification and certification required for autonomous operations.

The same infrastructure and software development requirements will apply to the numerous current air mobility platforms under development. It is not clear that many of these air mobility platform developers have fully absorbed the enormity of this challenge (looking at projected timescales for in-service commercial revenues) which is more to do with the airspace infrastructure and associated regulatory authorities than it is with the platform itself.

Many advances have been made in recent years with military autonomous rotorcraft programmes. A few specific examples are noted

- Northrop Grumman in 2009 introduced into service the MQ-8 Fire Scout as an unmanned autonomous helicopter developed for use by the United States Armed Forces to provide reconnaissance, situational awareness, aerial fire support and precision targeting support for ground, air and sea forces.
- Airbus Helicopters announced Nov 2020 that it successfully performed autonomous take-off and landing (ATOL) from a moving deck using its Vertivision Surveillance Rotorcraft 700 (VSR700) optionally piloted vehicle (OPV).
- Boeing, in 2020, completed flight tests with five high-performance surrogate jets operating autonomously in Cloncurry, Australia. Boeing's autonomy technology, including on-board command and control and data sharing capabilities, were tested using the 3.4-meter (11-foot) aircraft. They stated that "the tests demonstrated success in applying artificial intelligence algorithms to 'teach' the aircraft's brain to understand what is required of it. The data link capabilities enabled the aircraft to communicate with the other platforms so that they could collaborate to achieve a mission."

Avionics systems necessary for UAVs to complete an airborne mission have been in existence for some two decades or more. Without a pilot in the airborne mission loop, UAV avionics do not require man/machine interface devices such as displays and voice communication systems.

Equally, the UAV avionics systems that are required such as navigation, stores management, flight guidance and surveillance do not need the high levels of redundancy associated with passenger carrying aircraft. A significant caveat to this statement is that higher levels of redundancy may be required if the UAV platform needs to operate in civil aerospace.

However, despite success within the military unmanned arena, we expect to see bigger challenges yet to come in terms of civil autonomous flight with passengers on-board and no pilot directly in the loop.

Airbus successfully tested autonomous take offs with an A320 early in 2020. It also states that whilst its autonomous project "is to improve flight operations and overall aircraft performance, pilots will remain at the heart of operations. Autonomous technologies are paramount to supporting pilots, enabling them to focus less on aircraft operation and more on strategic decision-making and mission management".

In 2017 Boeing acquired Aurora Flight Sciences Corporation, a world-class innovator, developer and manufacturer of advanced aerospace platforms including expertise in autonomous flight control for UAVs.

In 2019 Boeing's flying taxi completed its first test flight. Boeing is developing the autonomous, multi-rotor passenger air vehicle (PAV) as part of the Boeing NeXt urban air mobility program. PAV is an electric vertical take-off and landing (eVTOL) aircraft designed to provide on-demand mobility. During the pilotless test flight, the aircraft completed controlled take-off, hover and landing whilst Aurora tested the vehicle's autonomous functions and ground control systems.

Interestingly, Boeing's Pilot and Technicians forecast, issued in Nov 2020, shows no reduction in pilot demand for the next 20 years. This suggests that they do not see large commercial airliners flying in complete autonomous control for at least two decades.

Neither Airbus nor Boeing would wish to create unnecessary controversy amongst pilots' unions who are still a very powerful and influential body within the aviation industry.

Equally, whilst there is multiple redundancy within avionics/flight control architecture, many of which are now FBW/PBW, the fact remains that when all the computers fail it is only the pilot that can perform the 'last ditch' efforts to land the plane safely.

In summary, Counterpoint sees continued advances within autonomous vehicles for military applications with the emphasis upon avionics needs including:

- Continued advances in common mission computing resources
- increased data fusion via high-speed networks
- artificial intelligence to help platforms 'learn' mission roles
- improved sensors/smart sensors to support improved mission performance
- intra-platform interoperability to enhance overall war theatre performance.

The route for total autonomy within the commercial arena is less clear in terms of both technologies and timescales. The needs of high density, air mobility taxis concentrated in urban areas may well be on a different certification path to that currently being pursued by large civil platforms.

The pressures facing both small air mobility UAMs and large commercial aircraft tend to be predominantly achieving carbon neutral footprints. It therefore remains to be seen if autonomy/pilotless air vehicles will attract sufficient interest/investment given the more urgent need to switch to alternative energy sources.

Recent developments in autonomous or AI-enable operations include:

- July 2024: **Lockheed Martin** has been awarded a $4.6 million contract by the Defense Advanced Research Projects Agency (DARPA) to develop Artificial Intelligence (AI) tools for dynamic, airborne missions as part of its Artificial Intelligence Reinforcements (AIR) program. This project aims to provide advanced Modeling and Simulation (M&S) approaches and dominant AI agents for live, multi-ship, beyond visual range (BVR) missions. It is a critical step in prioritizing and investing in breakthrough technologies for national security and to meet the evolving needs of customers. DARPA's AIR program will improve the government-provided baseline models' speed and predictive performance to better match how the Department of Defense's systems perform in the real world. During the 18-month period of performance, Lockheed Martin will apply AI and Machine Learning (ML) techniques to create surrogate models of aircraft, sensors, electronic warfare and weapons within dynamic and operationally representative environments.
- June 2024: **Lockheed Martin** Skunk Works has teamed up with the University of Iowa to demonstrate the use of AI in air-to-air interception scenarios. In successful trials, the AI piloted an L-29 Delfin jet using heading, speed and altitude commands, performing tactical exercises against a virtual adversary. The AI was able to transfer learned behaviours from simulation to reality, acting intentionally and decisively. These tests are part of a wider initiative to rapidly develop AI-driven autonomy for air-to-air missions.
- February 2024**: Genesys Aerosystems** announced that it has completed an MOU agreement with AI-enabled avionics developer Daedalean to develop an integration roadmap of Daedalean technology into the Genesys Avionics Suite. This comes after successful flight testing of Daedalean's OmniX evaluation kit on the Genesys OH-58 Kiowa Helicopter. This represents a major milestone for both companies in advancing progress toward

AI-enabled autonomous flight. Daedalean leverages the power of neural networks to build systems that process visual data in flight in real time for visual traffic detection, navigation, and landing guidance, offering what the company calls Situational Intelligence the ability to understand and make sense of the current environment and situation, and anticipate and react to potential threats.

- March 2023: **Green Hills Software** announced that Merlin, a developer of safe autonomous flight technology for fixed-wing aircraft, has selected the INTEGRITY® -178 tuMP safety-critical real-time operating system (RTOS) for its autonomous flight solution.

13.8 SENSOR DEVELOPMENT

Most avionics are dependent upon inputs from sensors in order to function in both civil and military platforms.

Many of the regulatory imposed improvements in recent decades (e.g., RVSM, FANS/Next Gen, ADS-B, TCAS, EGPWS) are dependent upon upgraded sensor performance especially around navigation, communications, autonomous dependence and surveillance.

State of the art transponders form a key sensor technology within autonomous operations, surveillance and identification functions. In 2010 EADS (now Airbus) launched the lightweight LTR 400-A transponder which can be used both for military applications to identify friendly units, as well as in civilian air traffic control. The unit operates to the latest civilian air traffic control standard, Mode S "Enhanced Surveillance", and, together with the QRTK3-NG encryption and decryption computer, can also be used in all military modes.

Within the military arena high performance aircraft are dependent upon AESA radars, electro-optical cameras, infrared sensors and lasers for a range of EW/ECM functions.

Counterpoint has compiled a separate report that considers the high growth of airborne sensors in recent years used for a range of functions including health and usage monitoring, predictive maintenance and data reporting.

Growth in sensors from 100s on early generation narrow body aircraft to 1000s now found on a modern large commercial aircraft has also been accompanied by new sensor technology development.

Many mechanical sensors have been replaced with solid state versions which typically reduces weight cost and volume.

Large complex 3-axis mechanical gyros, used for primary navigation, can now realistically be replaced by solid state versions that are a fraction of the cost.

Honeywell's third-generation air data inertial reference system (ADIRS) with digital gyros provides high system reliability and performance with reduced operation and maintenance in a 4 modular concept unit package. This solid-state inertial platform can be retrofitted with minimum aircraft wiring changes and interfaces with existing 4MCU standard fittings - it is therefore targeted at the upgrade market.

The application of electronics has allowed for the development of 'smart sensors' with intelligent communications and high-speed data interfaces.

Collins Aerospace latest generation of SmartProbe® Air Data Systems combine multi-function probes and air data computers with stall warning and protection for a superior air data system. The Collins SmartProbe Air Data System is a comprehensive, RVSM-compliant air data solution suited for a variety of new aircraft platforms and upgrade programs. Because each SmartProbe unit features its own air data computer to calculate air data parameters, the need for pneumatic tubing and some of the electrical wiring is eliminated.

Thales claims to be a world leader in airborne optronics and has recently developed a family of advanced pods for reconnaissance and surveillance. The TALIOS pod combines targeting and tactical recce capabilities in a single pod. It delivers unmatched image quality, including colour imagery, and disruptive capabilities such as Permanent Vision™ and embedded artificial intelligence to provide combat aircraft pilots and ground forces with reliable situational awareness in real time. The THALIOS pod went into active service on the Dassault Rafael in 2018.

In recent years, Thales has also worked with the UK MoD to develop Elix-IR™ which is a passive multi-function threat warning system using wide-spectrum colour infra-red sensing technology to deliver simultaneous and unimpeded Missile Approach Warning (MAW), Hostile Fire Indication (HFI) and situational awareness from a single sensor system to increase overall platform survivability and mitigate risk to life. Crews are constantly updated about threat types

and locations, with 360ř spherical IR imagery to improve situational awareness. Elix-IR™ is suitable for a wide range of aircraft including helicopters, transport aircraft, UAVs and business jets. It is available in airframe-mounted and podded configurations.

Whilst the F-35 has only been in service some 9 years there are currently a number of key sensor upgrades taking place as part of Lockheed's Continuous Capability Development and Delivery (C2D2) programme. Some of the key examples of this are as follows:

- RTX began deliveries of its Next Generation Electro-Optical Distributed Aperture System (EO DAS) for the Lockheed Martin F-35 fighter in January, as the F-35 program January, as the F-35 program looks to use military personnel to help sustain the Northrop Grumman AN/AAQ-37 DAS, which the RTX EO DAS is to replace, and the Northrop Grumman AN/APG-81 active electronically scanned array radar.
- The SDB II upgrade massively advances sensing technology with a tri-mode seeker able to use all-weather millimetre wave technology, semi-active laser targeting and infrared guidance, an innovation which also favours the kind of data-sharing being sought.
- Israeli upgrades to F-35 (Dec 2020). The DAS system is networked with the F-35s Electro-Optical Targeting system. That Electro-Optical Targeting system is a high-fidelity, long-range sensor intended to find enemy targets before the F-35 itself can be seen by any enemies. Merging this sensor system with advanced EW is a likely focus of Israel's F-35s upgrades.

In Jun 2019, Lockheed Martin stated that the F-35 Block 4 upgrade might lead to an F-35 that blurs the line between a fifth-generation fighter - characterised by stealth and sensor fusion - and a sixth-generation one, which at least currently is seen as having advanced network capabilities that could give the pilot control over external weapons, drones and sensors.

Many of these sensor upgrades and/or new technology 'smart' sensors require associated software upgrades in order for their effective installation and use. We consider the impact of software upgrades, be they avionic, computing or sensor driven, within the next section of this report.

In summary, Counterpoint sees advancing sensor technology development as one of the key growth drivers in enhancing improvements in navigation performance, operating costs, mission effectiveness, electronic warfare, and through life cycle costs (health and usage monitoring/predictive maintenance).

Specifically, within avionics we see continued above trend growth in:

- close coupling between remote sensors and avionic computing
- distributed or local computing at the sensor (i.e., 'smart' sensing)
- sensor data concentrators connected to high-speed networks (larger airframes and military platforms)
- high speed network connectivity for sensors
- military sensors (e.g., EASA Radar, Synthetic Vision Systems, IFF, threat detection, AI applied to sensor data for 'learning').

13.9 SOFTWARE DEVELOPMENT/DIGITAL SERVICES

In recent years, the total cost of developing a new platform, whether it be civil or military, has seen a far greater proportion of overall budgeted costs apportioned to software development.

The numbers vary greatly depending upon the role of the platform, but it is now expected that software development can account for between 15% and 40% of total development costs.

The main systems that account for a large proportion of this software development are listed as follows:

- Avionics (navigation, communications, surveillance)
- Mission computing (military platforms)
- Flight Control Systems (FBW/PBW)
- Engine controls (e.g., FADECs)

- Utility control functions (e.g., landing gear, ECS, power generation and distribution etc)
- IFE, Cabin services (commercial aircraft)
- Electronic countermeasures/Electronic warfare (military platforms).

Following the successful development and entry into service of any one of these software-dependent systems, there is then the need to maintain and update the software and associated databases.

Avionics is one of the main drivers for software updates largely because avionics represents the link with both the environment and ground- based systems that change over time.

A quick look at the avionics supplier listing contained within section 11.1 will show around 10 avionics software businesses that 10 or 20 years ago would not have featured in this listing.

However, these software suppliers represent only a part of the total software picture. These suppliers are largely focussed upon the Aerospace and Defense sector. There are global software brands which also service the A & D sectors amongst many others. Aerospace & Defence software solutions providers within these global leaders include Dassault Systemes, Microsoft, Autodesk, Cadence Design Systems, Ansys, Siemens PLM software, Synopsis, Hexagon, SAP and Adobe.

These software providers offer a wide range of general services, some of which relate to avionics, including Aviation Maintenance Management, Air Traffic Management applications, Flight operations software, Quality management system, Financials, HR, Procurement etc.

Equally, many of these lead software houses are engaged with the aerospace OEMs such as Airbus, Boeing, Honeywell, Collins Aerospace, Thales in developing a range of Aerospace & Defence solutions including secure Cloud storage, Cybersecurity protection, future common computing architectures, testing and verification of software for critical applications, 5G network service provision, and the application of Artificial Intelligence.

Cybersecurity risks possibly prevent Aerospace & Defence firms from embracing the Cloud in its current form. Still, GE Digital is pushing ahead with Cloud initiatives like Predix to reshape the Aerospace & Defence market with device connectivity solutions for predictive maintenance.

The switch from analogue to digital in recent decades has resulted in millions of lines of code now underpinning a modern aircraft platform (see table at the end of section 6). Specifically, within Avionics software has been utilised in a number of key areas. A few of the key examples are listed as follows:

- Integrated Modular Avionics or 'common computing' platforms - now being adopted widely in both civil and military platforms - standard software code acting as the common backplane for a wide range of utility functions - designed around 'open architectures' that allow the utility functions (hosted in partitioned software) to be added to/modified/upgraded by 3rd party owners/operators.
- Navigation — modern FMS systems derive their highly accurate position "output" from multiple navigation input sources including inertial reference systems, Radio nav, DME, ILS, VOR, GPS etc. The FMS typically utilises Kalman filters, i.e., software code, in order to 'blend' all of these inputs to arrive at a statistically sound and accurate output of position.
- Air data — used to derive altitude, air speed, angle of attack from multiple sensor probes. These probes can sometimes provide inconsistent data (failure, icing, FOD etc) in which case software algorithms are applied in order to provide voting logic and sanity checks in order to eliminate the spurious data.
- LED/flat panel displays — usually driven by high-speed graphics engines or symbol generators which are embedded in software.
- Synthetic Vision Systems — often a digitised blend of inputs from electro-optic, infra-red or laser sensors creating a potential 360-degree field of view.
- Software Defined Radios — benefits include standard platforms, ease of upgrade and re-use, in-situ re-programming to add features and provide 'future-state' assurance.

Once the software is embedded in hardware and certificated for use in service comes the challenge of maintaining the software, providing updates, maintaining databases, avoiding obsolescence issues (definitely a major design criterion) and being able to achieve all of the above without disrupting aircraft in active service.

As a result of this objective the industry has developed range of computer peripherals, wi-fi connections and high-speed data loaders that can be easily connected and software uploaded whist the aircraft is located at the terminal.

The proliferation of software and data in recent years, and their application to avionics and systems, has led to a significant number of subscription services being offered to end-users and operators.

These service providers are not restricted to the platform manufacturer or the OEM/Tier 1 integrator and they can also include airlines, software houses and 3rd party specialist providers.

A list of typical software/data service offerings provided by different vendors is as follows:

- Boeing Jeppesen, Honeywell and GE Aviation all offer a monthly update subscription service for the FMS navigation database (airport terminals, route structures, changing landscapes etc) which has to be periodically updated (usually every 28 days).
- Universal Avionics offer a range of subscription services including FMS nav databases, however, they have retained NavBlue as their preferred sub-contractor for packaging and distributing this service.
- Garmin provides its own proprietary nav databases to support its various FMS and navigation system products.
- Lufthansa also offers a similar FMS nav service via its Lido FMS brand which provides an update on a 28 day cycle.
- Thales offers its ATM Cybersecurity Solutions that advocates a holistic approach and offers solutions based on business risks i.e. Protect, Detect, Respond, Recover. Thales has combined its expertise in cybersecurity and Air Traffic Management to deliver business solutions for ANSPs, airports and other critical operators in the aviation domain.
- Collins Aerospace offers 'software only' Mission Flight Management Software (MFMS-1000) which provides global civil airspace access with seamless integration of existing mission flight management capabilities in a portable software only solution.
- Avionica's suite of flight data management solutions, which includes Wi-Fi, cellular and satellite connectivity, to address customer needs in flight analytics, aircraft health management and flight operations. Avionica's satellite and cellular wireless technologies support the transfer of flight data sets with global coverage, economical cost and easy installation.
- KGB Aviation Solutions provides customers with an integrated approach for their data service needs. Using their state-of-the-art tool, DART, KGB customers utilise an automatic and wireless transfer of the data, increasing efficiency and data access within minutes of aircraft data download. KGB recent agreements with Boeing, Universal Avionics and Curtiss-Wright allow the use of the DART tools to extract data from these aircraft and flight recorder products.
- Nov 2020 - Curtiss-Wright's Defense Solutions division announced that its recently acquired business, PacStar, a leading developer and supplier of advanced communications solutions for the U.S. Department of Defense (DoD), has released IQ-Core Software v5 containing major advances in management of Commercial Solutions for Classified (CSfC) systems, tactical radios, and vehicle-based networks. The release also includes upgrades in its support of open management standards and performance enhancements.

Counterpoint believes that the proliferation of software suppliers entering the Aerospace & Defence sector in the past decade or two reflects the greater investment and reliance placed by Avionics suppliers upon software solutions both at the initial platform development phase and the subsequent life cycle maintenance, upgrade and retrofit cycle.

We have already noted that software development represents 15% - 30% of the total airframe development cost. We therefore expect to see that the in-service support demand for software services will also likely grow from a relatively low base today to support double digit CAGRs.

13.10 CYBERSECURITY

With the proliferation of software and data comes the increased threat from security breaches.

The 'connected world' within both civil and military avionics arenas will generate an exponential increase in security threats similar to what we see in online banking and shopping.

It is neither practical nor sensible, within this report, to outline in detail the steps taken by the leading cybersecurity providers to counter this threat. Much of this information simply is not available, certainly within the classified military arena.

We do however note that major military avionics providers typically include 10% to 40% of their annual R&D budget as 'classified' activity.

This classified activity will certainly include projects aimed at improving network-centric arena activity including data and communications transmissions.

Encryption and jamming technologies are not new within the military arena and are now being adopted within the civil arena where the exposure has increased significantly in recent years.

A quick review of avionics software and hardware providers will show that they all offer full encryption services embedded within their range of avionics products that could be exposed to security threats.

Companies such as Honeywell, Thales, Collins Aerospace, BAE Systems, Raytheon Intelligence Systems, Ultra Electronics, Curtiss-Wright, Wind River, Lynx Software Technologies all offer specific encryption services.

13.11 BUSINESS AIRCRAFT MARKET TRENDS

Similar to the commercial aircraft constructors, business aircraft OEMs are requiring similar risk-sharing partnerships from their avionics supply chain. These demands coincide with a goal of reducing the certification risk of offering multiple avionics options and to shift this burden to a single supplier for each given aircraft program.

The tempo of business aircraft programs is considerably faster than the development of commercial aircraft programs. As commercial OEM constructors strive to maintain commonality with prior aircraft series to assist operators in managing training costs, business aircraft OEMs are less burdened by this requirement. For example, Gulfstream has launched significant new aircraft programs (G600, G700, G800) in the last ten years. Textron Aerospace (Cessna, Beechcraft) have unveiled a number of new aircraft programs (Latitude, Longitude, Denali, SkyCourier)

Avionics systems commonality across aircraft models reduces costs for the OEM constructor, but differentiation of features and benefits distinguishes the capabilities of specific aircraft types. So, often capability differentiation occurs between aircraft models rather than options within a particular aircraft type.

In the business aircraft models then, bespoke interiors, enhanced passenger connectivity and passenger amenities are options available to the purchaser without changing cockpit avionics standardisation.

The avionics OEM supplier base is dominated by fewer major players. Often, the popularity of the supplier base goes through cycles where the dominance of one OEM changes. Currently, Garmin (G1000, G3000, G5000), Collins (Pro Line, Pro Line Fusion), Honeywell (Epic, PlaneView, EASy) are the major suppliers, as outlined in table 37.

14 GLOBAL AIR TRAFFIC MANAGEMENT (ATM) INITIATIVES

The previous section covered some of the key technology drivers which tends to be focused upon product and software technology. However, much of this technology is driven by the over-arching requirement to have an improved global air traffic infrastructure that addresses current and future needs from both a commercial and military perspective.

There are a number of industry bodies operating at national and international level (e.g., ICOA, IATA, FAA, CAA, EASA) that are supporting what are essentially global initiatives to create the future state in terms of air transport.

14.1 GLOBAL AIR TRAFFIC MANAGEMENT PROGRAMMES

The international aviation community (both civil and military) is now facing important technological and operational challenges to allow a proper development and deployment of the CNS/ATM and Avionics innovations announced by the US NextGen, the European SESAR (Single European Sky ATM Research) and other programmes such as CARATS (Collaborative Actions for Renovation of Air Traffic Systems) in Japan and OneSky in Australia. Both the NextGen and SESAR programmes have been in operation for around a decade and will continue to evolve over the next decade.

It is these long-term initiatives that have resulted in many of the changes in regulatory avionics requirements such as Automatic Dependent Surveillance (ADS), Controller-Pilot Data Link Communication (CPDLC), and Performance Based Navigation (PBN). These initiatives will continue to drive evolution of future mandates to support efficient air traffic management and continuous safety improvements.

14.1.1 TRAJECTORY BASED OPERATIONS (TBO)

The current focus in the global air traffic management community is to use these technologies along with advanced airborne and ground-based automation to develop and implement Trajectory Based Operations (TBO). TBO is an air traffic management (ATM) concept designed to enhance strategic air traffic planning using precise four-dimensional (4D) aircraft trajectory data (latitude, longitude, altitude and time). With TBO, air traffic can be planned and managed through time-based knowledge of individual aircraft positions en-route from initial departure to arrival at their final destinations.

In the US, FAA ground-based automation systems already project trajectories in cooperation with aircraft on-board automation, such as the Flight Management System (FMS). The FAA has demonstrated that its systems can be more precise when exchanging individual trajectories with aircraft and operators. The modelling tools currently in use are designed to manage the inherent uncertainties in a predictive model, and the tools may be modified to support greater flight efficiencies. The methods for negotiating new routes and clearances based on the exchange of precise trajectories are under active development withing the NextGen programme.

In Europe, Air Navigation Service Providers (ANSPs) already exchange flight data for coordination and transfer of flights between neighbouring centres. Eurocontrol's Network Manager (NM) coordination facility and systems supported by Collaborative Decision Making (CDM) provides regional ATM that is designed for integration and collaboration at a global ATM level. Technology is enhancing ATM services while improved procedures and SWIM related information exchanges will move Europe into the mainstream information exchange paradigm.

These programmes, along with partner programmes throughout the world, will incorporate sharing of information needed to support global TBO, through exchange of trajectories from the flight planning phase to arrival at the gate. However, TBO capabilities will not be introduced as a single set of ATM system improvements; rather, new elements will be introduced incrementally in the decade ahead allowing a smooth transition to full TBO operations.

Experts withing the aviation industry are of the view that with TBO, there is also an opportunity in the development of Unmanned Traffic Management (UTM) and the air traffic control of air taxis in urban areas to implement time-based management for these aircraft as well, accomplishing trajectory-based operations for unmanned aircraft at lower altitudes. Once successful at lower altitudes these aircraft can be better and more safely integrated into the traditional airspace as managed at higher altitudes where airlines, business jets and piston-powered aircraft already coexist.

It is clear that the crucial challenge in the evolution of the capacity of the global airspace is that that Air Traffic Management must move from tactical to strategic control. Achieving strategic ATM on a global basis will depend on TBO as a key enabler of the component capacity and safety improvements needed to do so. It is also likely that changes will be required within both future and present avionics systems in order to support these strategic TBO capabilities.

14.1.2 SESAR

The Single European Sky ATM Research (SESAR) programme is an EU-led modernisation programme of Air Traffic Management throughout Europe, from research through to deployment; currently being delivered by the National Air Traffic Control Service (NATS).

The key work packages within SESAR are as follows:

- AF1' or 'extended arrival management and integrated arrival management ('AMAN')/ departure management ('DMAN') in terminal areas' improves the precision of the approach trajectory and facilitates air traffic sequencing at an earlier stage and the optimum utilisation of runways by deploying specific ATM solutions.
- 'AF2'or 'airport integration and throughput' facilitates the provision of approach and aerodrome control services by improving runway safety and throughput, enhancing taxi integration and safety and reducing hazardous situations on the runway.
- 'AF3' or 'flexible airspace management and free route airspace' enables airspace users to fly as closely as possible to their preferred trajectory without being constrained by fixed airspace structures or fixed route networks. It allows operations that require segregation to take place safely and flexibly and with minimum impact on other airspace users.
- 'AF4' or 'network collaborative management' improves the European ATM network performance, notably capacity and flight efficiency. AF 4 contributes to the implementation of a collaborative network for planning and decision-making, which enables the implementation of flight- and flow-centric operations.
- 'AF5' or 'system wide information management (SWIM)' consists of standards and infrastructure enabling the development, implementation and evolution of services for information exchange between operational stakeholders delivered through an internet protocol.
- 'AF6' or 'initial trajectory information sharing' or 'i4D' improves the use of target times and trajectory information, including where available the use of on-board 4D trajectory data by the ground ATC system implying fewer tactical interventions and improved de-confliction situation.

It is clear that these work packages AF1 thru AF6 all have implications for avionics systems and will undoubtedly result in future regulatory mandates as to acceptable levels of avionic capabilities and performance.

This in turn will sustain a healthy retrofit and upgrade market for legacy fleets operating within EU airspace.

14.1.3 NEXTGEN

The Next Generation Air Transportation System (NextGen) is the FAA-led modernisation of America's air transportation system to make flying even safer, more efficient, and more predictable. As part of NextGen, the U.S. Air Force awarded Lockheed Martin a modification worth up to $4.9 billion on the company's existing contract for the Next-Generation Overhead Persistent Reconnaissance (Next-Gen OPIR) satellite system for work associated with the manufacturing, assembly, integration, test, and delivery of three Next-Gen OPIR satellites and delivery of ground mission unique software and ground sensor processing software.

Via NextGen the FAA is creating new interconnected systems that fundamentally change and improve communications, navigation, and surveillance in the National Airspace System (NAS):

- Communications: In a modernised NAS, aircraft must be able to receive dynamic, complex instructions from ground systems that can identify where they need to be and at what time. Data Communications helps pilots and air traffic controllers to communicate more quickly, more easily, and with less risk of miscommunication than radio messages over busy frequencies.
- Navigation: The FAA has switched to a primarily satellite-enabled navigation system that is more precise than traditional ground-based navigation aids. Satellites enable the FAA to create optimal flight paths anywhere in the NAS for departure, cruising altitude, arrival, and landing operations. These precise, efficient procedures can reduce flying time, fuel use, and aircraft exhaust emissions while getting passengers to their destinations at more predictable times.
- Surveillance: The ongoing implementation of NextGen provides air traffic controllers with the exact location of aircraft and a clear vision of surrounding conditions, including weather patterns and aircraft.

The key NextGen Enabling Programs include the following:

- Data Communications (Data Comm), including CPDLC
- Performance Based Navigation (PBN)
- Automatic Dependent Surveillance-Broadcast (ADS-B) In and Out
- Decision Support System (DSS) Automation
- System Wide Information Management (SWIM)
- Weather
- Other Improvements
- Safety
- Environment and Energy

As with SESAR, we interpret many of the NextGen initiatives as requiring changes within avionics in order to deliver the operating efficiencies and new requirements.

NextGen is intended to meet the air transportation needs of the US in the 21st century — in particular, a significant growth in demand for air traffic services, possibly on the order of three times today's demand levels. Similar challenging objectives are set for the European SESAR program, which is also focusing on ATM fragmentation issues more severe in the European Air Space. With both R&D programs under way, it will be necessary to make clear how the enabling technologies will be deployed in the two continents in the near and mid-terms, and where the main synergies and differences lie between the European SESAR and US NextGen ATM programs. There are significant (technical, operational and legal) challenges for the NextGen and SESAR deployments, and to allow harmonisation and integration of the two programmes into the Global ATM Framework. Coordination is also fundamental between SEASAR/NextGen and other national/regional ATM modernisation initiatives (e.g., OneSky in Australia and CARATS in Japan).

In summary the key enabling technologies are listed as follows:

- Communications, Navigation and Surveillance Systems Performance Metrics
- Flow Management, Decentralisation and Collaborative Decision Making
- 4D Aircraft Trajectory Optimisation and Time-Based Operations
- Performance Based Navigation and Intent Based Operations
- Gate-to-Gate Optimisation Problems for SESAR/NextGen and CleanSky
- Dynamic Airspace Management (Time-Based and 4D)ATM Route Planning (ARP) and Flight Management Systems (FMS)
- HMI aspects of 4DT Management in Manned and Unmanned Aerial Vehicles

The increasing need to have military aircraft equipped to fly within civil airspace and growing demand for UAS/UAM vehicles provides an additional set of challenges for the ATM infrastructure.

Military aircraft and UAS are already equipped with ISR sensors (RADAR/LIDAR, SAR/ISAR, VIS/IR/EO sensors, laser rangefinders, etc.), SATCOM, GNSS, a variety of inertial sensors including platform/strap-down Inertial Navigation Systems (INS) and/or low cost MEMS, plus high throughput RF data links (for high data rate applications like free-stream video transmission) and conventional tactical data links for communications with legacy air, ground and see platforms in current network-centric scenarios. The concept of integrated multi-sensor navigation is no way limited in application to military avionic systems. There is a growing number of civil applications, where information from multiple sensors is combined to improve performance, provide redundancy management, increase robustness, or achieve graceful degradation when sensor failures (or outages) occur. Although the sensor integration possibilities are expanding the focus for military will be on integration of GNSS, INS and other sensors, such as RADAR, LIDAR and other Forward-Looking Sensors (FLS).

In military applications, further possibilities are also offered by Link 16 and other tactical data links. As the current standard for military anti-jam digital communications, Link 16 has been implemented in the JTIDS and MIDS/JTRS terminals. These systems provide Anti-Jam (AJ) communications using Frequency Hop and Pseudo Random Noise (PRN)

spreading techniques. As a result, there are accurate time-of-arrival (TOA) measurements between the transmitting terminals. It is therefore important to develop an integrated navigation filter capability, which optimally integrates MIDS/JTRS data with other sensors (e.g., GNSS, INS, FLS), providing a robust navigation solution in GNSS-denied conditions.

14.2 UAS DEVELOPMENTS

Research initiatives are underway in the US, Europe and Australia to assist the FAA, EUROCONTROL and CASA define safety thresholds and develop policies, procedures and systems that would make UAS unrestricted airspace access a reality. Before unrestricted UAS operations become possible, assurances must be made that they can operate safely. Developing a certifiable Sense and Avoid (SAA) capability for UAS is viewed as one of the most fundamental and yet most elusive tasks to be accomplished. For manned aircraft, one of the basic obligations of the pilot is to 'see-and-avoid other aircraft.' The see-and-avoid procedure has the advantage of not relying on any cooperative equipment in the threat aircraft. While see-and-avoid is subject to human limitations, it is proving difficult to develop a practical suite of sensors/systems that can provide anything nearly equivalent to human vision and associated decision making. SAA can be defined as the capability of a UAS to remain well clear from and avoid collisions with other airborne traffic. SAA provides the intended functions of self-separation and collision avoidance as a means of compliance with the regulatory requirements to 'see and avoid' compatible with expected behaviour of aircraft operating in the airspace system. From a conceptual point of view the SAA capability performs the following sub-functions:

- Detect — Determine presence of aircraft or other potential hazards
- Track — Estimates position and velocity of intruders based on surveillance reports
- Evaluate — Assess collision risk based on intruder and UA positions and velocities
- Prioritise — Determine which intruder tracks have met a collision risk threshold
- Declare — Decide that action is needed
- Determine Action — Decide on what action is required
- Command — Communicate determination action
- Execute — Respond to the commanded action

Counterpoint believes that the above initiatives will continue to be in force and supported over the next decade as the industry seeks to deal with many challenges including the need for improved operating efficiencies, management of congested airspace, commercial and military overlaps and the emergence of the UAS/UAM sector.

As has been the case in past decades the impact of these initiatives will be to both affect the design of future avionics architectures and to maintain a healthy retrofit and upgrade market.

15 AVIONICS IN NON-WESTERN MARKETS

In researching this report, we have identified a number of avionics suppliers located within emerging market countries such as China, India, Russia, Korea and Brazil. Equally many of the national bodies governing the development of aviation are actively supporting the industry in such areas as investment, education, and infrastructure.

Japan

With an established civil and military aviation history we have found little evidence of Avionic development within Japan. There are a number of large corporations that have developed positions within Aerospace e.g., Kawasaki, Mitsubishi, IHI corporation, Sumitomo. However, none of these have yet to successfully venture into Avionics.

This is all the more surprising when you consider Japan's significant technological capabilities within the broader electronics markets.

Equally Japan has sought to develop an indigenous airframe capability via Mitsubishi with its SpaceJet programme.

Unlike China, that effectively sought to leverage access to its indigenous Comac C919 programme by having western suppliers sign up to Joint Ventures within China, Japan has been comfortable sourcing all its SpaceJet avionics from western suppliers. The majority of the SpaceJet avionic suite is supplied by Collins based upon their integrated ProLine Fusion avionics.

However, as we compile this report in December 2020 Mitsubishi has announced that 95% of the workforce currently engaged in the SpaceJet project will be laid off or re-deployed. The press is speculating that this may be the final nail in the coffin for this programme given its troubled history regarding weight and performance.

Following the US decision not to allow export of F-22 fighters the Japanese elected to promote a new F-X fighter concept. This programme has yet to be formally launched. However, Japan has sought collaboration from both UK and US military contractors and will undoubtedly be reliant upon western contractors for avionic-related mission and sensor systems if and when the programme goes ahead.

Japan has held discussions with BAE Systems, Northrop Grumman, Lockheed Martin and L3 Harris corporation, we understand, in respect to its aspirations to develop (jointly) an indigenous military fighter platform.

Within the civil arena Japan has increased its participation in international joint development of civil aircraft and is a 35% partner in the production of the Boeing 787, and a 21% partner of the Boeing 777 and 777X jets. Japan is also a major components manufacturer for Airbus, supplying cargo doors, vertical stabiliser structure materials, titanium sheeting, carbon fibre and water tanks, etc.

Japanese aviation industry has certainly carved out a strong position as a strategic partner (structures) and systems provider. However, we remain somewhat surprised that there is not greater investment geared to developing indigenous supply of avionic equipment.

China

In 2015, the Chinese government released its 'Made in China 2025' strategic plan, through which it seeks to become a major manufacturer of high-end technology, including avionics and aerospace equipment. In pursuit of this goal, Chinese state-owned companies leverage the country's highly desirable market to persuade foreign companies seeking market access to share technology.

The COMAC C919 programme was utilised very effectively to encourage western suppliers to form JVs with Chinese AVIC subsidiaries as a condition of being selected (not formally declared as such). This has resulted in a number of JVs within the avionics domain as follows:

- Aviage Systems is a 50/50 joint venture between GE Aviation and AVIC. Currently, it specialises in the supplies of the integrated modular avionics system to the C919. Specifically, GE will contribute its commercial Integrated Modular Avionics (IMA) technology to the joint venture. The JV will supply IMA technology, displays, onboard maintenance systems, flight recorders and flight management system for the C919.

- Rockwell Collins (now Collins Aerospace) and China Electronics Technology Avionics (CETCA) have established a joint venture to develop and manufacture the communication and navigation systems for the Commercial Aircraft Corporation of China (COMAC) C919 aircraft.
- Honeywell Aerospace is another major supplier of avionics to the C919. According to Honeywell's Asia Pacific aerospace division, the company has more than 12,000 employees in China right now. "We have 700 aerospace experts working across seven manufacturing plants, including two joint ventures for the C919," Kaul said. "These include supplying the aircraft's fly-by-wire system with HonFei Flight Controls and the supply of the braking system under a joint venture with Boyun Aviation Systems."
- Thales and China Electronics Technology Avionics Co., Ltd. (CETCA), have a Joint Venture Agreement that brings together world-class technology solutions companies dedicated to the new C919 aircraft. The Thales system will be a scalable platform offering services ranging from interactive audio capability through to full in-seat on-demand services, with an emphasis on minimising weight, cost and power consumption. Future evolution of the system will likely include wireless networks and connectivity

It is interesting to note that Honeywell has a total of 5 JVs in China within its aerospace division. However, it does not have a JV specifically covering its avionics supply for C919.

It is worth understanding some of the history behind China's plan for avionics within Aerospace.

For a long time, China's avionics systems suppliers targeted only the domestic military aircraft platforms. And unlike the aerostructure manufacturers of AVIC, these local avionics suppliers lack experience on western commercial programmes under the shadow of an embargo on sensitive components. Both the ARJ21 and MA series are equipped with avionics system from Collins Aerospace. Although a few local suppliers are involved in these programs, their work packages are on non-core components. C919 is the first platform that the local avionic suppliers are seriously involved in (largely via the Aviage JV with GE Aviation described within this report in suppliers' profiles).

AVIC's China Avionics Systems and CETC's CETCA are two major domestic suppliers, both are state owned/related. As a legacy of the frequent restructuring in the past decade, both companies now have yet to form a synchronised manufacture and internal supply chain within their subsidiaries, although both claim that they offer avionics products across the whole value chain. For example, both AVIC Chengdu CAIC Electronics and AVIC Taiyuan Aviation Instrument manufacture air data systems, both AVIC Lanzhou Flight Control and Beijing Qingyun Aviation Instrument manufacture autopilot systems, and both AVIC Taiyuan Aviation Instrument and Beijing Qingyun Aviation Instrument manufacture integrated display systems. This induced inter-subsidiary competition is making AVIC's avionics business fragmented.

Another factor that has caused this fragmentation of AVIC's avionics business is the design logic behind China's avionics systems. Unlike the western giants, AVIC's avionic systems' design are solely driven by the development of specific aircraft programs. The designed systems have almost no subcomponents that are compatible with any other platforms because the assigned subsidiaries that worked on these aircraft programs are often different and as a consequence of the forementioned inter-subsidiary competition it can be challenging for these subsidiaries to work together. Thus, the level of technical capability for the 18 avionics companies under AVIC varies as well.

According to the 'Made in China 2025' road map China's strategy on avionics is to focus on R&D in

- Integrated Core Processing (ICP) systems
- Integrated Navigation Systems (INS)
- Cockpit Displays
- Onboard Maintenance Systems (OMS)
- Communications, Navigation, Surveillance (CNS) equipment

China's avionics market (supplied by local suppliers) is growing at a CAGR of 6-7%, mainly driven by military programs: China aims to expand its military fleet by 2,876 more aircraft by 2029.

In 2019 (pre Covid-19) China's domestically produced avionics equipment was worth $542 million. Affected by the Covid-19 pandemic 2020's market shrank by 10% but will quickly return to pre Covid-19 level in 2021 and restore the growth in 2022. We predict that the growth rate between 2022 and 2026 will be at 6% (slightly above the 5% CAGR driven by the military fleet expansion) because China will be keen to take the opportunity to accelerate its military programs while western OEMs recovery slowly from the pandemic.

Beside the military applications, China has long history on manufacturing civil helicopters since 2007 compared with other civil aircraft types. And under the government's promise to open more air space for civil use it is believed that around 2027, there will be a boom in civil helicopter programs in China, boosting the growth on the domestic avionics market to 7%.

As discussed earlier, we believe China still has a long way to go to be able to supply to western programs, but strategic partnerships like JVs are currently the only way to gain access to Comac's programs. Technology knowhow is likely to be transferred to the local manufacturers.

AVIC China Avionics Systems, a subsidiary of AVIC, is China's largest avionics system supplier. Initially focused on military aircraft, the company is now expanding its offering to commercial aircraft by participating in the C919 program. Two subsidiaries of the China Avionics Systems are directly involved in the development of C919. AVIC Chengdu CAIC Electronics in involved in the development of Air Data Heater Controller. Shanghai Aviation Electronic developed and is now the manufacturer of the C919 control panel components, dimming control systems, and circuit breaker board. In addition, AVIC's other subsidiaries are also taking part of the C919 development via JVs with western avionics giants.

CETCA is the second largest, and the only other state-owned company, that supplies avionics in China. The company was established in 2009 for the purpose to support the C919 program. The company is involved in the design and development of avionics systems for the C919, C929, AG600, MA700, and ARJ21.

The table below shows a list of JVs in China.

JV	Year	Chinese company	Share %	Western company	Share %	Product/Service
Collins Aviation Maintenance Services Shanghai Ltd	1997	China Easter Airline	35	Collins Aerospace	65	Provide aftermarket services and support of avionics and in-flight entertainment equipment for Chinese airline customers.
AVIAGE Systems	2012	AVIC CAE	50	GE	50	Provide integrated avionics solutions across 3 packages to C919 including 5 sub-systems including: onboard maintenance system, Common computing resources, flight management system, remote data concentration, aircraft data network, digital information system, digital ecosystem and big data analytics, integrated display system, 3rd party hosted subsystems integration, tier-1 system integration services, and flight recording systems.
AVIC Leihua Rockwell Collins Avionics Company	2013	China Leihua Electronic Technology Research Institute (LETRI)	99	Collins Aerospace	1	Established to develop the ISS which combines weather detection, traffic alert and collision avoidance, Mode S surveillance and terrain awareness and warning functions into a single system.

Rockwell Collins CETC Avionics Co. Ltd. (RCCAC)	2014	China Electronics Technology Avionics Company (CETCA)	99	Collins Aerospace	1	Established for development of the communication and navigation avionics solutions, which included audio, radio tuning, HF, VHF, GPS, DME, Radio Altimeter, VOR/ILS and an optional Inmarsat SATCOM solution
HonFei Flight Technology Co. Ltd. (HonFei)	2017	AVIC Xi'an Flight Automatic Control Research Institute (AVIC FACRI)	50	Honeywell Aerospace	50	Develops and produces flight control systems for commercial aircraft, including the COMAC C919
Other strategic partnership	2014	AVIC Chengdu CAIC Electronics	N/A	Honeywell Aerospace	N/A	Supply ADIRS for C919 from design, manufacture to MRO

Table 38: Avionics joint ventures in China

In recent years certain of these US based JVs have run into trouble owing to the onset of trade issues between China and US. Also, there are claims by the US that these JVs have exploited access to US derived IP which is now being utilised by Chinese companies.

Currently all the major western avionics suppliers, including Honeywell, Collins, Thales and GE Aviation benefit from the billions of dollars of avionic revenues generated to both supply and support the largely Airbus and Boeing dominated fleets in operation in China today.

The Comac C919, (together with the regional ARJ21, MA700 etc), is clearly a 'learning platform' for the Chinese Aviation industry and their aspirations to be self-sufficient in areas such as engines, avionics and systems will almost certainly result in there being Chinese competitors vying for contracts on any next generation platforms launching in a 2030+ timeframe.

India

The Defense Avionics Research Establishment (DARE), established as an electrical avionics research centre in the 1950s, works on the development of electronic warfare systems and mission avionics for aircraft. It is one the two laboratories of DRDO that works on electronic warfare systems, along with Defence Electronics Research Laboratory. DARE developed the first mission computer for the Light Combat Aircraft (LCA) in 1991. The computer was responsible for managing the interaction between avionics, displays, sensors and weapon systems.

Insofar as avionics are concerned, HAL represents the only business within India that has proven avionics capabilities. HAL Korwa division or Avionics Division Korwa (see HAL Korwa in the supplier profile section of this report) was established in 1983, to take up the production of Display Attack Ranging and Inertial Navigation system for Jaguar International aircraft for the Indian Air Force, followed by manufacturing & supply of avionic systems for Russian MiG-27 & Su-30MKI aircraft.

The HAL Korwa Division is manufacturing & repairing various Avionics Systems fitted on MiG-27M Upgrade, Mirage-2000, LCA, Jaguar upgrade, AJT-HAWK aircraft. The division has also been engaged in the maintenance of UAVs Systems since 2001.

The other electronics business within India that services the military market sector is Bharat Electronics. We have not covered this business with a supplier profile as it tends to service land and marine but not avionics. However, in 2010, Boeing announced that it received the Data Link II communications technology for the Indian Navy's P-8I from

Bharat Electronics Limited (BEL). Bharat delivered the Indian-designed communications system that would enable the exchange of tactical data and messages between Indian Navy aircraft, ships and shore establishment.

In contrast to manufacturing, arguably India has established itself as an ideal 'centre of excellence' for the provision of Engineering services to western avionics businesses in recent years. This is especially the case where digital products are concerned that also require considerable amounts of software code.

Both aircraft OEMs and Tier 1 suppliers have established engineering design centres throughout India in support of the development of avionics related products.

Boeing, for example, is investing almost $100m developing a new facility in Bengaluru (next to the airport) where a new building will eventually house 3,000 employees. It will be Boeing's largest engineering and product development facility outside of Seattle, when completed.

Whilst the project has slowed due to the 737MAX issues and the pandemic it will be used to help develop secure communications standards and health management systems for next generation aircraft.

Honeywell, GE Aviation and Collins have all invested in developing engineering service centres within India in support of developing avionic equipment for the western markets.

Collins, for example, has an Engineering Design Centre located in Hyderabad which it established in 2008 and it is totally dedicated to the development of software.

Brazil

Brazil's aviation industry has enjoyed considerable success with the development of both civil and military platforms that they have been able to successfully export.

Following its founding in 1964 Embraer enjoyed early success with regional turboprop aircraft such as the Bandeirante and EMB 120 Brasilia whilst on the military side it developed the AMX fighter and Super Tucano military trainer.

Its successful foray into business jets followed with Legacy 650 and more recently the Phenom and Praetor families of aircraft.

Currently it produces the very successful range of E jets that lead the worldwide regional jet market.

It has also recently designed and developed the KC-390 military transport aircraft which is attracting export interest.

The success of Embraer has helped to spawn over 100 Aviation supplier businesses within Brazil for a range of equipment.

In terms of avionics supply, Embraer has largely relied upon western sources over the years with Honeywell, Collins and Thales all providing commercial avionics.

The recent C-390 Millennium military transport relies upon Collins for an avionic suite based upon its ProLine Fusion offering including the HUD. AEL Sistemas has developed some of the more sensitive avionic functions including the Mission Computers, Self-Protection Systems and Countermeasures SPS and DIRCM, respectively, the HUD (Head-Up Display) and EVS (Enhanced Vision System).

AEL Sistemas has been involved in the development of avionics for the A1 (Brazil and Italy), F5-M, the AMX fighter, A29 Super Tucano, T27 Tucano and C-390 Millennium transport aircraft.

We are not aware that AEL has established a significant presence in supply of avionics to commercial platforms.

16 MAJOR RECENT CONTRACT WINS

Below is a tabulation of some of the recent avionic related contracts that have been secured by the avionics supply chain.

Supplier	Announcement
AEL Sistemas	January 2022: AEL Sistemas was awarded a contract to supply additional Hermes 900 UAS (Unmanned Aerial Systems) to the Brazilian Air Force (Força Aérea Brasileira "FAB"). The contract is in an amount that is not material to Elbit Systems and will be performed over a period of 16 months. Under the contract, the Company will supply its Hermes 900 UAS and spare parts.
Astronics	September 2021: Astronics announced it was awarded a $19 million order from Collins Aerospace for business jet connectivity equipment to be delivered in 2022. The order is a follow-on to the approximately $11 million order announced in February 2021. August 2021: Astronics announced a cooperative agreement with Aerotec Concept of Toulouse, France. The agreement will provide both companies the opportunity to offer a greater breadth of new technologies, applications, and/or modifications requiring EASA (European Union Aviation Safety Agency) and FAA (U.S. Federal Aviation Administration) certifications to the marketplace. More specifically, the cooperative agreement provides Astronics the means to expand its comprehensive design, development, analysis, substantiation, certification, kitting and manufacturing capabilities further into the aerospace market in Europe. Astronics and Aerotec have a rich history of successful collaborative efforts including qualification of The Edge, Astronics' newly launched fully scalable Cabin Network IFE Platform, certification of large radome installations and power solutions for portable electronic devices. February 2021: Astronics was awarded contracts by The Boeing Company to supply CorePower® aircraft power distribution units and custom-engineered exterior lighting for the MQ-25 unmanned aerial refueling program. The CorePower system replaces pilot-operated, thermal mechanical breaker systems with intelligently controlled, solid-state switches to provide safe, reliable performance remotely. The system planned for the MQ-25 incorporates the use of Astronics' latest generation ECBU products to create an evenly distributed system at a fraction of the wire weight and increased reliability compared with traditional systems. The MQ-25 is the U.S. Navy's first operational carrier-based unmanned aircraft and is designed to provide a much-needed refuelling capability. The contract supports Boeing's engineering and manufacturing development program. February 2021: Astronics was awarded an order of approximately $11 million from Collins Aerospace for business jet connectivity equipment. The order is a follow on to previous orders for inflight connectivity (IFC) hardware that Astronics has been providing to Collins. Astronics' equipment supports the growing interest in the business jet connectivity services offered by Collins Aerospace. Having received many strong customer reviews, Collins' system provides unparalleled high-speed world-wide connectivity that enables a broad variety of remote conferencing services as well as streaming entertainment.

Supplier	Announcement
BEL	March 2023; The Ministry of Defence (MoD), Government of India, has signed 10 contracts worth Rs.5,498 Crores with BEL. Amongst, avionics related contracts are: Air Force Projects: a) EW Suite Equipment for Medium Lift Helicopter (90 Nos.) has been signed with BEL-Bangalore. It is indigenously designed and developed by the DRDO lab, Combat Aircraft Systems Development and Integration Centre (CASDIC). It comprises Radar Warning Receiver (RWR), Missile Approach Warning System (MAWS) and Counter Measure Dispensing System (CMDS). b) AMC for Akash Missile System has been signed for maintenance of two Squadrons with BEL-Bangalore. The Akash Missile System (AMS) is a medium- range, surface-to-air missile (SAM) system, developed by DRDO and manufactured by BEL. AMS includes Surveillance Radar, Fire Control Radar, Control and Command Centre developed by BEL. ARMY PROJECTS: a) Automated Air Defence Control and Reporting System (Project Akashteer) has been signed with BEL-Ghaziabad. b) Instant Fire Detection and Suppressing System (IFDSS) for T 72 has been signed with BEL-Kotdwara. IFDSS is indigenously designed by DRDO and will be manufactured by BEL-Kotdwara. NAVY PROJECTS: Sarang (12 Nos.) will be installed on Kamov 31 Helicopters of the Indian Navy which intercepts, detects and identifies the Radar emitters comprising state-of-the- art technologies. The project is indigenously designed and developed by DLRL and manufactured by BEL-Hyderabad. d) Three more projects were signed with Indian Navy - INS-SA, CMS for P17 and P28 and Varuna EW system. All these are flagship projects showcasing the indigenous design and manufacturing capabilities of Indian Defence industry led by BEL, involving other Public Sectors, Private Sectors and MSMEs. These projects will add another milestone to the 'Atmanirbhar Bharat Abhiyaan' and 'Make in India' initiative of the Government of India.
Collins Aerospace	May 2024: Collins Aerospace was awarded a multi-billion-dollar subcontract as part of a team led by SNC to design, develop and deliver systems and products for a new aircraft under the U.S. Air Force's Survivable Airborne Operations Center (SAOC) program. The SAOC program delivers next-generation of the E-4B National Airborne Operations Center, providing top military leaders with a survivable aircraft to ensure performance of the National Military Command System. Collins Aerospace is on contract to deliver multiple products from across the business. February 2024: Collins Elbit Vision Systems (CEVS) a joint venture between Collins Aerospace, and Elbit Systems of America (Elbit America) announced that it has delivered the 3,000th F-35 Gen III Helmet Mounted Display Systems (HMDS) to the Joint Strike Fighter. The F-35 Gen III HMDS is the world's most advanced helmet-mounted display system. Its next-generation user interface serves as a pilot's primary display system, providing them with intuitive access to vital flight, tactical and sensor information day or night. With the 3,000th delivery, CEVS has provided over 20,000 systems to warfighters and have logged more than 1 million flight hours on 40 different fighter aircraft platforms. September 2023: Collins Aerospace had been selected by BAE Systems as the provider for Large Area Display technology to be integrated into the cockpits of future Eurofighter Typhoon aircraft. The ultra-high-definition Large Area Display (LAD) will be used by BAE Systems as part of its rapid capability development programme, Project Medulla, which sees it investing in future technologies for use across its combat air portfolio, including Eurofighter Typhoon. The LAD will serve as a pivotal tool for pilots, consolidating critical flight data, sensor inputs and tactical information into a single, easily accessible interface. Through real-time data feeds from radar, targeting systems, and threat detection, pilots will maintain an up-to-the-second view of the battlefield, enabling swift and precise decision-making during high-stakes engagements.
Curtiss Wright	October 2023: Curtiss-Wright has secured a $34-million contract to deliver data recorder technology for US and Australian manned and unmanned maritime aircraft. Under the contract, the company will supply and service its Keyed Broad Area Maritime Surveillance Airborne Recorder Network Attached Storage or K-BAR NAS. K-BAR NAS is an open architecture technology that collects flight data during test and monitoring operations. Once shipped, the recorder will be integrated into the MQ-4C Triton long-endurance drone and the PMA-290 maritime patrol and reconnaissance aircraft. The North Carolina-based company will also provide associated docking stations, chassis, removable storage modules, and laboratory cable sets.

Supplier	Announcement
	October 2023: Curtiss-Wright has secured a five-year, $34 million firm-fixed-price indefinite delivery, indefinite quantity (IDIQ) contract with the Naval Surface Warfare Center (NSWC). The contract encompasses providing Modular Open Systems Approach (MOSA) based airborne data recorder technology. This technology is earmarked for deployment on both U.S. and Australian manned and unmanned maritime aircraft. A highlight of this agreement is the provision of Keyed Broad Area Maritime Surveillance Airborne Recorder (K-BAR) Network Attached Storage (NAS) solutions. This will include a comprehensive range of equipment such as chassis, docking stations, removable storage modules, and lab cable sets. Drawing from its stature as a premier supplier of MOSA-based encrypted, solid-state network-attached storage subsystems, Curtiss-Wright's commitment is clear: to deliver top-tier, commercial-off-the-shelf (COTS) open architecture K-BAR NAS equipment. Such equipment will bolster the capabilities of the MQ-4C Triton aircraft and the forthcoming PMA-290 aircraft models. June 2023: Curtiss-Wright's Defense Solutions division today announced that it was selected by Airbus to provide a flight test instrumentation (FTI) system solution for use during flight tests of one of the Eurofighter Typhoon instrumented production aircraft (IPA). The Eurofighter Typhoon IPA aircraft are fitted with telemetry instruments to support dedicated flight testing and systems development. Under the contract, Curtiss-Wright will provide Airbus Defence and Space GmbH with data acquisition and encoding units (DAU) designed to capture critical test flight data, including the Axon and KAM-500 DAU product families and NSW-12GTH Ethernet switch. June 2023: The US Air Force's Nellis AFB has awarded Curtiss-Wright a $24-million contract to provide Flight Test Instrumentation (FTI) equipment for the F-35 Technology Refresh 3 program. Technology Refresh 3 is an ongoing modernization effort for the service's hardware and software components on the F-35 Lightning II stealth multirole combat aircraft. The program aims to improve the fighter's memory, display, and computer processing capabilities and support future technology requirements. Work for the contract is being conducted at Curtiss-Wright's Teletronics Technology Corporation facility in Newtown, Pennsylvania. February 2023: The US Air Force has awarded Curtiss-Wright a $287-million contract to deliver its High Speed Data Acquisition System. The system uses radio frequency links to collect, process, and transmit data from planes to aircrews. The platform also analyzes and displays information for users. The initial phase of the program is being funded with $123 million. Work will be conducted over five years, followed by an additional five-year option. Once delivered, the capability will support flight trials and related programs at the Edwards Air Force Base Air Force Test Center. June 2021: Curtiss-Wright announced that it was awarded a contract by Lockheed Martin to provide its Modular Open System Approach (MOSA) computers and video processing modules to upgrade the Mission Computer and Flight Management Computer (MC/FMC) on the U.S. Navy's fleet of Sikorsky MH-60R/S Seahawk helicopters. The initial contract is valued at $24 million, with an estimated lifetime value of $70 million. Under the contract, Curtiss-Wright is providing Lockheed Martin with rugged single board computers and video processing modules. The modules result from Curtiss-Wright's Modified COTS program, which enables system integrators to upgrade individual modules in their legacy systems without having to replace the entire system, significantly speeding delivery of advanced technology to the warfighter. Shipments began in December 2020. April 2021: Curtiss-Wright's Defense Solutions division announced that it was selected by Scientific Research Corp. (SRC) to provide a version of its Fortress flight recorder system to upgrade the T-6 Texan II trainer aircraft used by the U.S. Air Force and Navy. Under the contract, shipments began in the first quarter of 2021 and are scheduled to continue through the first half of 2023.
Elbit Systems	November 2023; Elbit Systems was awarded a contract by Airbus Defense and Space to supply the Direct Infrared Counter Measures (DIRCM) and Infrared (IR) Missile Warning Systems for installation on the MRTT A330 refueling aircraft for Canada. The contract will be performed over a period of five years.

Supplier	Announcement
	July 2023; Elbit Systems announced that it was awarded a contract worth approximately $114 million with an Asian-Pacific country to supply two long-range patrol aircraft (LRPA) equipped with an advanced and comprehensive mission suite. The contract will be carried out over a period of five years. The two LRPA aircraft will be based on new ATR 72-600 and Elbit Systems will integrate in each aircraft a mission suite that includes a Mission Management System, Electro-Optics, Radar, SIGINT, Communication and more. June 2023; Elbit Systems announced that it was awarded an additional contract by Airbus Helicopters for the Federal Office for Bundeswehr Equipment, Information Technology and In-Service Support, for the provision of Airborne Electronic Warfare (EW) self-protection systems for the CH53 GS/GE transport helicopters, as part of the platform upgrade program led by Airbus Helicopters. Under the contract, Elbit Systems, supported by Elbit Systems Deutschland, will provide digital Radar Warning Receivers (RWR), EW Controllers (EWC) and Counter Measure Dispensing Systems (CMDS). April 2023; Elbit Systems announced that it was awarded a follow-on contract worth approximately $100 million to convert commercial aircraft into Intelligence and Electronic Warfare (EW) aircraft for an international customer. The contract will be performed over a period of three years. As part of the contract, Elbit Systems will equip the aircraft with advanced Intelligence Mission Suite and EW capabilities. March 2023; Elbit Systems was awarded four contracts to supply the Romanian Ministry of National Defense with aircraft upgrades as well as electronic warfare suites, electro-optical infrared (EOIR) payloads and Brightnite systems for the IAR 300 helicopters. As part of one of the contracts, the Company will integrate Elbit Systems SPECTRO XR payload onto IAR 330 helicopters to enhance the Romanian Navy's operational capabilities. In a second contract, Elbit Systems will supply a comprehensive electronic warfare (EW) suite including Radar Warning Receiver (RWR), Laser Warning System (LWS), Infrared Missile Warning System (IR MWS) and Counter Measure Dispensing System (CMDS). The suites will be supplied to a domestic supplier for the installation and integration onboard six PUMA helicopters with an option for an additional six in the future. The contract is a follow on order to additional EW suites that are already installed other Romanian Armed Forces' platforms. It will be carried out over a period of three years.. The Company will also provide, as part of a third contract, Elbit Systems HDTS type head systems, SPECTRO XR electro-optical systems and an aircraft mission package that includes smart displays, digital maps and reconnaissance systems. Elbit Systems will also supply Brightnite systems to IAR Brasov for the Romanian Air Force's Puma 330 SAR helicopters. This contract will be carried out over two years. Under a fourth contract, Elbit Systems will supply advanced avionic suites, live training embedded virtual avionics system, advanced monitors, overhead display, navigation system and weapons activiation systems to Avioane Craiova that is upgrading the Romanian Air Force's (RoAF) IAR99 advanced fighter trainer aircraft. March 2023; Elbit Systems was awarded a contract to supply Electronic Warfare (EW) self-protection suites for a fighter aircraft that is being supplied to a NATO member country in Europe. As part of the contract, Elbit Systems will equip the aircraft with its EW self-protection suite, including Radar Warning Receivers (RWR) and Countermeasure Dispensing Systems (CMDS). January 2023; Elbit Systems announced that it signed a contract in an amount of approximately $95 million with the Israeli Ministry of Defense (IMoD) to supply and maintain advanced electro-optical systems for the Israeli Defense Forces (IDF) infantry forces. The contract will be performed over a period of 10 years. November 2022; Elbit Systems announced that it was awarded a contract valued at approximately $200 million to supply Electronic Warfare and airborne laser technologies to protect military helicopters of a country in Asia-Pacific. The contract will be executed over a four-year period. Under the contract, Elbit Systems will supply self-protection suites comprised of the Infra-Red Passive Airborne Warning Systems (PAWS IR) and the Mini-MUSIC Direct Infra-Red Counter Measure (DIRCM) Systems.

Supplier	Announcement
	September 2022; Elbit Systems announced that it was awarded a contract valued at $120 million to supply Hermes 900 Maritime Unmanned Aircraft Systems (UAS) and training capabilities to the Royal Thai Navy. The contract will be performed over a three-year period. Under the contract, Elbit Systems will provide the Rroyal Thai Navy with Hermes 900 Maritime UAS featuring maritime radar, Electro Optic payload, Satellite Communication, droppable inflated life rafts and other capabilities. July 2022; Elbit Systems announced that its subsidiary, Universal Avionics Systems Corporation ("Universal Avionics") was awarded a contract valued at approximately $33 million from AerSale Corporation, to supply Enhanced Flight Vision Systems (EFVS) for Boeing 737NG aircraft. The contract will be executed through 2023.Under the contract, Universal Avionics will supply the ClearVision EFVS systems featuring the SkyLens 360-degree field of view Head Wearable Display and the EVS-5000 cameras. July 2022; Elbit Systems was selected to supply a Direct Infrared Counter Measures ("DIRCM") system and an airborne Electronic Warfare ("EW") system for a Gulfstream G650 aircraft of The Netherlands Ministry of Defense. Elbit Systems will provide J-MUSIC DIRCM system together with the Company's Infra-Red-based Passive Airborne Warning System (IR-PAWS), for a Gulfstream G650 aircraft, providing high levels of protection and redundancy. July 2022; Elbit Systems announced that it was awarded a $80 million contract to supply Direct Infrared Counter Measures ("DIRCM") and airborne Electronic Warfare ("EW") systems for a country in Asia-Pacific. The contract will be performed over a two-year period.Under the contract, Elbit Systems will provide C-MUSIC DIRCM systems together with the Company's Infra-Red-based Passive Airborne Warning Systems (IR-PAWS), for several aircraft types, providing high levels of protection and redundancy. May 2022; Elbit Systems was selected by Airbus Defence and Space to provide J-MUSIC DIRCM (Direct Infrared Countermeasures) including the Company's Infra-Red-based Passive Airborne Warning Systems (PAWS IR), for Airbus A330-200 MRTT aircraft of additional European Air Force. January 2022; Elbit Systems announced that its subsidiary in the United Arab Emirates , Elbit Systems Emirates Limited, was awarded an approximately $53 million contract to supply Direct Infrared Countermeasures ("DIRCM") and airborne Electronic Warfare ("EW") systems for the Airbus A330 Multi-Role Tanker Transport aircraft of the UAE Air Force. The contract will be performed over a five-year period.Under the contract, Elbit Systems Emirates will deliver a multi-turret configuration of the J-MUSIC Self-Protection System together with the Company's Infra-Red-based Passive Airborne Warning System, providing high levels of protection and redundancy.
ENSCO	July 2021: ENSCO Avionics announced that Picatinny Arsenal has chosen its IData® and IDataMap as their development tool for its Future Attack Reconnaissance Aircraft (FARA) program. The goal of the FARA program is to develop and field the next generation of tactical assault/utility aircraft as part of the Future Vertical Lift program. ENSCO Avionics IData Tool Suite accelerates the creation of mission- and safety-critical embedded display applications by providing a robust and flexible development framework to easily design, develop, prototype and deploy rich graphics for any target display application regardless of platform.
Garmin	November 2022: Garmin announced L3Harris Technologies' selection of Garmin's G3000™ tandem integrated flight deck as part of a U.S. Special Operations Command (USSOCOM) Armed Overwatch program contract. L3Harris' Sky Warden™ platform includes the first forward-fit deployable combat aircraft featuring Garmin's G3000 tandem integrated flight deck. The G3000 provides USSOCOM with the latest communication, navigation, surveillance air traffic management (CNS/A™) capabilities with commercial-off-the-shelf (COTS) solutions based on Garmin's modern open system architecture design. L3Harris has integrated its mission management system along with a wide range of military sensors, communications equipment, and weapons systems into the G3000 touch screen human machine interface (HMI). The proven G3000 integrated flight deck will enable L3Harris to rapidly deploy new technologies quickly, provide lower life-cycle costs, and ensure access to the latest in avionic technologies.

Supplier	Announcement
	September 2022: Garmin announced the selection of the Garmin G3000® integrated flight deck by Tactical Air Support, Inc. (Tactical Air) as part of a contract with the U.S. Department of Defense (DOD) F-5N+/F+ Avionics Reconfiguration and Tactical Enhancement/Modernization for Inventory Standardization (ARTEMIS) program. Tactical Air first selected the Garmin G3000 for their F-5 adversary aircraft training fleet in 2018. This recent award builds upon Tactical Air and Garmin's strategic relationship now serving the DOD fleet of F-5 adversary aircraft. Garmin's commercial-off-the-shelf (COTS) G3000 open architecture supports integration with a wide range of mission equipment including military sensors, helmet mounted displays, and advanced electrically scanned radar systems. December 2021: Garmin announced a long-term agreement with Heart Aerospace to provide the state-of-the-art Garmin G3000® integrated flight deck for the ES-19 electric airliner. Heart Aerospace is working to develop the new ES-19, a 19-seat electric airliner that has the potential to provide the regional air transport market with a more sustainable and environmentally friendly aircraft option as early as 2026. Additionally, United Airlines has conditionally agreed to purchase 100 ES-19 aircraft once the aircraft meets United's safety, business and operating requirements.
GE Aerospace	September 2023: GE Aerospace announced the selection by Bell Textron for work on the development of a Common Open Architecture Digital Backbone (COADB), Voice and Data Recorder, and the Health Awareness System (HAS) for the Bell V-280 Valor. Following the U.S. Army's Future Long-Range Assault Aircraft (FLRAA) program contract award, the V-280 Valor will enable the U.S. Army and its allies to maintain battlefield superiority including transformational capabilities in speed, range, payload, and endurance. The GE Aerospace systems will be part of an open, scalable, high-speed data infrastructure consistent with the U.S. Army's Modular Open Systems Approach (MOSA) that enables rapid testing, verification, and fielding of mission-focused capabilities for future vertical lift programs. June 2023: GE Aerospace was selected by Korea Aerospace Industries (KAI) to supply the Health and Usage Monitoring System (HUMS) for the Korean Marine Attack Helicopter (KMAH). HUMS shipset deliveries will commence in 2024 and will include: Data Acquisition and Processing Unit (DAPU); Optical Blade Tracker (OBT); Multi-Platform Ground Station (MPGS). GE Aerospace sites in Southampton (UK) and Grand Rapids (MI USA) will develop and supply the HUMS to KAI. This follows an award KAI has received from the Korean Government to develop and supply the Korean Marine Attack Helicopter (KMAH). April 2023: GE Aerospace has signed an agreement with Lockheed Martin to support avionics and electrical power systems on the F-35 globally. The four-year agreement entails maintenance, repair, and overhaul for GE Aerospace systems on the F-35 Lightning II aircraft. GE Aerospace will service the F-35 systems at their repair and maintenance locations in California, Georgia, and Utah as well as GE sites at Grand Rapids, Michigan, Long Island, New York and Cheltenham, United Kingdom. December 2022: With Boeing asked to build two KC-46 tanker aircraft for the Japanese military, GE Aviation Systems will be providing mission control system avionics and flight management system (FMS), from their facilities in Grand Rapids, MI, and Clearwater, FL. November 2021: GE Aviation is supplying the data concentration network, advanced power management system and health management system for the recently unveiled Gulfstream G400 and Gulfstream G800 business jets. The data concentration network for the G400 and G800 is common from the G500 and G600 and builds on GE's common core system from the Boeing 787. The system provides a highly configurable integrated data network for the aircraft and offers a way to seamlessly connect avionics and manage aircraft functions. Using GE's tool suite, the data concentration network can be rapidly re-configured, enabling efficient integration and significantly reducing cost of change over the life of the airplane.

Supplier	Announcement
Honeywell	February 2024: The U.S. Air Force is ordering advanced multicore avionics data processors for upgrades to the F-15 jet fighter aircraft under terms of a $61.2 million order, involving Honeywell and Boeing. Boeing has been asked to build full-rate-production versions of the F-15 Advanced Display Core Processor II (ADCP II) for integration into the Air Force F-15 aircraft fleet. The ADCP II flight computer comes from the Honeywell Inc. Aerospace segment in Phoenix. The avionics computer is based on commercial technology and provides multicore processor capabilities. Its high-speed processing and interface designs enable advanced systems integration, increased mission effectiveness, augmented fault-tolerance, enhanced system stability, and aircrew survivability, Air Force officials say. Boeing will oversee production and integration of the ADCP II boxes and related equipment into the aircraft. December 2023: Boom Supersonic has selected the Honeywell Anthem integrated flight deck for its Overture aircraft. As part of the agreement between the two companies, Honeywell's next-generation flight deck and its modular avionics platform will be incorporated into Overture. The Honeywell Anthem flight deck will be tailored for Overture's specific mission requirements, helping to enable exceptional situational awareness and enhanced safety. The advanced avionics interface provides continuity to Overture pilots from initial simulator-based flight training through to actual flights. Honeywell successfully completed the first flight of its Anthem integrated flight deck using its Pilatus PC-12 test aircraft in May 2023, paving the way for Federal Aviation Administration certification. July 2023: Honeywell and Swedish aerospace and defense company Saab reached an agreement regarding the acquisition of Saab's heads-up display (HUD) assets. The HUDs will be integrated into the Honeywell Anthem flight deck (following a three-year collaboration) and will be available as an option for Honeywell's Primus Epic flight deck as well. June 2021: Lilium has engaged with Honeywell to develop the 7-Seater Lilium Jet's avionics and flight control systems. Honeywell's Compact Fly-by-Wire System will act as the flight control system on the all-electric 7-Seater Lilium Jet, responsible for controlling its moveable parts, including the 36 control surfaces and ducted fans that will provide its high levels of manoeuvrability in every stage of flight. Alongside the flight control system, Honeywell will deliver the next generation integrated avionics system, which will provide a simplified user interface for the pilot to fly the Lilium Jet. The selection of Honeywell's next-generation UAM avionics system is the result of ongoing collaboration between Lilium and Honeywell to converge on the specific technical requirements suitable for the Lilium Jet. The avionics system is designed to reduce training time and will support operation by a single pilot, freeing up greater passenger capacity. May 2021: Honeywell's flight deck technologies will act as core systems on Dassault's all-new Falcon 10X jet. The newest model from Dassault features a range of 7,500 nautical miles, which allows it to fly from Los Angeles to Sydney or Hong Kong to New York with nary a stop. Along with the extended range, the aircraft will offer enhanced comfort and safety to optimize the passenger experience. Furthermore, Honeywell's advanced flight deck technologies will bring a user-friendly experience for future pilots of the Falcon 10X.
L3Harris	June 2024: L3Harris Technologies received a $34 million contract from the U.S. Air Force to help modernize the B-52 Stratofortress bomber. The award is part of the Air Force's Global Strike Command B-52 Quad Crew Program to consolidate the functions of the electronic warfare officer and navigator into one position. The B-52H is currently operated by a five-person crew that includes two pilots, two navigators and an electronic warfare officer. The consolidation of the two crew positions will include moving the control and display unit panels to the navigator station. The joint effort with the customer-led Crew Station Working Group will include a series of analysis such as aircraft weight and balance, structural and electrical load analysis and thermal cooling to identify any impact on the B-52 airframe and inform the modification kit design. L3Harris has been providing critical B-52 technology for decades as the Original Equipment Manufacturer of the AN/ALQ-172 systems for this aircraft fleet. The company continues to help the Air Force evolve its capabilities from analog to digital solutions to defeat the continuously changing threat landscape.

Supplier	Announcement
Kontron	October 2023: Kontron announced the securing of two design wins with a combined volume of approximately EUR 100m. These wins involve Kontron providing IFEC systems to be installed on aircraft operated by multiple airlines, including one that utilizes satellite-based technology. For the first design win, Kontron will supply major components of a satellite-based IFEC (in-flight entertainment and communications) system which will be installed in aircraft from multiple airlines over five years starting in 2024. Kontron will deliver leading-edge technology, allowing connectivity through geostationary (GEO), medium earth orbit (MEO), and low earth orbit (LEO) satellite constellations. Potential revenues amount to roughly EUR 90m over a five-year span. In addition, Kontron announces a second design win with a volume of around EUR 10m over a two-year span. Starting in 2024, Kontron will supply a major satellite communications operator with IFEC equipment which will be installed in aircraft from multiple airlines. The agreement includes options to increase the volume and add further deployments.
IS&S	May 2023: Innovative Solutions & Support announced that it is providing its Utilities Management System (UMS) for the recently announced Pilatus PC-24 under a multi-year production contract. The IS&S UMS integrates multiple aircraft utility functions commonly supported by multiple individual controllers and monitors. The UMS-24 will monitor aircraft sensors and control aircraft systems as required achieving the system functions. This open architecture system will allow Pilatus to design and/or refine control and monitoring algorithms, in-house. The UMS-24 consists of four identical LRUs each one servicing up to 334 signals and controls. The four LRUs are data-linked through a high speed multi-line Ethernet ring. The interconnected system will integrate the PC-24 mechanical and electrical systems with the main avionics suite. Each unit contains two channels with dissimilar hardware and software.
Lockheed Martin	July 2024: Lockheed Martin has been awarded a $4.6 million contract by the Defense Advanced Research Projects Agency (DARPA) to develop Artificial Intelligence (AI) tools for dynamic, airborne missions as part of its Artificial Intelligence Reinforcements (AIR) program. This project aims to provide advanced Modeling and Simulation (M&S) approaches and dominant AI agents for live, multi-ship, beyond visual range (BVR) missions. It is a critical step in prioritizing and investing in breakthrough technologies for national security and to meet the evolving needs of customers. DARPA's AIR program will improve the government-provided baseline models' speed and predictive performance to better match how the Department of Defense's systems perform in the real world. During the 18-month period of performance, Lockheed Martin will apply AI and Machine Learning (ML) techniques to create surrogate models of aircraft, sensors, electronic warfare and weapons within dynamic and operationally representative environments. March 2024: The U.S. Air Force Advanced Range Threat System Variant 3 (ARTS-V3) program office awarded Lockheed Martin an initial $276M contract, which includes production options, to develop and produce the Variable Aperture Digital Radar (VADR) system. VADR will leverage both X-band and C-band radars to train aircrew for engagements against advanced adversarial threats. The VADR system is a software-defined sensor that can be reprogrammed to emulate different adversary systems and training events. It will be built using Distributed Digital Active Electronically Scanned Array (AESA), leveraging commonality with other key radars in the Lockheed Martin portfolio.
CMC Electronics	August 2023: CMC Electronics announced a multi-year contract with Swiss-based Pilatus Aircraft Ltd. for the purchase of its cutting-edge avionics solutions for the PC-21 Next Generation Trainer. This contract includes the supply of the Head-Up Display (HUD) sub-system, the Flight Management System, and the GNSS receiver. The award follows the acquisition of additional PC-21 turboprop-powered advanced trainers by Spain, an order that will bring Spain's PC-21 fleet to 40 aircraft. March 2023: CMC Electronics announced a new multi-year contract with Sikorsky, a Lockheed Martin company, for the supply of its military Flight Management System (FMS) on several Sikorsky helicopter models including the UH-60M, HH-60M, HH-60W, S-70i and the S-70M. The helicopters with CMC's equipment will be delivered to the US Army, the US Air Force as well as numerous international Black Hawk customers for use in a wide range of missions including search and rescue, troop transport, medical evacuation, disaster relief, aerial firefighting and border patrol.

Supplier	Announcement
	November 2022: CMC Electronics was selected by aviation technology leader Merlin to provide its civil-certified PU-3000 avionics computer to power their autonomous flight solutions. Merlin's autonomy systems aim to reduce crew in large cargo aircraft, and to eliminate crew entirely in small aircraft, solving a key aviation issue in an industry facing a severe global pilot shortage. As a strategic partner to Merlin, CMC will provide its latest multicore avionics computer certified by Transport Canada to host their advanced flight control software that enables autonomous flying. The PU-3000's open architecture platform offers high-performance multicore processing capability and an unrivaled set of interfaces, allowing Merlin to easily adapt the system for use on different aircraft types. The PU-3000 allows customers to retain their intellectual property by implementing their own applications using CMC's comprehensive Software Development Kit (SDK). The computer can host software applications developed to various Design Assurance Levels, up to DAL A. July 2022: CMC Electronics (CMC) announced that Korea Aerospace Industries (KAI) has awarded a new contract to CMC for the modernization of the Republic of Korea Air Force (ROKAF) fleet of KA-1 trainer aircraft used for advanced mission training and light attack missions. CMC worked closely with KAI to meet their request and proposed its state-of-the-art mission computer-based cockpit built on the PU-3000, the world's first certified multicore mission computer. The PU-3000 and its partitioned, embedded, software applications offer a flexible solution to integrate several conventional multifunctional displays (MFDs) or a single large area display (LAD) configuration as used in the KA-1 solution. The PU-3000 software development kit also allows KAI to develop specific proprietary mission applications on their own. March 2022: CMC Electronics was selected to supply its state-of-the-art mission-ready avionics and software applications for the all-new Calidus B-250, a next-generation light attack combat and training aircraft. CMC's solution includes the PU-3000, the latest generation certified avionics computer with video processing capabilities powering both a Large Area Display (LAD) and a heads-up display for critical missions. The PU-3000 is an open-architecture system that comes equipped with a Software Development Kit (SDK). The SDK will allow Calidus and third parties to develop and customize their own software applications such as PFD, EICAS and more. In addition to Calidus' custom applications, the PU-3000 will host CMC's Synthetic Vision System (SVS) and Flight Management System (FMS) software applications. The SVS enhances operational flexibility and safety by increasing the pilot's situational awareness, reducing workload and minimizing flight technical errors, particularly during the approach and landing phases of flight.
Wind River	January 2023: Wind River® announced it had worked with Airbus to support the A330 Multi-Role Tanker Transport (MRTT) aircraft for automatic air-to-air refueling (A3R). The MRTT aircraft is the world's first tanker to be certified for automatic air-to-air refueling boom operations in daylight. Airbus uses VxWorks 653 for the A330 MRTT air-to-air refueling boom system (ARBS). This system is comprised of multiple ARINC 653-compliant applications running at multiple levels of safety-criticality and achieved DO-178C DAL A certification. With this development, the Airbus A330 MRTT A3R capability has earned the distinction of being certified by the Spanish National Institute for Aerospace Technology (INTA), involving multiple ED-12C / DO-178C DAL A applications running simultaneously on multiple cores on a multicore processor. May 2022: BAE Systems has selected Wind River to provide the software development and testing platform for the development of the Tempest sixth generation fighter jet's development. Last August the Ministry of Defence (MOD) awarded a contract worth approximately £250m (US$348m) to BAE Systems to progress the design and development of Tempest, the UK's Future Combat Air System (FCAS). An industrial consortium that also includes lead partners Rolls Royce, Leonardo and MBDA are working with the UK's RAF Rapid Capabilities Office and the MOD to develop the fighter jet by 2035. BAE Systems will be using Wind River's VxWorks 653 platform and associated DO-178C DAL B safety certification evidence packages, and AdaCore GNAT Pro Assurance as part of ongoing technology demonstration project work in support of the program.

Supplier	Announcement
BAE Systems	July 2024: BAE Systems has received $133 million in contracts to provide radar warning receivers (RWR) for the US Air Force's C-130J Super Hercules military transport aircraft. The announcement specified the delivery of the company's proprietary AN/ALR-56M Advanced RWR, which had already been ordered for the service's C-130J fleet and F-16 Fighting Falcon jets in previous agreements over the past 30 years. The AN/ALR-56M sustains a platform's situational awareness and enhances aircrew survivability by detecting hostile radars from the air and the ground. Its scanning capability applies to dense environments and covers modern search, tracking, and acquisition radars. The receiver can also be integrated with a plane's existing jamming systems, countermeasures, and avionics. June 2024: BAE Systems received an $95 million contract from the U.S. Navy for advanced countermeasure pods to protect the P-8A Poseidon Multi-Mission Maritime Aircraft from missiles and other threats. The electronic warfare (EW) pod detects and counters inbound threats, protecting the Poseidon and its crews, and expanding the aircraft's operating range in contested environments. BAE Systems' survivability pod provides early threat detection and effective countermeasures to protect U.S. and international high-value airborne assets. The system's flexible, open architecture design allows rapid and affordable modernization, is compatible with future threat-detection and decoy countermeasure capabilities, and can host third-party EW techniques. April 2024: BAE Systems was awarded a 10-year, near-half-billion-dollar contract by Officials of the Army Contracting at Aberdeen Proving Ground, Md., for AN/ARC-231A multi-mode aviation radio suite hardware components, repair services, as well as technical, engineering, and logistic support. The value of the contract is $459.8 million over the next decade. The BAE Systems AN/ARC-231A avionics radio is part of the company's Fire series of aviation radios, which are software communications architecture (SCA) and software-defined radio (SDR) designs. September 2023: BAE Systems received a five-year contract from Lockheed Martin to sustain the AN/ALR-94 advanced digital electronic warfare (EW) system for the F-22 Raptor. Under the contract, BAE Systems will continue to manage EW system repairs and upgrades, supplier logistics, test equipment maintenance, and provide depot-level spares and engineering support to maintain F-22 EW readiness and relevancy for today's air dominance mission. As the original manufacturer of the complex AN/ALR-94 EW system, BAE Systems has provided life cycle management of the system since the program's inception. July 2023: The UK Ministry of Defence has awarded BAE Systems and Leonardo a contract to modernize the radars of the Royal Air Force's Typhoon combat aircraft fleet. Under the 870-million pound ($1.1 billion) agreement, the companies will equip the fighter jets with the European Common Radar Systems (ECRS) Mk2, a programmable electronic warfare device that uses wideband attacks to detect and jam adversary radars. Work for the radar's development and integration will run for five years, with an initial flight test scheduled for 2024. The contract builds on the UK's 2.35-billion pound ($2.98 billion) plan announced last year seeking revamped Typhoon radars in response to emerging aerospace threats. Completing this effort will allow the Typhoon jets to deploy alongside F-35B Lightning IIs in various combat scenarios without the risk of detection. In addition, the radar's extended range and passive operability will allow pilots to identify threats far from enemy air defenses. April 2023: BAE Systems received $491 million in contracts from Lockheed Martin to produce state-of-the-art Block 4 electronic warfare (EW) systems for future Lot 17 F-35 Lightning II fighter jets, adding to the 1,200 F-35 EW systems it has delivered to date. The powerful Block 4 systems will accelerate the delivery of advanced EW capabilities to warfighters by combining adaptable hardware and incremental software updates. The Block 4 EW systems will include significantly upgraded hardware and software that improves sensing and signal-processing capabilities. New, high-performance sensors will boost the system's ability to detect difficult-to-observe threats and more threats simultaneously.

Supplier	Announcement
HENSOLDT	November 2023: HENSOLDT will work with BAE Systems in a contract awarded by the UK Ministry of Defence. This contract centres on the development of the Striker ® II helmet-mounted display for the Royal Air Force's Typhoon fleet. Building upon a history of successful collaboration and the development of Striker I, HENSOLDT South Africa will supply the advanced optic sensors for the helmet and will be responsible for the development of its intelligent tracking system. Developed at BAE Systems in Rochester, UK, the Striker II is one of the world's most advanced fighter pilot helmets, which uses the latest technologies to integrate its all-digital night vision system and daylight-readable colour display. At its core lies the optical helmet tracking system developed by HENSOLDT's Optronics business in South Africa. April 2022: HENSOLDT has been awarded a mid-three-digit million euro contract for the next phase of Eurofighter maintenance. The contract covers service tasks for HENSOLDT's share of various Eurofighter systems in the areas of radar, self-protection and avionics. HENSOLDT's service contributes to the desired increase in the number of Eurofighter flying hours. The full service flight hour contract is organised through consortial partnerships in the four Eurofighter core nations (UK, Italy, Spain and Germany) and mandated through several national contracts via the Eurofighter partner companies (Airbus GE, Airbus SP, BAE Systems UK, Leonardo Aircraft Division IT). HENSOLDT is the national leader of the Radar- and DASS- (Defensive Aids Subsystem) Consortium for the service of the German user until the end of 2026 and is also the service and consortium partner for the other nations. When the contract comes into force, the assemblies of the four Eurofighter core nations with their total of approximately 500 aircraft will be maintained by the HENSOLDT sites in Ulm, Friedrichshafen, Taufkirchen, Neuburg and Laage.
Leonardo	July 2023: Leonardo announced a contract from the UK Ministry of Defence worth around 134million euros (115 million pounds) that will launch the next stage of the Excalibur Flight Test Aircraft (FTA) project. The FTA will support the introduction into service of a new combat aircraft, which will be at the heart of the UK's Future Combat Air System (FCAS). This next generation fighter is being delivered for 2035 by the Global Combat Air Programme (GCAP), an international collaboration between the UK, Italy and Japan. The Excalibur project is a key part of FCAS, which will include the crewed fighter and a broader range of capabilities such as uncrewed aircraft, F-35, information systems and weapon systems. Central to the development of the crewed fighter is the FTA; a Boeing 757 aircraft that will be completely overhauled, turning it into a flying laboratory for combat air technology. Leonardo will primarily use the airliner to test new technologies being developed by the trilateral programme. The UK Tempest Partners, BAE Systems, Leonardo UK, Rolls Royce & MBDA, working together with the UK Ministry of Defence, are continuing to collaborate on a range of test and demonstration activities, including Excalibur, to enable the successful delivery of GCAP in the required programme timelines. March 2023: Leonardo has been awarded a new contract for the modernisation of the Italian Air Force's C-27J Spartan aircraft fleet. The contract was signed between Leonardo and the Italian Ministry of Defence's (MoD) Directorate for Air Armaments and Airworthiness (Armaereo). According to the contract, the company will work on the development, integration, qualification and certification of the C-27J aircraft's new avionics configuration, along with the upgradation of several general systems, flight simulators and self-protection systems. Leonardo will deliver the first aircraft to the Italian Air Force in upgraded configuration while the remaining 11 aircraft are expected to undergo the same retrofitting process. Work includes integration of new features such as a flight management system, mission computer, head up/down displays and radio and satellite communication systems in the avionic suite of C-27J military tactical transport aircraft.

Supplier	Announcement
Diehl Aerospace	June 2022: Diehl Aerospace and Volocopter, the pioneer of urban air mobility are further expanding their cooperation. The contract extension provides for the development and production of an optical splitter to complement the flight control system as well as other components for the battery management system for the first all-electric VoloCity air taxi. Diehl Aerospace has already developed the Flight Control Computer (FCC) for the VoloCity, including the primary and backup control computers. In addition, Diehl Aerospace is developing the Data Concentration Unit (DCU) for Volocopter, which is the counterpart to the optical splitter. The DCU collects optical signals from 18 rotors via an optical interface and converts them into digital data for the avionics. This provides the pilot with feedback on the status of engine speed and temperature. With the DCU box, Diehl Aerospace completes the Volocopter's Fly-By-Light system for the VoloCity.
Mercury	July 2024: Mercury Systems announced an agreement with the U.S. Navy to advance sensor processing technologies that will allow radar and electronic warfare (EW) capabilities to be designed on much shorter timelines. The Office of Naval Research's Open Rapid Chipletized Approach (ORCA) program aims to reduce the time needed to design edge processing solutions by increasing the modularity of components at the chip level. Under a $13.2 million contract, Mercury will develop a next-generation RF System-in-Package (SiP) that integrates the latest commercial chips from major semiconductor providers within a smaller and lighter footprint. This work will build on Mercury's RFS1140 SiP, which integrates an AMD Versal FPGA, Jariet Electra-MA high-speed data converters, and Micron memory. March 2024: Mercury announced that it will advance the manufacturing of defense technologies in Switzerland in collaboration with Lockheed Martin. This project is a direct result of the offset program between Lockheed Martin and the Swiss government as part of Switzerland's purchase of the F-35 Lightning II. Under two initial engineering development agreements, Mercury will begin manufacturing several embedded computing technologies at its production facility in Geneva. These projects will be enabled by the transfer of two of armasuisses's key security-relevant technologiessoftware-defined radio technologies and cryptologyto Swiss industry. Mercury expects to receive further expansion opportunities over time to bring the manufacture of additional capabilities to Switzerland. March 2024: Mercury announced that it received a five-year, $243.8 million, indefinite delivery/indefinite quantity contract to deliver rapidly reprogrammable electronic attack training subsystems for the Naval Air Warfare Center Weapons Division. These subsystems build on more than 25 years of test and training technology from the Mercury Processing Platform to bring the most advanced, near-peer jamming and electronic warfare capabilities to U.S. pilot training organizations. December 2023: Mercury Systems was awarded an $16.8 million order from the U.S. Navy for ruggedized data transfer units, high-definition video recorders, and other avionics accessories for the F/A-18C-F jet fighter-bombers and EA-18G Growler electronic warfare (EW) aircraft. Mercury Mission Systems (formerly Physical Optics Corp.) will provide 48 data transfer units and 121 high-definition video recorders for the F/A-18 aircraft. This equipment is part of a Small Business Innovation Research Phase III topic N102-0129 called Automatic Real-Time, Reconfigurable Interface Generalization Hardware Multiprotocol Data Recorder. Mercury won similar orders in September and December 2022. The company won a $35.7 million order for 104 1553 data-transfer units – 68 for retrofit on F/A-18C-F aircraft and 36 for EA-18G production aircraft; and 144 high-definition video recorders for retrofit on F/A-18C-F aircraft.

Supplier	Announcement
	November 2023: Mercury Systems announced an agreement with the U.S. Navy to develop manufacturing capabilities that would allow commercial photonics chiplets to accelerate edge processing in defense applications. The Office of the Under Secretary of Defense for Research and Engineering (OUSD(R&E)) Trusted and Assured Microelectronics Program's Project KANAGAWA aims to mature the domestic supply chain and manufacturing processes for multi-chip packages, where co-packaged optics are integrated with electronic integrated circuits to enable long-reach and high-bandwidth data transfer. Compared to conventional copper connections, photonics uses optical fibers to enable orders of magnitude improvement in data bandwidth at a fraction of the power needed. The promise of this technology for defense systems has been well-known for decades, but demonstrations have relied on expensive and custom approaches that are not compatible with high volume production. July 2023: Mercury Systems received a five-year contract worth as much as $83 million from the U.S. Naval Air Systems Command to deliver high-definition, digital Head-Up Display (HUD) systems for the T-45 Goshawk training aircraft. This firm-fixed-price delivery order was issued under a previously awarded basic ordering agreement. The Navy is the first customer to adopt Mercury's HUD1080 technology that enables aviators to see critical flight and weapons data in real-time without taking their eyes off the sky. Under this program, Mercury expects to deliver nearly 300 HUD systems, with the first $45 million production order awarded in conjunction with this contract. March 2022: The US Air Force (USAF) awarded Mercury a $165m firm-fixed-price indefinite-delivery/indefinite-quantity (IDIQ) contract. This contract involves the delivery of flight data recorders to support secure mission data systems (SMDS) on the F-16 fleet. These flight data recorders are expected to improve performance, security and reliability for the F-16 jets' current and future mission requirements. The contract includes an initial order worth $16.4m and carries a 72-month planned performance and shipment period.
Northrop Grumman	December 2023: Officials of the Army Contracting Command announced an $106.6 million order to Northrop Grumman Mission Systems in Rolling Meadows, Ill., for the AN/APR-39 radar signal detecting set program. It detects radar threats to aircraft, such as radar ground sites and particularly radar-guided missiles, and provides 360-degree coverage around the aircraft. When the system detects enemy radar, it alerts the aircraft crew to each threat with a graphic symbol on the cockpit display. The APR-39 also functions as an electronic warfare (EW) management system, and serves as the heart of Northrop Grumman's suite of integrated sensors and countermeasures that integrates and displays data from onboard sensors radio frequency and electro-optical sensors. December 2023: The U.S. Defense Logistics Agency announced a $121.5 million contract to the Northrop Grumman Mission Systems segment in McLean, Va., for AN/APQ-164 offensive radar low observable antennas for the B-1 aircraft. Late-model B-1 aircraft have received upgrades to install the Northrop Grumman Scalable Agile Beam Radar-Global Strike (SABR-GS) - a multi-function active electronically scanned array (AESA) radar developed as an affordable low risk radar retrofit for the B-1. SABR-GS is replacing the APQ-164 radar antenna deployed on late-model B-1 bombers. Large synthetic aperture radar like the SABR-GS provides the B-1 with advanced image processing, and sensor integration for situational awareness and intelligence, surveillance, reconnaissance, and targeting. November 2022: Northrop Grumman has been selected to provide engineering services for the KBR-led $156.7 million, five-year Department of Defense Information Analysis Center's (DoD IAC) multiple-award contract (MAC) vehicle. IAC MAC task orders are awarded by the U.S. Air Force's 774th Enterprise Sourcing Squadron to develop and create new knowledge for the enhancement of the Defense Technical Information Center (DTIC) repository and the research and development (R&D) and science and technology (S&T) community. The UH-60V is a comprehensive digital cockpit redesign that replaces the UH-60L's legacy analog instrumentation with a fully open and integrated avionics suite. The architecture flying in UH-60V is applicable to both Current Fleet and Future Vertical Lift aircraft, and is extensible to Apache, Black Hawk and Chinook aircraft.

Supplier	Announcement
	March 2022: Northrop Grumman has been awarded a $65 million contract by the U.S. Navy to execute the full rate production of Link-16 for the U.S. Marine Corps AH-1Z and UH-1Y aircraft, which will involve the integration of data link hardware across the fleet. Link-16 is a secure data link that allows H-1 crews to share data and communications with other aircraft and users on military networks. This capability is a critical mission enabler as the Department of Defense moves to Joint All-Domain Command and Control. Northrop Grumman's mission systems solution for the H-1 fleet is trusted and combat-proven, with more than 450,000 total flight hours. The innovative processes, capabilities and open architecture developed for the H-1 fleet are directly applicable to other platforms and could be utilized in future aircraft development programs such as NAVAIR Vertical Take Off and Landing Family of Systems (VTOL FoS), MUX, and others.
Raytheon	April 2024: Raytheon will develop its 'Controlled, Advanced, Distributed Radio Frequency Effects' (CADRE) enough to integrate them with the US Navy's Next Generation Jammer (NGJ). The US Department of Defense allocated $40.59m to the supplier on 3 April 2024, to advance CADRE from technology readiness level (TRL) three to TRL six. The work will be divided into three phases: System Design and Risk Reduction; Detailed Design, Integration and Verification; and Ground Test and Flight Demonstration. These phases aim to achieve measurable progress toward the long-term Future Naval Capabilities objective of multi-aircraft flight demonstration. Work will be performed in McKinney, Texas, and the base effort is expected to be completed in November 2025. NGJ is the next step in Airborne Electronic Attack (AEA). It is needed to meet emerging electronic warfare (EW) threats. The system will augment, and ultimately replace, the legacy ALQ-99 Tactical Jamming System that is currently used on the Navy's EA-18G Growler Electronic Attack aircraft. December 2023: The United States Navy awarded Raytheon an $80 million contract in a down select to prototype Advanced Electronic Warfare, or ADVEW, for the F/A-18 E/F Super Hornet. This prototype will be considered as a replacement for the existing AN/ALQ-214 integrated defensive electronic countermeasure and AN/ALR-67(V)3 radar warning receiver with a consolidated solution that will deliver superior electronic warfare capabilities to the backbone of the Navy's carrier air wing. Raytheon's Advanced Electronic Warfare offering will provide significant performance upgrades by modernizing existing electronic warfare systems into fewer components and incorporating government-defined open architecture. Development of this new solution will closely align and integrate with other combat-proven, radio frequency sensors and effectors employed by the Super Hornet. ADVEW will ensure F/A-18E/Fs maintain their operational electronic warfare advantage, while significantly improving survivability against advanced, complex threats. Development and testing of ADVEW will mainly take place in Goleta, California. During the prototype phase, the system will undergo preliminary design review, critical design review, and flight testing over a 36-month period. September 2022: Raytheon Intelligence & Space has been awarded a competitive indefinite delivery indefinite quantity contract from the Federal Aviation Administration with a ceiling value of $375 million over the next 10 years. Task orders, valued at $215 million, were executed at contract award to provide technical refresh and Dual Frequency Operation (DFO) upgrades to the FAA's Wide-Area Augmentation System, or WAAS, a space-based precision navigation system, that will enhance safer air travel in support of the National Airspace System. Under the WAAS DFO-2 contract, RI&S will deliver more modern, and therefore sustainable, processing, system security, and network architecture, while also adding dual frequency service. WAAS is a Satellite-based Augmentation System (SBAS), which provides GPS corrections for critical navigation for the aviation community, first responders and other government agencies, ensuring pilots can land safely in austere environments, despite weather challenges.

Supplier	Announcement
	December 2021: Raytheon UK has been awarded a £110m contract to upgrade the RAF's Shadow surveillance aircraft fleet. The current fleet of Shadow surveillance aircraft fleet will be upgraded with the latest UK Sovereign Defensive Aids Systems (DAS). The advanced DAS safeguards the aircraft from possible attack while allowing it to continue intelligence gathering in the future. The contract will also see the addition of two more aircraft, taking the RAF's existing fleet of six aircraft to eight. Around 150 jobs will be supported at Broughton, UK, as well as specialist aerospace skills and apprentices and other positions at the company's facilities at Harlow and RAF Waddington. Furthermore, the award is expected to sustain an additional 350 jobs across the UK supply chain.
Rohde & Schwarz	April 2022: Rohde and Schwarz is one of several companies working with General Atomics, which has been awarded a €15.5 million contract by NATO's Support and Procurement Agency (NSPA) for Risk Reduction and Feasibility Studies (RRFS) associated with the Alliance Future Surveillance and Control (AFSC) program. The aims of this effort are to examine ways in which the organization can conduct surveillance and control following the planned retirement of the current Boeing E-3A Airborne Warning and Control System (AWACS) fleet around 2035. March 2021: Officials of the Air Force Sustainment Center at Robins Air Force Base, Ga., announced a $38.4 million five-year contract to Rohde & Schwarz to provide kits to assemble the Versatile Diagnostic Automatic Test Station (VDATS). VDATS is the Air Force member of the U.S. military families-of-testers, and is the Air Force's directed and preferred automatic test solution. The station has a modular open-architecture design and is adaptable to most electronic test and measurement needs. It was designed originally for depot testing capabilities, but is suitable for intermediate-level testing under controlled conditions. January 2021: Rohde & Schwarz was selected by the Brazilian Air Force (FAB) to equip its modernised Embraer E-99M aerial early warning and surveillance aircraft with modern and secure communications. FAB is modernising five aircraft, each E 99M equipped with highly secure software defined radios and waveforms of the SOVERON family, widely used in the country.
Saab	September 2023: Saab presented Poland with the first Saab 340 Airborne Early Warning (AEW) aircraft, just two months after Poland placed an order for two AEW aircraft, equipped with the Erieye radar. June 2023: Saab announced its Arexis sensor suite has been selected by Germany's defence procurement office (BAAINBw) as the preferred solution for the German Eurofighter Electronic Warfare (EW) variant. The German defence procurement office. The order marked the start of the first phase of Saab's delivery of Arexis within this programme. Saab received the order from Airbus, which will equip 15 of the German Air Force's Eurofighters for EW missions with solutions including Saab's Arexis. These aircraft will replace the German Air Force's Tornado ECR, which are set to be decommissioned from 2030. May 2021: Saab received an order from Panavia Aircraft GmbH to upgrade the radar warning equipment on the Tornado aircraft operated by the German Air Force. The order value is approximately 400 million SEK. Saab will supply modern digital components, which will enhance the processing power and extend the lifetime of the Tornado's radar warning equipment. Deliveries will take place between 2021 and 2025. Saab will carry out the work at its sites in Nuremberg, Germany and Järfälla, Sweden.
Safran	January 2021: Safran Electronics & Defense has been chosen by Textron Aviation to incorporate its range of Cassiopée flight data monitoring (FDM) services on Cessna Citation jets. Cassiopée is initially available to all ARes II-equipped Cessna Citation CJ4 light business jets. Safran's Cassiopée FDM services were designed for irlines, business aviation and helicopter operators. Its user interface provides a complete overview of all operations by data visualization, including automatic events notification, flight path, crew feedback and reports, and operational statistics.

Supplier	Announcement
Sierra Nevada Corporation	June 2024: SNC has been awarded a $170-million contract to deliver two RAPCON-X jets to the Finnish Border Guard as part of the "MVX" program. Currently in production, the RAPCON-X family of systems is SNC's newest integrated aerial intelligence, surveillance and reconnaissance (A-ISR) solution. For this program, SNC is using a RAPCON-X-configured Bombardier Challenger 650 aircraft tailored to the Finnish Border Guard's MVX specifications that provides a modernized and dramatically increased capability to the fixed-wing fleet. The Finnish Border Guard's current fleet monitors borders and territorial waters, supports rescue efforts in maritime emergencies, identifies environmental emergencies at sea and supports clean-up efforts. The new, more efficient multi-purpose aircraft will significantly improve Finland's border security and the monitoring of territorial integrity, particularly along the eastern border. May 2024: SNC has been selected by the U.S. Air Force for its Survivable Airborne Operations Center (SAOC) contract. Under the multi-billion-dollar award, SNC will modernize and deliver a replacement for the USAF's current fleet of E-4B "Nightwatch" aircraft. This highly specialized aircraft serves as an airborne command center for the President (POTUS), Secretary of Defense (SECDEF) and Chairs of the Joint Chiefs of Staff (CJCS) to ensure continued critical command, control and communication (C3) during national emergencies. The USAF's selection of SNC marks one of the largest aircraft modernization contracts awarded to a company other than the original aircraft manufacturer (OEM) and indicates a new acquisition approach that prioritizes open systems which fosters innovation, speed and cost competitiveness. SNC has championed this change as one of the only private mid-tier A&D prime contractors. November 2023: SNC has been awarded a multi-year, $554-million contract to deliver aerial intelligence, surveillance and reconnaissance (A-ISR) jets in support of the Army's Theater Level High-Altitude Expeditionary Next AerialSignals Intelligence (ATHENA-S) project. Currently in production, the RAPCON-X family of systems is the newest addition to SNC's turnkey, A-ISR-as-a-service model for contractor-owned-contractor-operated (COCO) capabilities including aircraft, pilot, flight and maintenance operations, and logistics support that is deployable within just hours. The ATHENA-S project is a critical part of the Army's "campaign of learning" to familiarize its aviation and intelligence branches with high-altitude sensing operations. March 2023: SNC was awarded a five-year, $716.8 million contract to provide components and engineering support for the U.S. Navy's Multi-Intelligence Sensor Development (MISD) suite. The MISD suite is designed to support sensor tasking and data management functions for manned and unmanned aircraft platforms.
ScioTeq	September 2023: ScioTeq has been selected by Airbus Defence and Space for its display computer PU-5200, avionics video touchscreen displays RDU-3068 and the MOSArt® Platform software, for the new generation Airbus A330 Multi-Role Tanker Transport (MRTT) aircraft. The new Open Architecture Display Computer and Displays will be replacing ScioTeq's previous generation computers and displays on the aircraft.
Thales (including former Cobham)	March 2024: Cobham Aerospace Communications has been selected by Dassault Aviation for the audio/radio communication system of French Navy's next generation Surveillance and Maritime Intervention (the acronym of which is AVSIMAR in French language) aircraft. This aircraft is based on a Dassault Aviation Falcon 2000 business jet plate-form, that is missionized with specific sensors and systems. One of the most relevant of these specific mission systems is the audio/radio management system combined with radio control. Cobham Aerospace Communications will supply this audio/radio management system, that manages the crew communications, both internal and external to the aircraft. This system features full compliance with French military requirements, together with significant weight savings and enhanced reliability compared with traditional technologies. February 2024: Lockheed Martin Corporation and Cobham Aerospace Communications are continuing a long-standing partnership through a recent contract extension that includes Cobham's AVIATOR 700D safety Satcom system for the C-130J. Engineered for use in military, government, air transport, business, and VIP platforms, AVIATOR D provides critical safety, navigational, and performance data directly to the C-130J cockpit, expanding connectivity and reducing pilot workload for increased efficiency and overall operational safety.

Supplier	Announcement
	June 2023: Cobham Aerospace Communications was selected by Airbus Helicopters to develop a new generation of dual-mode visible and infrared search and landing lights for the H160M GUEPARD developed in the frame of the light multirole helicopter program led by the French Armament General Directorate. The system is based on a new innovative generation of headlights integrating a three-axis kinematics. Combined with a new generation of on-board computers and communication with the avionics systems, our solution allows an illumination without ground limitation and a wide range of operational possibilities. May 2023: Embraer has selected Cobham Aerospace Communications for the next generation audio communication system of the multirole military transport C-390. Cobham Aerospace Communications will supply the system that manages the communications of the flight deck, both internal to the aircraft (with the crew) and external to the aircraft (through existing radios). March 2023: Cobham Aerospace Communications has been selected by Airbus Helicopters for a critical mission system of the HIL program (French Armed Forces' multirole light joint helicopter, based on the H-160 platform), led by the French Armament General Directorate: the integrated audio/ radio management system. This system is an integrated audio management system that is fully compliant with the latest Avionics, Airbus and NATO Norms standards and that provides advanced functions for the communications of the pilots and the crew (SDIP-27, DO-160, SPX, DO178C). The system is based on innovative and new generation of audio computers and Audio Control panels allowing secure and protected communications combined with Cybersecurity requirements. January 2023: As part of an ongoing series of avionics upgrades to the USAF fleet of Boeing C-17 transport aircraft, Boeing has selected Cobham Aerospace Communications' AVIATOR 700D Satcom System to provide global Inmarsat Aero H+ and SwiftBroadband services. The program, for +300 aircraft, is expected to be completed in 2025. May 2022: Thales has been selected by Airbus to equip its commercial airliners with the most powerful and innovative flight management system on the market. The new flight management system, which is based on the PureFlyt product and has been adapted to meet the specific requirements of Airbus, will process and share vast amounts of data to optimise flight operations, enhance interoperability and reduce environmental impact. The new flight management system (FMS), which is based on the PureFlyt product and has been adapted to meet the specific needs of Airbus, will be developed by Thales to equip Airbus commercial airliners, and in particular the A320, A330 and A350, with service entry planned for the end of 2026. The new system will improve interoperability for airlines and pilots and optimise flight paths to help reduce the carbon footprint of airline operations.
Ultra Electronics	June 2024: Ultra Intelligence and Communications has announced a $31.9 million agreement through an Other Transaction Agreement (OTA) with Consortium Management Group, Inc. (CMG) on behalf of Consortium for Command, Control and Communications in Cyberspace (C5) from the U.S. Air Force Cryptologic and Cyber Systems Division to deliver over-the-network rekey and remote management system upgrades for operationally deployed communications security (COMSEC) devices including identification friend or foe (IFF), Link-16 and in-line encryptors to reduce service costs and ensure reliable tactical networks.
Universal Avionics	March 2024; Universal Avionics announced that Eirtech Aviation Services, a leading aircraft modification provider, has selected UA's cutting-edge data link solution for its Airbus A320 fleet upgrade program. The upgrade features Universal's UniLink Communications Management Unit (CMU), which enables air-to-ground digital communications between pilots and Air Traffic Control (ATC), as well as Airline Operational Control (AOC) through its database of Aircraft Communications Addressing and Reporting System (ACARS) messages. October 2023; Universal Avionics has been selected as a lead supplier of integrated flight decks for De Havilland Canada's firefighting aircraft. Following an exhaustive search and through discussions with its base of operators, De Havilland Canada selected Universal's retrofit and forward-fit solutions for the CL-215T, CL-415, and DHC-515 to support aerial firefighting operations with NextGen flight display, flight management, data communication, and connectivity systems.

Supplier	Announcement
	October 2023; Universal Avionics has been selected by Widerøe Airlines, the largest regional airline in Scandinavia, to equip its fleet of Dash 8-400 aircraft with Connected Flight Management Systems (FMS). This fleet upgrade package increases efficiency and safety with newly developed supplementary iPad applications. June 2023; Universal Avionics has been selected by Amelia to provide Flight Management System (FMS) upgrades for its fleet of 13 Embraer jets. This modification will allow the airline to meet operational airspace requirements while enabling complex procedures. The installation includes a dual UNS-1Lw FMS configuration, replacing previously fitted UNS-1K Flight Management Systems. The STC issued by EASA allows Amelia to upgrade aircraft to the latest Satellite-Based Augmentation System (SBAS) FMS model, which provides operators with precision navigation for increased reliability and advanced capabilities. The later addition of a Localizer Performance and Vertical Guidance (LPV) monitor will bring additional efficiencies, enabling LPV approaches with a descent as low as 200-250 feet above the runway. July 2022; Universal Avionics has been selected by Everts Air Cargo (EAC) to supply cockpit upgrades for installation on its fleet of McDonnell Douglas MD-80 aircraft. Fitted in partnership with LB Aviation, the addition of Universal Advanced Flight Displays, SBAS-Flight Management Systems (FMS) with LPV capability, integrated GPS, and UniLink Communications Management systems will provide safety enhancements and operational efficiency for Everts' MD-80 fleet. EAC will also be a lead customer of FlightPartner, UA's recently unveiled Connectivity Ecosystem. July 2022; Universal Avionics was awarded a contract valued at $33 million to supply ClearVision systems Enhanced Flight Vision Systems (EFVS) from AerSale (NASDAQ:ASLE). The solution featuring the SkyLens Head Wearable Display (HWD) and EVS-5000 cameras for the Boeing 737NG, is part of the AerAware installation, developed by AerSale. June 2022; Universal Avionics has been selected by Aeronaves TSM to supply cockpit upgrades on 15 McDonnell Douglas MD-80s and 11 Douglas DC-9 aircraft. The addition of Universal SBAS-Flight Management Systems (FMS) improves the efficiency of cargo operations with Localizer Performance with Vertical guidance (LPV), among others, while bringing safety enhancements and compliance with the Automatic Dependence Surveillance-Broadcast (ADS-B) mandates. June 2022; Universal Avionics has been selected by Airbus Helicopters to supply its EVS4000 multispectral Enhanced Vision cameras for installation on 8 new Airbus H145 helicopters destined to the Bavarian Police. The addition of the EVS4000 improves safety by increasing situational awareness in low-visibility situations including inclement weather and during night missions.

17 PROFITABILITY

Compared to other segments of the aerospace supply chain, the Avionics sector earns relatively high margins.

There are several factors that contribute to profitability in the sector:

- Intellectual property and differentiation are key elements of avionics technologies
- The presence of an aftermarket with opportunities for replacements and upgrades
- Certain avionics technologies can demonstrate operational improvements, allowing for value-based pricing
- Avionics suppliers tend to be larger companies that have greater bargaining power
- Compared to other parts of the aerospace supply chain, there is less transparency in cost base
- The complexity of the offering and the certification requirements create barriers to entry – both for new entrants and for backwards integration from OEMs
- Switching costs are high and suppliers have a strong degree of lock-in to a particular programme once won

At the same time, certain elements of the industry structure create headwinds for profitability:

- OEMs have strong bargaining power on new programmes and these can be highly competitive
- Although there is an aftermarket, it is not as sizeable in relative terms as some other aerospace segments

Garmin is a classic example of a manufacturer that has quickly established a credible track record within aerospace, offering a wide range of product and services whist reporting 20%+ operating profit margins.

We do note that the profitability for large US defence contractors can be typically fall within the 10%–15% range which, we believe, is largely due to the US government/DoD 'open book' approach to defence contract pricing.

Below we show some suppliers' reported results. Individual commentary can be found within the respective profiles.

Company	Estimated % revenue from Avionics	2023 sales	2022 sales	2023 operating profit	2022 operating profit	2023 margin	2022 margin
Astronics - Aerospace segment	14%	$604.8m	461.2	24.6	(1.9)	4.1%	(0.4%)
Collins Aerospace	16%	$26,253m	23,052	3,825	2,816	14.6%	12.2%
Garmin - Aviation segment	82%	$846.3m	792.8	226.4	213.2	26.8%	26.9%
Honeywell Aerospace	23%	$13,624m	11,827	3,741	3,228	27.5%	27.3%
Innovative Solutions & Support	69%	$34.8m	27.7	7.4	7.2	21.2%	26.0%
Mercury Systems	44%	$973.9m	988.2	(21.7)	31.6	(2.2%)	3.2%
Teledyne - Aerospace and Defense Electronics	55%	$726.5	682.4	199.6	184.1	27.5%	27.0%
Thales	34%	€5,211m	4,705	371	235	7.1%	5.0%

18 INDUSTRY CONSOLIDATION AND M&A

18.1 SUPPLIER CONSOLIDATION AND OWNERSHIP

There has been significant consolidation within the avionics industry in recent decades which appears to be continuing.

Some of the major historical consolidation moves include the following:

- 2000: Northrop Grumman acquired Litton Industries
- 2001: Northrop Grumman acquires Litef GmbH
- 2007: GE Aviation acquired Smiths Aerospace (2007) who had acquired Lear Siegler (1987)
- 2005: Finmeccanica (now Leonardo) acquires BAE systems Avionics — renamed Selex
- 2010: Raytheon acquires Applied Signal Technology
- 2017: Rockwell Collins acquires B/E Aerospace (interiors and cabin systems).
- 2018: Elbit Systems acquires Universal Avionics
- 2019: TransDigm acquired Esterline (2019) which in turn had acquired Barco Aviation (2015) and CMC Electronics (2007)
- 2018: L3 and Harris agree to merge their businesses.
- 2018: Raytheon acquires Collins Aerospace (2019) which had only recently acquired Rockwell Collins.
- 2019: Thales to Acquire the Helmet Mounted Display and Motion Tracking Businesses of Gentex Corp.
- 2020: Moog Inc. has completed the acquisition of Genesys Aerosystems for a purchase price of approximately $77.7 million.
- 2021: Teledyne Technologies to acquire FLIR systems for $8 billion (closing expected mid-2021). FLIR makes infra-red sensors for defence and industrial uses.
- 2021: Eaton to acquire Cobham Mission Systems (CMS). CMS is not a significant avionics provider but has mission related capabilities.
- 2023: Cobham Aerospace Communications was acquired by Thales
- 2023: L3Harris Technologies announced it will sell its commercial aviation business to New York-based private-equity firm TJC. TJC also owns Freeflight Systems / Flight Data Systems.
- 2024: CAES was sold to Honeywell

It is equally notable that many of the leading avionics providers are also investing in non-traditional avionics companies that are able to bring AI, digital services, data analytics, Internet of Things and software services to the aviation industry.

Examples of these include the following:

- August 2023: **Saab** acquired all shares in the U.K.-based company **BlueBear**, a world-leading provider of AI-enabled autonomous swarm systems for complex defence and security applications.
- September 2023: **Saab** acquired **CrowdAI**, accelerating the development and implementation of Artificial Intelligence (AI) / Machine Learning (ML) capabilities into Saab's portfolio.
- December 2023: **Lynx** announced the acquisition of **Timesys Corporation**, a provider of development tools, cybersecurity solutions, and differentiated software engineering services for open-source embedded and edge software applications.
- May 2024: **Lockheed Martin** announced a $10 million USD investment in **PV Labs**, a Canadian firm renowned for its expertise in developing turnkey aerial imaging solutions.

We see a continuing trend for the traditional avionics houses to either acquire, form JVs or invest internally in order to access the 'new skill-sets' associated with modern avionics which can fall outside their existing core competencies. These new skills involve developing critical software on proprietary processors, digitisation of operations, real time operating systems, data analytics, artificial intelligence (learning) and the Internet of Things.

In reviewing the ownership and parentage of the companies identified within our supplier capability matrix (Table 22) we have noted the following in terms of the make-up and structure:

- Compared to other areas of aviation, including aero-structures, engine and airframe systems, we see smaller levels of ownership by private equity, although this has grown over the past few years
- There are a number of large, publicly-traded corporations which have increasingly strong leverage relative to the aircraft OEMs who are the customers for their avionics e.g., RTX, Honeywell, GE Aerospace, Northrop Grumman, General Dynamics. The scale of investment required for avionics likely requires a sufficiently large company size, hence a bias towards larger entities
- 33 of the avionics businesses are located or headquartered within North America and there are a further 12 businesses located within Europe
- Beyond the companies listed in this report, we see continued opportunities for bolt-on acquisitions of smaller companies with innovative technologies

18.2 ANNOUNCED DEALS IN AVIONICS

June 2024: **L3Harris** completed the sales of the company's antenna and related businesses to an affiliate of **Kanders & Company, Inc** for $200 million. The businesses L3Harris divested were part of the company's Space & Airborne Systems segment which employed approximately 375 people.

June 2024: **Mannarino** is acquired by business transformation specialists, **Scalian Group** (assisted by private investment firm **Wendel**). According to Wendel, the acquisition "is to be funded through a mix of drawdown on Scalian's existing committed credit facilities and shareholders' equity contribution, including a €43.7m equity injection from Wendel in Scalian." The acquisition is motivated by Scalian's strategy to expand internationally and focus on safety-critical systems and software engineering.

May 2024: **BAE Systems** acquired unmanned aircraft systems (UAS) developer **Callen-Lenz**, absorbing the business into its FalconWorks technology incubator.

May 2024: **Lockheed Martin** announced a $10 million USD investment in **PV Labs**, a Canadian firm renowned for its expertise in developing turnkey aerial imaging solutions. This investment represents one of the largest Lockheed Martin has made under Canada's Industrial and Technological Benefits (ITB) Policy, tied to the In-Service Support Contract for the CC-130J aircraft. The funds are directed towards advancing the commercialization of PV Labs' innovative airborne technology, specifically their Fifth-generation Advanced Stabilization Turret (FAST) technology. This modular and scalable gimbal technology, protected by intellectual property rights, promises unprecedented performance in smaller, lighter systems. Lockheed had previously invested in the company back in 2019.

April 2024: **HENSOLDT** completed the acquisition of **ESG Elektroniksystem- und Logistik-GmbH**, which was agreed last year, having received all official approvals. ESG is a leading platform- and manufacturer-independent system integrator as well as an established technology and innovation partner for defence and security. The acquisition adds strong design and system integration capabilities to HENSOLDT's product and solutions business. Founded in 1967, ESG is a manufacturer-independent system integrator and technology and innovation partner for defence and public safety. The company develops, integrates, supports and operates highly complex, security-relevant electronic and IT systems in the fields of defence and security. The company has played a key role in important current and future programmes such as FCAS (Future Combat Air System) and the F-35. The company employs around 1,400 people in Germany, the Netherlands and the USA and generated sales of around 330 million euros in 2023.

March 2024: **Honeywell** has agreed to acquire Italy's **Civitanavi Systems S.p.A.**, a provider of position, navigation, and timing (PNT) technology to the aerospace, defense, and industrial markets, a deal that adds new technology to its product portfolio that will strengthen its ability to help customers for autonomous operations. The $217 million deal is expected to close in the third quarter subject to clearing anti-trust authorities, approvals in Italy, the United Kingdom, and Canada related to foreign direct investment regulations, and the tender of at least 95 percent of Civitanavi's outstanding shares. Honeywell said Civitanavi's controlling shareholder, which owns 66 percent of the company, has

agreed to the deal. Civitanavi specializes in fiber optic gyro technology that currently is not part of Honeywell's navigation product suite. Honeywell said that Civitanavi's inertial navigation, geo-reference, and stabilization systems will complement its existing navigation and sensors business.

February 2024: **BAE Systems** completed the acquisition of **Ball Aerospace** from Ball Corporation. The transaction closed at a purchase price of $5.5 billion (approximately £4.4 billion), which has been funded through existing cash and new external debt.

January 2024: **Lynx** announced the acquisition of **Thompson Software Solutions, LLC**. (TSS), a provider of software development, engineering, and integration solutions to mission-critical aerospace and defense (A&D) platforms, spanning military and commercial fixed- and rotary-wing aircraft, commercial space flight, hypersonic platforms, and command-and-control systems. Its customers include the U.S. Department of Defense (DoD), prime integrators, A&D original equipment manufacturers, and commercial space companies.

December 2023: **Lynx** announced the acquisition of **Timesys Corporation**, a provider of development tools, cybersecurity solutions, and differentiated software engineering services for open-source embedded and edge software applications. The combination of Lynx and Timesys creates a scaled software solution provider focused on Mission Critical Edge and embedded software applications for customers with the most demanding reliability, security, and interoperability needs. With the addition of products and services offered by Timesys, the LYNX MOSA.ic platform will be able to deliver incremental value, functionality, and security to mixed-criticality systems requiring the real-time software determinism of Lynx's core IP and the flexibility of the Linux open-source platform. All products currently offered by Lynx and Timesys will remain available and supported.

November 2023: **L3Harris Technologies** announced the signing of a definitive agreement under which an affiliate of **TJC L.P.** will acquire L3Harris' Commercial Aviation Solutions (CAS) business for $800 million. The acquisition includes a $700 million cash purchase price and $100 million earnout based on the achievement of certain 2023 and 2024 financial performance targets, which together represent an approximate 15x LTM 9/30 EBITDA purchase multiple. The transaction is expected to close in the first half of 2024 and is subject to customary closing conditions and regulatory approvals. The CAS transaction includes the sale of L3Harris' surveillance joint venture and is subject to a right of first refusal; if exercised, an affiliate of TJC L.P. will acquire the rest of CAS. L3Harris' CAS business employs approximately 1,450 people and offers pilot training, flight data analytics, avionics, and advanced air mobility products and services, among other capabilities.

October 2023: **Safran Electrical & Power** today completed the acquisition of **Thales**' aeronautical electrical systems business, which covers electric conversion, power generation, and motors for civil and military aircraft. Thales's aeronautical electrical systems business employs nearly 600 people and generated revenues of €145 million in 2022. This acquisition includes Thales Avionics Electrical Systems and Thales Avionics Electrical Motors in France, with sites in Chatou, Meru, and Conflans-Sainte Honorine. It also includes the support, maintenance and production activities for aeronautical electrical equipment in Orlando (USA) and Singapore. Business activities in France are integrated into Safran Electrical & Power with immediate effect. Business activities in the USA and Singapore will be absorbed at the end of a transition period, during which the necessary certification approvals will be obtained.

September 2023: **Saab** acquired **CrowdAI**, accelerating the development and implementation of Artificial Intelligence (AI) / Machine Learning (ML) capabilities into Saab's portfolio. Future operations will be carried out primarily in San Diego, California. CrowdAI is known for its practical, user-friendly no-code platform for mission-specific AI and its industry-leading work leveraging dual-use computer vision for military applications. The company's work with Fortune 500 corporations, the U.S. military, and the Intelligence Community has pushed the boundaries of AI derived computer vision models tailored to the unique needs of customers. CrowdAI has contributed significant advancements to the AI / ML field, earning a place among America's most promising AI companies as listed by Forbes in 2021.

August 2023: **Saab** acquired all shares in the U.K.-based company **BlueBear**, a world-leading provider of AI-enabled autonomous swarm systems for complex defence and security applications. The acquisition of all shares in BlueBear is part of Saab's continued international growth journey across key markets, which include the United Kingdom, Australia, the United States and Germany. BlueBear is a world-leading provider of AI-enabled autonomous swarm systems for complex defence and security applications. BlueBear employs 65 employees at their site outside Bedford, England with a turnover of £8 million in 2022.

August 2023: **Kontron** has acquired **Hartmann and W-IE-NE-R,** a group of rugged computing systems manufacturers based in Germany and the United States, from Phoenix Mecano AG. The companies generated revenues of around EUR 18 million and an EBITDA of approximately EUR 3 million in 2022. The purchase price is EUR 22.1 million subject to

adjustment depending on the balance sheet upon closing. Hartmann designs and manufactures integrated modular VPX computing systems for ultra-high speed and harsh environments resilient to radiation and external influences. W-IE-NE-R complements the portfolio with redundant VPX power supplies. The biggest markets are United States, Germany, and Switzerland.

June 2023: The **IS&S** entered into an Asset Purchase and License Agreement with **Honeywell** International, Inc. pursuant to which Honeywell sold, assigned or licensed certain assets related to its inertial, communication and navigation product lines, including a sale of certain inventory, equipment and customer-related documents, an assignment of certain contracts and a grant of exclusive and non-exclusive licenses to use certain Honeywell intellectual property related to its inertial, communication and navigation product lines to repair, overhaul, manufacture sell, import, export and distribute certain products to the Company for cash consideration of $35.9 million.

June 2023: **Kontron** announced the signing of an asset deal with **Telit Cinterion**, a US-based company headquartered in Irvine, California, United States. The agreement entails Kontron's acquisition of Telit Cinterion's Cellular Automotive Module Unit, marking a significant strategic move to enhance its Internet of Things (IoT) offerings with its proprietary software technology. The assets of the module unit achieved revenues of slightly above EUR 100 million in 2022 and will be integrated into Kontron Europe GmbH, a subsidiary of Kontron AG. The purchase price is EUR 24.5 million. Closing is expected by August. The acquisition of Telit Cinterion's Cellular Automotive Module Unit presents a compelling opportunity for Kontron to enhance its product portfolio and to bolster internal engineering capacities, while preparing for the increasing demand for advanced 4G/5G solutions. By integrating Telit Cinterion's solutions into its own IoT software technology portfolio, Kontron aims to leverage its expertise.

March 2023: **ScioTeq** had acquired **IRTS**, a manufacturer of ruggedized displays and embedded computers for defense, aerospace and industrial applications. Headquartered in Toulon, France, IRTS was founded in 1995 and has earned a reputation as a premier manufacturer of industrial electronics that prioritizes research and development and maintains a team of highly experienced engineers. IRTS's specialty, state-of-the-art products are mission-critical in ground army vehicles and other military applications.

March 2023: **CAES** announced that **Herley** has joined CAES, further expanding the company's footprint in the RF market. Herley delivers high-integrity, small Size, Weight and Power (SWaP) and application specific RF and electronic warfare assemblies, tactical RF products and missile flight instrumentation solutions. With facilities in Woburn, Massachusetts; Whippany, New Jersey; and Lancaster, Pennsylvania, the company brings an experienced team, strong customer relationships and new strategic programs to CAES. With the combination, CAES grows its portfolio of solutions with added capabilities in missile flight instrumentation, customized RF solutions for microwave assemblies and tactical radio frequency.

July 2022: **Safran Electronics & Defense** acquired **Orolia**, a company offering positioning, navigation and timing (PNT) and related activities, technologies and equipment. Orolia employs more than 435 people in Europe and North America and has revenues of around €100 million. Its solutions include atomic clocks, time servers, simulation and resilience equipment for GNSS* signals, as well as emergency locator beacons for commercial aviation and military applications.

July 2022: Following advice from the UK Ministry of Defence and after careful consideration of responses to a consultation, the UK Business Secretary cleared the acquisition of **Ultra** by **Cobham** to proceed. The announcement followed the Business Secretary consulting on steps to address the national security concerns raised by the proposed acquisition of Ultra by Cobham (acquired by US private equity firm Advent International). The Business Secretary has accepted the undertakings from the parties to mitigate national security risks, with a small number of changes to reflect the responses to a consultation on them.

May 2022: **Saab** AB and **Lumibird** SA have today completed a transaction whereby Lumibird, through a newly established Swedish subsidiary based in Gothenburg, is acquiring Saab's laser rangefinder business. The transaction, which was signed in March 2021, was subject to a number of conditions, all of which now have been fulfilled. As part of the transaction, 27 Saab employees in Gothenburg will be affected and join the newly established subsidiary Lumibird Photonics Sweden AB. The divested operations had revenues of around EUR 10 million in 2021.

May 2022: **Lynx** announced it has received a strategic investment from affiliates of **OceanSound Partners**, LP, a private equity firm that invests in technology and technology-enabled services companies serving government and enterprise end markets. Joe Benavides, Managing Partner of OceanSound commented "[CEO Gurjot Singh] and his team have done a phenomenal job growing Lynx over the last few years, most notably having the LYNX MOSA.ic software framework support the upgrade of the mission system avionics for the F-35 Joint Strike Fighter Program. The selection of

Lynx's core platform in the Department of Defense's largest and most important program is a testament to the robustness of Lynx's core technology and validates their growth potential. The completion of this transaction marks the beginning of an exciting new chapter for Lynx, and we look forward implementing our engineering-like approach to value creation and pursuing strategic growth initiatives in partnership with the management team."

January 2022: **Aptiv PLC** announced a definitive agreement to acquire **Wind River®** from TPG Capital, the private equity platform of global alternative asset management firm TPG, for $4.3 billion in cash. Wind River is a global leader in delivering software for the intelligent edge. Used on over two billion edge devices across more than 1,700 customers globally, Wind River's software enables the secure development, deployment, operations and servicing of mission-critical intelligent systems. This edge-to-cloud software portfolio spans the aerospace and defense, telecommunications, industrial and automotive markets and is anchored by Wind River Studio, a highly versatile, comprehensive cloud-native intelligent systems software platform that enables full product lifecycle management for edge-to-cloud use cases. Wind River generated approximately $400 million in revenues in 2021.

November 2021: **Mercury** acquired **Atlanta Micro, Inc.** (Atlanta Micro). Based in Norcross, Ga., Atlanta Micro is a designer and manufacturer of high-performance RF modules and components, including advanced monolithic microwave integrated circuits (MMICs) which are critical for high-speed data acquisition applications including electronic warfare, radar and weapons.

October 2021: **CAES** announced that it has acquired **Colorado Engineering, Inc. (CEI)**, a leading Radio Frequency (RF) and high-performance computing (HPC) solutions provider in Colorado Springs, Colo. CEI's cutting-edge advancements in providing solutions to complex defense and commercial systems, along with their extensive experience in RF, digital, analog hardware and software solutions, complement CAES' leading RF, microwave and millimeter wave expertise and manufacturing capabilities across advanced electronics that serve the Aerospace and Defense industry.

May 2021: **Mercury** announced that it has acquired **Pentek Technologies, LLC** and **Pentek Systems, Inc**. Based in Upper Saddle River, N.J., Pentek is a leading designer and manufacturer of ruggedized, high-performance, commercial off-the-shelf software-defined radio and data acquisition boards, recording systems and subsystems for high-end commercial and defense applications.

19 AVIONICS SUPPLIER PROFILES

19.1 AVIONICS SUPPLIER PROFILES --- NORTH AMERICA

19.1.1 AVIATION COMMUNICATION & SURVEILLANCE SYSTEMS (ACSS)

Aviation Communication & Surveillance Systems (ACSS) is a joint venture 70% owned by L3Harris and 30% owned by Thales. Established in 2001, it is a leader in safety avionics systems that increase safety, situational awareness and efficiency for aircraft operators in all phases of flight.

ACSS products include the TCAS 2000 and TCAS 1500 traffic alert and collision avoidance systems, a family of Mode S transponders, the T2CAS, a combined traffic and terrain collision avoidance system, and MASS, an enhanced TCAS system for military operations. More than 8,000 units of ACSS's TCAS products are operating in commercial, corporate and military aircraft.

ACSS has been supplying the commercial and military aviation markets with advanced safety, communication, surveillance and antenna products for nearly 20 years, with over 75,000 units fielded.

Financials

We estimate that ACSS generated $82m sales in 2023.

We further estimate that ACSS revenues are split 50/50 between forward fit and upgrades/retrofit.

Locations

The ACSS JV does not have dedicated facilities but relies upon L3Harris's facilities in the US and Thales facilities in France for design development and manufacture of its range of product offerings.

Capabilities

TCAS variants/MASS: During military formation flight, the Military Airborne Surveillance System (MASS) works with the Mode S-IFF (identification friend or foe) data link transponder to identify and distinguish between cooperative member and non-member aircraft. It supports unrestricted formation and rendezvous operations and can be installed on aircraft equipped with the ACSS TCAS 2000 and a Mode S-IFF transponder with a simple software upgrade. The MASS complies with ATC guidelines to work in both military and civil airspace, providing TCAS/ACAS II operations during non-military flights.

The civil T3CAS is an integrated surveillance equipment certified on all Airbus A320 aircraft and long-range A330/A340 aircraft. This equipment is a single unit Traffic Collision Avoidance System (TCAS), a Terrain Avoidance Warning System (TAWS) and a Mode S transponder. The TAWS function features full Low RNP (Required Navigation Performance) 0.1NM (Nautical Miles) capability and unique performance-based algorithms that consider aircraft status (engines, weight, flaps/slats configuration, gears) and atmospheric conditions (temperature, pressure) for its Terrain Advisories (TA), hence improving the level of awareness and comfort of the flight crew.

The ACSS Mode S transponder boasts full ADS-B DO-260A certified capability, the latest definition of ADS-B OUT standard compliant with all the latest and upcoming mandates in the world (Canada, Australia, Singapore, Hong Kong). The Mode S transponder software is easily upgradeable to DO-260B for subsequent mandates in Europe (2015) and US (2020) to be compliant with NextGen and SESAR requirements.

Customers and contracts

Within ACSS Thales Avionics is the exclusive sales and support agent of ACSS products to Commercial Air Transport customers operating Airbus and Boeing aircraft.

L3Harris is responsible for the military designated sales in the US and for export markets.

Customers include Airbus, Boeing, Commercial airlines, Airbus Helicopters, General Atomics, General Dynamics.

Platforms supported in the civil arena include the Boeing 777, 737, A320 and A330/340.

ACSS also supports rotorcraft and UAS/UAV platforms for customers such as Boeing, General Atomics, Airbus, Sikorsky and Bell.

Strategy

ACSS is focussed upon TCAS/TAWS, together with the necessary transponders, as part of its surveillance product offerings for both civil and military market sectors. In 20 years the business has built a market leadership position within this important growth area.

Recent Developments

February 2024: Thales' motion (launched January 2024) for a preliminary injunction in aid of arbitration against L3 for its intended sale of its stake in ACSS to a private equity group was granted. Arguments relating to both public interest and balance of equities were upheld. The granting of the preliminary injunction preserves the status quo pending the outcome of the ICC arbitration process.

February 2024: Malaysia Airlines is embarking on a partnership with Thales which focuses on installing avionics equipment onboard 20 of its Airbus A330neo aircraft. The selected equipment includes Thales' signature avionics equipment - the Flight Management System (FMS) and ACSS' Traffic Collision Avoidance Systems (T3CAS). The Thales FMS includes powerful hardware and the latest certified Airbus Release 1A software. The avionics equipment will be installed and maintained from Thales' Aviation Global Services (AGS) centre in Singapore. The avionics expertise in Singapore dates back 50 years to 1973 when the facility started supporting the expansion of Airbus in Asia.

January 2024: Thales took initial legal action against L3 through the International Chamber of Commerce to prevent L3 from selling its 70% stake in ACSS to private equity buyer, Jordan Group. Thales contended that L3's sale of their stake violated the terms of the parties' LLC Agreement, would cause harm to Thales, and that the public interest favours a preliminary injunction stopping the sale in order to allow the arbitral tribunal to decide whether to award effective relief.

June 2023: China Eastern Airlines has expanded its partnership with Thales and ACSS by selecting avionics products for its 100 new A320neo aircraft. China Eastern Airlines' linefit selection of Thales/ACSS avionics package for its 100 new A320neo aircraft includes Thales' Flight Management System (FMS), Low Range Radio Altimeter (LRRA) and the ACSS' TCAS integrated surveillance solution. The aircraft deliveries are scheduled between 2024 and 2027.

July 2022: The British low-cost leisure airline Jet2.com and Thales have signed an agreement for selectable supplier furnished equipment (SSFE) on their A321 NEO fleet (51 units on order). Both the flight management system (FMS) and integrated surveillance equipment (T3CAS) developed by ACSS, will be supplied. Thales products will contribute to flight path optimization and generate significant weight savings helping to reduce the carbon footprint of the airline's operations. Deliveries are planned from 2023 to 2029.

Counterpoint comment

A very capable JV enjoying considerable success in terms of growth and market leadership. Their product offering has so far been limited to surveillance. In the past two years, L3Harris appeared to be shifting its focus more on national security and defence and military related contracts, and paying down debt. Thus, the recent dispute with Thales on selling 70% of ACSS. It is unclear now how this will affects ACSS's future performance.

19.1.2 ASTRONICS CORPORATION

Astronics Corporation (NASDAQ: ATRO) serves the world's aerospace, defence, and other mission critical industries with proven, innovative technology solutions. They work with customers, integrating an array of power, connectivity, lighting, structure, interior, and test technologies to solve complex challenges. For 50 years they have delivered customer-focused solutions. Today global airframe manufacturers, airlines, military branches, completion centres, and Fortune 500 companies rely on the collaborative spirit and innovation of Astronics.

Astronics offers a breadth of technology solutions and services through 11 subsidiary business units and a number of product brands.

Astronics offers the market 6 product technology groups with avionics covering data loading/data recorders, avionics I/O and interface devices, Satcom, antennas and Enhanced Vision Systems (EVS).

Financials - Aerospace Segment (including Avionics revenue)

FYE 31/12/23 - USD million	2023	2022	2021	2020	2019
Sales $m Avionics	113.1	97.2	64.9	76.1	106.8
Sales $m Aerospace	604.8	461.2	365.2	418.0	692.6
Operating Profit/Loss (Aerospace)	24.6	(1.9)	(8.6)	(89.8)	16.7
Operating Margin (Aerospace)	4.1%	(0.4%)	(2.4%)	(21.5%)	2.4%

Avionics revenue increased by $15.9 million, a 16% rise from the previous year.

Astronics commented: "Aerospace segment sales increased $143.6 million, or 31.1%, to $604.8 million. The improvement was driven by a 37.4%, or $117.6 million, increase in commercial transport sales. Sales to this market were $432.2 million, or 62.8% of consolidated sales in 2023, compared with $314.6 million, or 58.8% of consolidated sales in 2022. Higher airline spending and increasing OEM build rates drove the increased demand. General Aviation sales increased $17.4 million, or 27.5%, to $80.8 million due in part to higher demand in the business jet market for electrical power and motion and avionics products. The Company expects strong demand in the business jet industry to drive higher OEM production rates in the near future, resulting in further increases in demand for its products. Military Aircraft sales increased $7.1 million, or 13.0%, to $61.6 million from increased production of higher sales of lighting and safety and avionics products. Aerospace segment operating profit improved to $24.6 million compared with an operating loss of $1.9 million last year, which included an Aviation Manufacturing Jobs Protection ("AMJP") Program grant offset to Cost of Products Sold of $6.0 million. Operating margin expansion reflects the leverage gained on higher volume, partially offset by the $11.1 million in charges related to the customer bankruptcy, an increase in litigation-related legal expenses and reserve adjustments of $2.9 million, and an increase in incentive compensation expense of $2.8 million."

We believe the Avionics segment within electronics has overlap with IFE systems, which are not included in the scope of this report. We therefore estimate revenues for Astronics of $82m in 2023.

Locations

Astronics has 11 subsidiary companies supporting its 6 product focussed offerings. Its facilities have a total of 1.2m square feet in terms of total space. It designs and manufactures within the following facilities:

- Satcom/antennas/satellite business located in New Hampshire, US.
- Data/databus/connectivity business located in Everett, Washington State, USA.
- Enhanced Vision Systems (Astronics PECO) located in Oregon USA.

Capabilities

Under the Aircraft Connectivity and Data Solutions umbrella, solutions are offered in the following areas:

- Aircraft Data Systems
  - Aircraft Interface Devices
  - Avionics I/O Computers
  - Avionics Test & Simulation Interfaces
  - Embedded Avionics Devices
  - Smart Sensing Systems
- IFC Antennas and Radome Systems
  - Aircraft SATCOM Antennas
  - Aircraft Radomes
  - Adapter Plates

  - Bird Strike Protection
- Inflight Entertainment System Hardware
  - IFEC Embedded System Hardware
  - Corded and Cordless Controls
  - IFE Integrated Power
  - Portable IFE Systems
  - Systems Certification
- Smart Sensing Systems
  - Smart Aircraft System
  - Vibration Monitor Units
  - Aircraft Interface Devices (AID)
- VIP IFEC & CMS Systems
  - VIP Inflight Entertainment Systems
  - VIP Cabin Management Systems

Astronics serves global customers with integrated hardware and software systems that deliver SATCOM, data, databuses, and avionic I/O connectivity.

Enhanced Vision Systems: Designed to enhance safety and situational awareness in flight Max-Viz dual sensor enhanced vision systems (EVS) utilises multi-spectral imagers include a long wave infrared sensor, a visible light + near infrared sensor, and patented blending and dynamic range management image processing to enable pilots to see clearly during day and night.

Data: "Silo" is an intuitive software tool that can enable Astronics I/O Computers to be used for turn-key data recording. Avionics I/O Computers are rugged, COTS devices that combine computing capabilities and multi-protocol databus interfaces in a small, lightweight package.

Antennas: AeroSat aircraft SATCOM antenna systems are available for OE or retrofit applications, these certified HTS-ready solutions have provided seamless inflight connectivity through millions of flight hours for more than a decade.

Avionics I/O computers: Rugged, conduction-cooled, COTS devices combine a powerful computer processor, multi-protocol databus interfaces (MIL-STD-1553, ARINC 429, ARINC 717, ARINC 708), Ethernet, USB, serial, discrete I/O, and other I/O in a small, lightweight package. They deliver outstanding performance on the ground and in the air and are routinely deployed on helicopter, fixed wing, ground mobile, and marine platforms.

Customers and contracts

Astronics customers include:

Airbus, American Airlines, Bell Helicopter, Boeing, Carson Helicopters, Cirrus Aircraft, Comlux, Dassault Aviation, Delta Air Lines, Embraer, General Dynamics, Gogo, Gulfstream, Honeywell, Hughes, Intel, L3 Technologies, Leonardo, Lockheed Martin, NASA Panasonic Avionics Raytheon Company, Rockwell Collins, Sikorsky, Textron, Thompson Aero Seating, United Airlines, U.S. Army/Navy/Air Force/Marines, Zodiac Aerospace

Collins has selected Astronics to provide its Ku-band tail-mounted satellite communications (SATCOM) antenna technology for the Collins Aerospace KuSAT-2000 solution.

We estimate that Astronics sells 40% of its products to the end users such as airlines, defence operators and business jet users as upgrades and retrofits.

Strategy

Astronics is focussed upon servicing Aerospace with both OE and retrofit products. It states its strategy is "to increase its value by developing technologies and capabilities, either organically or through acquisition, which will provide innovative solutions to its targeted markets."

Recent developments

May 2024: Astronics announced today the global delivery of 350 shipsets of the EmPower® UltraLite G2 Power System since its launch in 2022. The Company has backlog of 300 more systems to be delivered by the end of 2024 demonstrating the rapid increase in adoption rate for the next generation passenger power solution which delivers more power with less weight.

May 2024: Astronics announced that it has been awarded contracts from multiple customers for the Astronics Dual-Modem ModMan (ADMM) valued up to approximately $75 million over the next 3 to 5 years. The Company expects to receive a series of purchase orders throughout the duration of the contracts. The ADMM is unique in that it provides the means to support multiple-orbit, multi-band capability in a single LRU providing a faster time to market for Managed Service Providers (MSP), airlines, and Original Equipment Manufacturers (OEMs) with the ultimate in flexibility.

March 2024: Astronics launched the Typhon T-400 Series SATCOM system. The Typhon T-400 Series is designed to seamlessly operate on any GEO-based Ku Satellite network, effectively addressing challenges associated with the high cost of equipping an aircraft with SATCOM connectivity.

November 2022: Astronics received the Best Inflight Connectivity Innovation Award from the APEX and IFSA Associations at the APEX EXPO event in Long Beach, California. The award was for innovation in its newly introduced Wi-Fi 6E-enabled CWAP, CabinAXe. CabinAXe is the first CWAP to utilize Wi-Fi 6E, creating a more compelling onboard connectivity experience for passengers. Wi-Fi 6E extends spectrum for less network congestion and larger channel widths to provide multi-gigabit speeds. Built-in reliability is provided through Wi-Fi 6E's interference avoidance, with tri-radio functionality optimized for high wireless density cabin environments. CabinAXe offers backwards installation capability with existing servers and wiring for easy overnight installations and unmatched efficiency.

June 2022: Astronics announced the introduction of EmPower® UltraLite G2, the industry's most powerful and intelligent cabin power system for charging passenger electronic devices (PED). The UltraLite G2 is a highly flexible and scalable passenger power system, allowing airlines to deploy the optimal PED power system for their budget and passenger's needs. It provides up to 60W of USB Type C power at every seat. UltraLite G2 is the next-generation system to Astronics' EmPower® UltraLite system introduced in 2018. The UltraLite system is a lightweight architecture providing high output power for passenger use without the need for a power supply installed at each seat group. The result is a lower cost, lower weight system, that does not encroach on passenger foot space, allowing for greater installation flexibility over traditional, seat- group-based architectures.

May 2022: Astronics announced a strategic partnership with LG Display to bring their OLED display technologies to the aviation marketplace. This relationship provides Astronics access to LG Display's broad family of industry leading OLED displays as well as technical support for development and integration from LG Display engineering resources.

September 2021: Astronics announced it was awarded a $19 million order from Collins Aerospace for business jet connectivity equipment to be delivered in 2022. The order is a follow-on to the approximately $11 million order announced in February 2021.

August 2021: Astronics announced a cooperative agreement with Aerotec Concept of Toulouse, France. The agreement will provide both companies the opportunity to offer a greater breadth of new technologies, applications, and/or modifications requiring EASA (European Union Aviation Safety Agency) and FAA (U.S. Federal Aviation Administration) certifications to the marketplace. More specifically, the cooperative agreement provides Astronics the means to expand its comprehensive design, development, analysis, substantiation, certification, kitting and manufacturing capabilities further into the aerospace market in Europe. Astronics and Aerotec have a rich history of successful collaborative efforts including qualification of The Edge, Astronics' newly launched fully scalable Cabin Network IFE Platform, certification of large radome installations and power solutions for portable electronic devices.

June 2021: Astronics announced the launch of new protocol models for its Ballard ME1000 family of mPCIe avionics interface cards for embedded aerospace applications. The new models provide interfacing capability for ARINC 429 and ARINC 717 databus protocols, and join models for MIL-STD-1553 that were previously released. The Ballard ME1000, a

Mini PCI Express® (mPCIe) card family designed and built by Astronics, interface with ARINC 429/717 or MIL-STD-1553 databuses and enable host devices, such as small form factor mission computers, to reliably communicate with and monitor avionics equipment.

May 2021: Astronics announced that the United States, Canada and EASA approved Astronics' Max-Viz 1200 and 1400 Enhanced Vision Systems (EVS) for Airbus Helicopter EC130 B4 and T2 models. In cooperation with AVIO dg in Calgary, Canada, Astronics obtained the Supplemental Type Certificates ("STC") for its Max-Viz 1200 and 1400 EVS from the U.S. Federal Aviation Administration (FAA), Transport Canada Civil Aviation (TCCA), and the European Union Aviation Safety Agency (EASA). The initial Maz-Viz 1400 installation using the newly approved STC was performed by Ontario-based EuroTec Canada Ltd., part of EuroTec Vertical Flight Solutions LLC, headquartered in Euroda, Kansas. The EVS will be displayed on the upgraded Garmin TXi avionics.

May 2021: Astronics announced availability for order of its latest cabin network platform, branded as "The Edge™ ". The Edge offers airlines, IFE suppliers, MRO's and system integrators a cost-effective platform for full-featured in-flight entertainment (IFE) with reduced time to market. The Edge takes advantage of a distributed network architecture that utilizes Smart WAPs. The solution combines an industry first Wi-Fi 6 wireless access point and server functionality as compute nodes that minimize installation wiring and provide a redundant and fault tolerant system. The Edge system is designed to be installed overnight.

April 2021: Astronics announced its next-generation circuit card diagnostic and test system, the PinPoint 3-PXIe (P3-PXIe). Combining more than 30 years of development of the PinPoint Circuit Card diagnostic system with industry-standard PXIe technology, the P3-PXIe identifies failures down to the component level and can test a variety of mixed-signal products with the flexibility of PXIe. Ideal for use on avionics equipment, radar, weapons systems, military or commercial aircraft, ships, and more, the P3-PXIe offers component-level troubleshooting with an intuitive graphical interface and comprehensive suite of tools, including the ability to generate gate level schematics for undocumented or legacy circuit cards. The integration of PXIe capability allows use for a wider range of applications and ability to functionally test from the edge connector, determining if a circuit card is Ready for Issue (RFI).

April 2021: Astronics announced that its wholly owned subsidiary, Astronics Test Systems ("ATS"), has approved Muirhead Avionics, a division of AMETEK® MRO, as an Approved Service Center for Astronics' CTS 6000 series of communication test solutions. ATS has provided Muirhead with the CTS 6025 CSAR test set to ensure accurate and complete calibration services of the full range of communication test solutions in the CTS-6000 series. With this partnership, Astronics has expanded its support capabilities of its CTS-6000 series that provides complete radio frequency, analog and digital test capabilities into Europe and the Middle East.

March 2021: Astronics began shipping its new NG3 Avionics I/O Computers to the United States Coast Guard (USCG) in support of the Minotaur program. The NG3 is part of the NG Family, a new generation of secure Ballard Boxes for avionics interfacing and computing. These flexible COTS (Commercial-Off-The-Shelf) avionics computers feature low-power Intel 64-bit, quad-core E3950 processors and are densely packed with a variety of avionics and computer I/O. The Coast Guard is outfitting its fixed wing surveillance aircraft with Minotaur mission system architecture. Minotaur incorporates sensors; radar; and command, control, communications, computers, cyber, intelligence, surveillance and reconnaissance equipment and enables aircrews to gather and process surveillance information that can be transmitted to other platforms and units during flight.

February 2021: Astronics was awarded contracts by The Boeing Company to supply CorePower® aircraft power distribution units and custom-engineered exterior lighting for the MQ-25 unmanned aerial refueling program. The CorePower system replaces pilot-operated, thermal mechanical breaker systems with intelligently controlled, solid-state switches to provide safe, reliable performance remotely. The system planned for the MQ-25 incorporates the use of Astronics' latest generation ECBU products to create an evenly distributed system at a fraction of the wire weight and increased reliability compared with traditional systems. The MQ-25 is the U.S. Navy's first operational carrier-based unmanned aircraft and is designed to provide a much-needed refuelling capability. The contract supports Boeing's engineering and manufacturing development program.

February 2021: Astronics was awarded an order of approximately $11 million from Collins Aerospace for business jet connectivity equipment. The order is a follow on to previous orders for inflight connectivity (IFC) hardware that Astronics has been providing to Collins. Astronics' equipment supports the growing interest in the business jet connectivity services offered by Collins Aerospace. Having received many strong customer reviews, Collins' system provides unparalleled high-speed world-wide connectivity that enables a broad variety of remote conferencing services as well as streaming entertainment.

Counterpoint comment

Astronics experienced a substantial decline in operating margin following the pandemic's impact. However, over the past year, the company has demonstrated a recovery, achieving a positive operating margin. Despite this improvement, there has yet to be a notable acquisition of significant contracts that would provide sustained growth in sales. It is very much a niche player in avionics but it does have growth products in EVS, data and avionics I/O devices.

19.1.3 BOEING JEPPESEN

Since 1934 when Captain E.B. Jeppesen began selling the world's first aviation navigation charts, the company that bears his name has evolved over 80 years.

In 2000 Boeing acquired the flight information service provider Jeppesen from Tribune Co. for $1.5 billion in cash. Jeppesen provides aviation maps and navigational data, pilot training, computerised flight planning, aviation software, aviation weather services and maintenance information to both airlines and flyers.

At the time of acquisition, Jeppesen generated $235 million in revenues with 1,400 employees. Located in Denver, at offices in other U.S. locations, and in Germany, Australia, China, the United Kingdom. Jeppesen claims an 80 percent market share in aircraft navigational products, which amounts to nearly three-quarters of the company's business. The company also has a 25 percent market share in operations services, such as weather and maintenance information, an 80 percent share in pilot training services and a 30 percent share in trip planning.

Financials

There have been several new entrants to the navigation data service market since 2000, however, the addressable market has also grown significantly.

We believe therefore that Jeppesen is still the market leader for navigation data services and generated $380m of revenues in 2023.

Locations

- North & Central America
  - Englewood (Denver), CO, USA Corporate World Headquarters
  - San Jose, CA, USA
  - Wilsonville, OR, USA
  - Montreal, Canada
- Asia Pacific
  - Beijing, China
  - Hyderabad, India
  - Singapore
- Europe
  - Crawley, United Kingdom
  - Gdansk, Poland
  - Goteborg, Sweden
  - Neu Isenburg, Germany
- Middle East & Africa
  - Dubai, United Arab Emirates

Capabilities

Jeppesen's services cover commercial, business jets, general aviation and government and military sectors.

They offer a range of product services comprising databases, training and simulation needs including the following:

- Airspace Solutions
- Crew Solutions
- Data Management Solutions
- Flight Efficiency and Sustainability
- Flight Planning and Dispatch
- Navigation Solutions
- Network and Operations Management
- Training and Pilot Supplies

Each of these solutions is underpinned by a generic process that Jeppesen describe as Plan, Dispatch, Fly, Analyse and Control as an end-to-end process that provides feedback in a closed loop learning fashion.

Jeppesen claim to have more than 18,600 global airports in their records:

- 246 providers in 195 countries (in 24 languages and many different formats)
- Error-checking every chart with up to 16 data-verifying calculations
- Leading to 47,000 data changes per AIRAC cycle
- 2.6 million Jeppesen Aviation Data records to offer the market

Jeppesen offers the market a myriad of menu driven options via subscription services that includes terrain databases, airport layouts, route planning, flight simulation and training, fuel saving procedures, live weather data updates, play-back for learning, en-route navigation changes.

Customer and contracts

We believe that Jeppesen has 1,000's of customers within bizjet, GA, rotorcraft, commercial and military sectors.

They also work closely with avionics providers. This includes Honeywell and they support the Honeywell Forge service support offering. They also work with Collins Aerospace, Garmin, Avidyne and other avionics providers to provide navigation database and other services.

They offer single operators of smaller GA/bizjet aircraft a range of subscription services for navigation devices.

These annual subscription charges vary from $400 for coverage in the US and Canada to $1,500 for a global set of data depending on menu options and the avionic equipment (e.g. Garmin, Avidyne, Universal Avionics etc).

Strategy

The cost of Navigation data has been steadily falling in recent years as more players enter the market. Jeppesen has increased its service offering beyond its traditional area of navigation we believe in part to maintain revenue growth. Through the acquision of ForeFlight, Jeppesen has a more direct line to general and business aviation use through the popular ForeFlight applications and integrations with cockpit avionics.

Recent developments

November 2022: Boeing Jeppesen experienced a cyber incident that affected certain products and services. The company stated that they initiated an incident response process and worked to reactivate affected products and services.

July 2022: Air France has selected Boeing's Jeppesen Crew Rostering solution to optimize crew schedules for the nearly 13,000 cabin crew at the airline, as part of a five-year contract signed at the Farnborough Airshow. Jeppesen Crew Rostering leverages an industry-leading optimization engine to construct productive and balanced crew rosters by

considering complex factors such as legal requirements, training, crew availability, crew preferences, reserves and other critical factors. The powerful optimizers allow for faster roster construction, closer to the day of operation, which support greater operational stability and opportunities to capture additional revenue.

May 2022: Boeing's Jeppesen Operator/OpsMan product line has been acquired by Aviation services group Gozen. The agreement adds to the Turkish company's comprehensive aircraft operations management tool developed specifically around the needs of business aviation. The deal, the terms of which were not disclosed, is an unusual instance of Boeing selling software to a third party. It also marks a significant step for the new digital aviation unit of parent company Gozen, which also includes the Gozen Air Services flight support division.

March 2022: Boeing has been selected to provide Etihad Airways with the Jeppesen FliteDeck Advisor digital solution for the carrier's 787 Dreamliner fleet to optimize operational efficiency and reduce fuel consumption. Etihad has already found benefits from the use of FliteDeck Advisor. During a trial on several of its 787 Dreamliners, the airline found that the digital solution delivered cruise fuel savings of 1.4%, saving an average of 350 kilograms of fuel and 1,100 kilograms of CO2 per flight. Since 2019, Boeing and Etihad have collaborated on sustainability efforts centered on the airline's 787 Dreamliner fleet, including on Etihad's participation in Boeing's ecoDemonstrator program, where the FliteDeck Advisor solution was initially trialed. In 2021, the two companies renewed and expanded their sustainability alliance to focus on enhancing the efficiency of navigation and flight operations, airframe technologies and sustainable practices to reduce emissions.

Counterpoint comment

Jeppesen is a recognized market leader in the navigation database sector, offering an extensive portfolio of services and benefiting from the strategic backing of Boeing. The company maintains key partnerships with industry leaders such as Boeing Global Services, Honeywell, Collins, and Garmin, positioning it well for continued success. However, it is noteworthy that Jeppesen has not secured any new contracts over the past two and a half years.

19.1.4 CCX TECHNOLOGIES

Established in 2017, CCX develops a wide range of cybersecurity and testing solutions for the aviation, and military and government markets. CCX has developed cybersecurity software and hardware platforms that help avionics manufacturers defend and protect an aircraft's onboard network.

Financials

We estimate that CCX generated $4m of avionics related revenues in 2023.

Locations

The company's head office is located in Ottawa, Canada. They also have two facilities in the USA: an office in Lewes, Delaware, USA, and a support facility in Bedminster, New Jersey.

Capabilities

CCX claim to have a unique approach with their cybersecurity solutions in that they operate over connections that are often bandwidth restricted and are installed right onboard the vehicle.

Their main solutions comprise:

- SystemX Aviation (cyber defence and security software platform protecting onboard aircraft networks)
- SystemX Avionics Intrusion Detection System
- SystemX Secure Voice (fully encrypted VoIP system)
- Flight Data Monitoring and Operations Quality Assurance
- Secure Data Feed for Electronic Flight Bag (EFB) Software
- Modern, Secure Cabin Networking

CCX offers its SystemX™ Cybersecurity Software Platform as an innovative system for monitoring onboard vehicular networks. It is available as SystemX™ Military & Government and SystemX™ Aviation. It's AP-250 Inline Cybersecurity Appliance, and AP-250 Inline Cybersecurity Development Kit are also intended for the onboard networks of aviation, and military and government vehicles.

The AP-150 Secure Networking Appliance (AP-150) is a flexible secure component used for a variety of onboard networking applications. It can be configured as a WAP, Server or Router, and customised to fit required applications. Powered by a SystemX™ Cybersecurity Software Platform, the AP-150 offers advanced data monitoring and firewall, plus IDS and IPS (Intrusion Detection and Prevention Systems) and secure boot.

It can be utilised on rotorcraft platforms in addition to fixed wing aircraft.

Customer and contracts

CCX does not identify its customers, some of whom may be classified, however, the products are targeted for communications networks in rotorcraft and military transport aircraft largely within the North American arena we believe.

Strategy

Developer of cybersecurity software and test devices for radio communications within sir, land and sea defence applications. They are expanding into the US market via their new facility in New Jersey, USA

Recent developments

April 2023: CCX Technologies unveiled its T-RX GPS at the AEA International Convention & Trade Show's New Product Introduction. The latest in the company's T-RX product line, this standalone GPS tester comes already calibrated for future upgrades offering maintainers flexibility while saving time. The T-RX GPS is designed with an intuitive interface to reduce the time between set-up and testing. It is smaller and lighter than competitive products and, like its companion testers, features a large colour touch screen. The T-RX GPS offers testing on all active SBAS systems including WAAS, EGNOS, GAGAN, and MSAS. It features integrated Wi-Fi and Ethernet, which permits in-the-field software upgrades, feature updates and painless test report generation. Users can add tests as needed and even upgrade to full T-RX RP+ tester capabilities if desired.

February 2022: The CCX Technologies T-RX Avionics Radio Tester has been approved for sale in Europe, having met European regulatory requirements and granted CE certification. A portable, touchscreen tablet device, the T-RX Tester can be used to test a variety of aircraft radios, from VOR/LOC/glideslope to VHF com radios (including 8.33-kHz spacing), marker beacon receivers, HF com, Selcal, 406 MHz ELT, TCAS, transponders, both bands of ADS-B Out and In, and Arinc 429 RX. More than 100 tests are available, eliminating the need to use a variety of testing devices. CCX also updates the T-RX's testing capabilities as requirements change via software, either over the air or on the web.

Counterpoint comment

CCX is a small software and digital solution provider focused on radio comms cybersecurity protection which can be embedded in land, sea or air equipment. They have yet to establish a solid track record of deliveries within the avionics world.

19.1.5 COLLINS AEROSPACE

Founded as a radio company in Cedar Rapids, Iowa, in 1933, Rockwell Collins left its mark on history, from establishing communications with Rear Admiral Richard Byrd at the South Pole to helping forge today's global positioning system. The company has become a leader in aviation and high integrity solutions, built on a legacy of quality, trust and customer service.

United Technologies Aerospace Systems (UTAS) was formed when UTC acquired Goodrich Corporation and merged the aerospace activities with Hamilton Sundstrand in 2012.

Rockwell Collins was acquired by UTC in 2019 and, when combined with UT Aerospace systems (UTAS), the combined entity became Collins Aerospace. Subsequently United Technologies formed a merger with Raytheon to create an

aerospace business that now includes Collins Aerospace, Pratt & Whitney and Raytheon Intelligence and Space and Raytheon Missiles and Defense.

Raytheon today services 12 capability areas including avionics which is covered within this section of the report in respect to Collins Aerospace.

We cover the Raytheon Intelligence and Space division under a separate section.

Financials

FYE 31/12/23	2023	2022	2021	2020	2019
Sales $m	26,253	23,052	21,152	19,288	26,028
Operating income $m	3,825	2,816	2,380	1,466	4,100
Return on sales %	14.6%	12.2%	11.2%	7.6%	15.8%

In overall terms, Collins continued its upward trajectory over the past few years. Sales increased by 14% on the previous year, while operating income improved by over one third (36%).

Comparing the latest results with FY 2022 the company commented: "The organic sales increase of $3.2 billion in 2023 compared to 2022 primarily relates to higher commercial aerospace aftermarket sales of $2.1 billion, including increases across all aftermarket sales channels. These increases were principally driven by the continued recovery of commercial air traffic which has resulted in an increase in flight hours. Commercial aerospace OEM sales increased $1.1 billion due to increased production rates in narrow-body, wide-body, and business jets. Military sales were relatively consistent in 2023 compared to 2022.

The increase in Other net sales of $0.1 billion in 2023 compared to 2022 was primarily due to net favorable customer settlements in 2023, including a $112 million favorable customer settlement recorded in the fourth quarter of 2023, partially offset by a $57 million charge related to a customer litigation matter recorded in the third quarter 2023.

The organic operating profit increase of $0.9 billion in 2023 compared to 2022 was primarily due to higher commercial aftermarket volume and favorable mix, partially offset by lower commercial aerospace OEM as drop through on volume was more than offset by higher production costs. This increase in commercial aerospace operating profit was partially offset by $0.2 billion of higher selling, general and administrative expenses and research and developments costs primarily due to increased employee-related costs. Military operating profit decreased $0.1 billion primarily due to unfavorable mix and higher production costs.

The increase in Other operating profit of $0.2 billion in 2023 compared to 2022 was primarily due to the absence of $141 million of pretax charges related to global sanctions and export controls with respect to Russia recorded in 2022, the absence of $69 million of charges associated with the disposition of two non-core businesses in 2022, and the net favorable customer settlements discussed above. The above items were partially offset by $62 million of divestiture costs related to the pending sale of our actuation and flight control business."

In arriving at our estimate for Collins Aerospace's total avionic sales in 2019 of $5,097m we have added in avionic service sales from the IMS division and the contribution from UTAS (largely Air Data systems relating to Navigation) and deleted revenues associated with the non-airborne defence sector.

Total estimated revenues for Collins Aerospace's avionics business in 2023 was $4,100m.

Locations

Collins Aerospace has circa 5,000,000 ftš of avionic related facilities within the US and around 1,000,000 ftš split between EU, Middle East and Asia.

A significant proportion of the design manufacture and test of avionics takes place in their Cedar Rapids, Iowa facility which extends to 2,900,000 ftš.

Collins Aerospace also has facilities located in the Philippines (770,000 square feet), Winston-Salem, North Carolina (660,000 square feet), Melbourne, Florida (400,000 square feet), Annapolis, Maryland (370,000 square feet), Richardson, Texas (280,000 square feet), Everett, Washington (240,000 square feet), Heidelberg, Germany (240,000 square

feet), Nogales, Mexico (230,000 square feet), Irvine, California (210,000 square feet) and Coralville, Iowa (200,000 square feet).

Further, it also has a global network of approved support centres that provide technical advice, spares, repairs, overhaul, exchange units/loaners and stockists who support a range of components.

Capabilities

Collins summarises its avionics capabilities as follows:

- (Airborne) Displays & Controls: Control Display Units (CDU); Head Down Displays (HDD); Head-Up Guidance System / Enhanced Vision System (HGS™ /EVS); Helmet Mounted Displays (HMD)
- Autopilot: APS-85 Autopilot System; FCS-7000 Flight Control System; Piccolo™ Flight Management Systems
- Avionics Integration: installation/A-Kits; aircraft wire harnesses; electromechanical assemblies; avionics support packages; equipment trays; RF/specialty cables and connectors
- Computing & Networks: Data Transfer & Storage; Mission Computers; Multi-core Processing Systems; Aircraft Networks
- Integrated Cockpit Solutions: C-130 AMP Inc. 2; Common Avionics Architecture System; Flight2™ Integrated Avionics System; HeliSure™ Flight Situational Awareness Solutions
- Mosarc™ Solutions for Open Systems Architecture: Computing; Networking; Software; Displays
- Weather Radar: RTA-4100 Hazard Detection System
- Software Applications: Avoidance Re-router (ARR-7000); Mission Flight Management Software (MFMS-1000)
- Surveillance: Integrated TCAS Solutions; Mode S Transponders; Traffic Collision Avoidance Systems

Collins has the following Joint Ventures which have been in place for a significant number of years:

- AVIC Leihua Rockwell Collins Avionics Company, a joint venture with China Leihua Electronic Technology Research Institute, a subsidiary of the Aviation Industry Corporation of China (AVIC), which provides integrated surveillance system products for the C919 aircraft in China
- Rockwell Collins CETC Avionics Co., Ltd. a joint venture with CETC Avionics Co., Ltd. to develop, produce and maintain communication and navigation products on Chinese commercial OEM platforms
- Data Link Solutions LLC (DLS): DLS is a joint venture with BAE Systems, plc for the joint pursuit of the worldwide military data link market
- ESA Vision Systems LLC (ESA): ESA is a joint venture with Elbit Systems, Ltd. for the joint pursuit of helmet-mounted cueing systems for the worldwide military fixed wing aircraft market.

ADS-B Autonomous flight: a range of solutions certified from the Textron King Air through to the Boeing 787. A key product is their Multi Mode Receiver (MMR) for which Collins is a market leader. Many of these solutions have been designed to be retrofitted to existing in service aircraft.

Avionic installation and integration: it has a list comprising 100s of STC product solutions that fit most aircraft in active service today. Collins will undertake the necessary work to upgrade aircraft with the product, installation and certification required.

Communications: Collins provides a range of solutions including Data link services, SATCOM, voice and data and commercial aviation services. It provides Controller-Pilot Data Link Communications (CPDLC) and Automatic Dependent Surveillance-Contract (ADS-C) capabilities enhancing oceanic and remote flight operations and support compliance to airspace regulations and mandates. Collins Aerospace VHF, HF and SATCOM radios use the latest in software-defined radio technology. It provides global voice and data communications that enable customers to maximise flight and airline operations efficiency. It provides Communication Management Units such as the CMU-900 which is the newest ARINC 758 compatible Communications Management Unit and is designed to satisfy Data Link Communication needs into the future.

Head Up Displays (HUDs): HUDs offer benefits in day or night, allowing pilots to fly consistent approaches no matter what the conditions. With less go-arounds, diversions and cancellations because of low-visibility many of the world's airlines, business and regional operators, military tankers and transports, and NASA have acquired Collins Aerospace HUDs and Head-up Guidance Systems (HGS).

Flight Display solutions; Collins offers a wide range of display size and formats for integration within modern cockpits. Their AFD-2100 solution has the following features;

- 15.1 inches of useable display area
- Advanced Super View (ASV) technology, providing superb colour fidelity over a wide field of view
- Remote Light Sensor providing a consistent presentation by adjusting to ambient light changes
- True split screen capability
- Adaptable to evolving cockpit technology/applications such as:
  - Moving Map
  - Real time weather
  - Electronic Flight Bag applications
  - Synthetic and Enhanced Vision
  - CDTI applications

Navigation: offers a range of capabilities including GPS based guidance, landing systems and multi-mode receivers. Its Global Positioning System Landing System receiver, the GLU-925 offers Category I GLS, Category III ILS and Performance-Based Navigation RNAV/RNP operations. The system is standard equipment on the Airbus A350 and A380 and Boeing 747-8 as well as being certified for other Airbus and Boeing platforms. The Multi-Mode Receiver GLU-2100 is a fully digital, MMR with integrated instrument landing system (ILS), global positioning system (GPS), GPS landing system (GLS) and VHF omni-directional receiver (VOR). It also offers a full range of VOR, DME and ADF navigation products.

Surveillance: offers a range of products including transponders and weather radar, in order to provide traffic alerts, collision avoidance and weather conditions. The ISS-2100 configurable integrated surveillance system simplifies surveillance by joining several features — such as weather detection, traffic alert and collision avoidance, Mode S surveillance and terrain awareness and warning functions — into a single system.

Air Data Systems: offers a range of Air Data products that support navigation and standby instruments. These include pitot probes, pitot-static probes, multi-function probes with flow angle measurement, various flight test products and SmartProbe® air data systems.

Enhanced Vision Systems: EVS-3600 cuts through low-visibility conditions like smoke, smog, fog and darkness by displaying high-clarity visual references on HUDs, allowing pilots to see what's out there. This spectral coverage during critical phases of flight gives aircraft the ability to go more places more safely. The EVS uses short-wave infrared, long-wave infrared and a visible camera for the earliest possible detection of visual references.

Pro Line 21 and Pro line Fusion: (see section 9 for Pro-Line description) both are options for OE forward fit and available as retrofit packages. However, Pro Line Fusion aims to deliver the latest functionality in terms of surveillance and airspace modernisation.

The Pro Line 21 system is designed to be intuitive, so pilots quickly understand and act on the ever-changing mountain of data they are presented with. All flight data, including navigation, engine performance, and sensor readings are displayed on large, flat-panel LCD's. The Primary Flight Displays (PFD) complement the Multi-Functional Display (MFD). Real-time weather and terrain data ahead of the planned flight route can be accessed via the Broadcast Graphical Weather system. The Collins FMS-3000 is an integral part of the system, which provides cutting-edge flight planning, flight management, and multi-sensor navigation capabilities. Electronic charts are a feature: pilots can access airport approach plates, electronic checklists, and digital airport maps which display the real-time position of the jet. Another feature of the Pro Line 21 suite is the heads-up navigation Guidance System display. It that is designed to increase safety and precision in approaches, particularly during poor weather.

Collins Aerospace states that upgrading to Pro Line fusion offers the following benefits:

- ADS-B Out V2
- FANS 1/A
- RNP AR
- Graphical weather
- European ATN
- Multiscan weather

All of the above capabilities apply to both civil and military applications. Collins also has capabilities that are specific to the military sector as follows.

Reconnaissance pods: offers a SEEK EAGLE certified pod for F-16 and other fast-jet applications. With an integrated DB-110 sensor, this pod offers advantages over competing systems by relying on dual-environmental conditioning systems, to provide robust ground cooling and operations over a wide range of altitudes. Full-size fore and aft data-link antennae enable maximum data-link range throughout a full 360ř azimuth.

Mission computing: MC-4000 flight mission computers provide a combination of high-integrity, general purpose, multi-core processing resources, scalable I/O capabilities and high-integrity graphics generation. They also supply powerful, real-time video processing functionality based on a digital signal processing module.

Customer and contracts

Collins Pro Line 21 avionics have been fitted to various Cessna, Raytheon, Bombardier, Gulfstream, and Dassault platforms. The Pro Line 21 system is currently used in the CJ1+, CJ2+, CJ3, CJ4, Encore+, XLS+, the Premier 1A, both the Challenger 350/3500 and Challenger 605, LearJet60XR, Gulfstream 150, Piaggio Avanti II, King Air B200 and 350, and Hawker 800XP, 850XP, 750, and 900XP. Dassault Collins dealers have retrofitted the line to the Falcon 20 and Falcon 50. Additional retrofits have taken place in the Challenger 601, Citation 550, Hawker 700 and 800, and the King Air 90, 200, 300 and 350.

Other applications include:

- A220: Pro Line fusion avionics, Head Up display (option).
- A320; Radio Comms HFS-900 VHF system, SAT-2100 high speed data satellite comms, GLU 929 Multi-Mode Receiver, ADF, DME, VOR radio, Weather mapping radar WXR-2100.
- A330: VHF-900B VHF transceiver, TPR-901 transponder, SAT-609 SATCOM, WXR-2100 weather radar, Moving maps, Radio Altimeters, Multi-Mode Receiver GLU-920, ADF, DME, VOR equipment.
- A350: Avionics full duplex switched Ethernet, avionic communication management system, Information on-board management system, ADF, DME, VOR equipment
- A380: Radio comms equipment, VHF-920 digital radio, HFS-900 HF radio, inflight information system, avionics comms management system, ADFX Ethernet switch, ADF, DME, VOR navaids, Multi-Mode Receiver.
- A400M: Radio comms/management system, SATCOM, Full duplex Ethernet switch, DME,
- Airbus CN295: Radio comms equipment, Pro Line fusion avionic suite.
- Boeing 737: Airborne Comms System, ICS-300 SATCOM (737MAX), Enhanced Vision Systems, Head up Guidance system, Radio Altimeters, MMRs, DME, ADF, VOR, TCAS.
- Boeing 747: Radio comms equipment, VHF-920 transceiver, SATCOM, Mode S transponder, Flight recorders, Autopilot, Data management unit, Weather mapping radar, WXR-2100 multiscan hazard detection, MMRs, ADF, DME.
- Boeing 767: FMS, Display systems (KC-46), EVS, Air Data Computers, HUD, MMRs, DME, ADF, VOR, Surveillance Air defence radar (KC-46), Tactical situation awareness (KC-46), CCIS systems, Link 16 and SATCOM (KC-46).
- Boeing 777: Avionics gateway secure server, Weather mapping radar, Multiscan threat weather tracking, Primary LCD display suite, EFIS, TCAS, mode S transponder, Head up displays, MMRs, DME, VOR, ADF navaids.

- Boeing 787: Radio comms management, core and common data network, flight deck display system and crew alert system, head up display system, integrated surveillance system, voice and data recorders.
- Comac ARJ21: Pro Line 21 avionic suite, weather radar, AHRS.
- Comac C919: Weather mapping radar, Integrated surveillance system, TCAS, Mode S transponder, terrain warning system.
- F-15: Radio comms equipment, Tacan, HIS indicator, Helmet mounted displays, LCD display suite, ILS systems, Airborne GPS system, ADF, ILS receiver.
- F-18: Radio comms equipment, Helmet mounted displays.
- Embraer C-390: Radio comms equipment, HF-9000 HF radios, Pro Line fusion avionics suite, ADF.
- Leonardo helicopters: EVS, TAWS (most models)
- Airbus helicopters: Radio comms equipment, Mode S transponder, VOR, DME, ADF (most models)
- F-35 lightning: Helmet mounted displays,
- C-130J: Head up displays

Strategy

Collins Aerospace has continued to build out its avionics capabilities and is adding significant digital, software and service offerings in support of its installed fleet. It is a market leader within Communications, MMRs, and Integrated avionics (Pro Line Fusion). It is not yet a 'cockpit integrator' within large air transport in the same way that Honeywell, Thales and to some degree GE Aviation have become. However, under Raytheon's ownership this could change.

Recent developments

May 2024: Cessna Citation CJ1+/2+ aircraft registered in Europe can now be upgraded with the advanced functionality of the Collins Aerospace Pro Line Fusion® integrated avionics system after receiving certification approval from the European Aviation Safety Agency (EASA). Fusion's modularity and intuitive technology integration improves pilot workload, providing real-time data, visual clarity and predictability that simplifies operations during the most critical stages of flight.

May 2024: Collins Aerospace was awarded a multi-billion-dollar subcontract as part of a team led by SNC to design, develop and deliver systems and products for a new aircraft under the U.S. Air Force's Survivable Airborne Operations Center (SAOC) program. The SAOC program delivers next-generation of the E-4B National Airborne Operations Center, providing top military leaders with a survivable aircraft to ensure performance of the National Military Command System. Collins Aerospace is on contract to deliver multiple products from across the business.

February 2024: Collins Elbit Vision Systems (CEVS) a joint venture between Collins Aerospace, and Elbit Systems of America (Elbit America) announced that it has delivered the 3,000th F-35 Gen III Helmet Mounted Display Systems (HMDS) to the Joint Strike Fighter. The F-35 Gen III HMDS is the world's most advanced helmet-mounted display system. Its next-generation user interface serves as a pilot's primary display system, providing them with intuitive access to vital flight, tactical and sensor information day or night. With the 3,000th delivery, CEVS has provided over 20,000 systems to warfighters and have logged more than 1 million flight hours on 40 different fighter aircraft platforms.

February 2024: Collins Aerospace has been selected by Air India for a full suite of avionics hardware catering to the airline's expanding Boeing 737 MAX fleet. The comprehensive package includes communication, navigation, surveillance equipment and air data sensors, designed to enhance safety, fuel efficiency and operational performance of Air India's fleet. Collins' suite of advanced avionics will work in harmony to improve operations through every phase of flight on Air India's MAX aircraft. Multi-mode receivers enable precision satellite and ground-based navigation, facilitating high position accuracy, improved integrity and future upgrades through a simple software update. Collins' radio altimeters provide accurate digital height measurements during crucial approach, landing and climb-out phases, while actively filtering and mitigating any potential 5G cellular interference. Air India will also receive Collins' MultiScan ThreatTrack™ weather radar, which predicts adverse weather conditions and actively displays and analyzes cells providing real-time route adjustments, reducing long deviations and delays, and ensuring passengers enjoy a smoother journey.

February 2024: Collins Aerospace now includes the Flight Profile Optimization (FPO) solution within its FlightHub offering. The solution improves access and availability of data by rapidly reviewing the changing environment and suggesting opportunities for more efficient route planning. FPO delivers real-time route recommendations to pilots throughout the flight, offering optimized alternative routes toward their destination, which could improve fuel efficiency and reduce CO2 emissions. FlightHub launched last year and can be integrated into current airline systems and third-party applications or used as a stand-alone system.

February 2024: Malaysia Airlines Berhad (MAB) have signed an avionics hardware and support agreement for its fleet of 737-8 aircraft with Collins Aerospace. Critical communications, navigation, surveillance systems and air data sensors will be provided and serviced by Collins' Dispatchsm solution a comprehensive service plan covering maintenance, assets and logistical support. MAB will have access to original equipment manufacturer-certified spares, repairs and service, while ensuring parts availability and expedited turnaround times at predictable costs.

September 2023: Collins Aerospace had been selected by BAE Systems as the provider for Large Area Display technology to be integrated into the cockpits of future Eurofighter Typhoon aircraft. The ultra-high-definition Large Area Display (LAD) will be used by BAE Systems as part of its rapid capability development programme, Project Medulla, which sees it investing in future technologies for use across its combat air portfolio, including Eurofighter Typhoon. The LAD will serve as a pivotal tool for pilots, consolidating critical flight data, sensor inputs and tactical information into a single, easily accessible interface. Through real-time data feeds from radar, targeting systems, and threat detection, pilots will maintain an up-to-the-second view of the battlefield, enabling swift and precise decision-making during high-stakes engagements.

November 2022: Collins Aerospace and PT Dirgantara Indonesia (PTDI) today announced an agreement to modernize the Indonesian Air Force C-130 military transport aircraft as part of its Phase 2 rollout plan, and eleven C-130 aircraft will be upgraded. Serving as a contractor to PTDI, Collins will provide its Flight2™ aftermarket avionics solution, which delivers the most cost-effective and lowest-risk CNS/A™ upgrade solution. Flight2 transforms a federated analog system into a modern digital glass cockpit. With its advanced displays and integrated military/civil flight management system, Flight2 delivers the most advanced capabilities available today, including required navigation performance, area navigation flight management system with high altitude release point, and computed air release point precision airdrop software. At the same time, it's the most cost-effective and lowest-risk CNS/A™ upgrade solution.

May 2022: Collins Aerospace is beginning installation of its new Enhanced Flight Vision System (EFVS) for Boeing 737 aircraft. Texel Air, operating out of Bahrain International Airport, will be among the first operators to receive the new system that includes Collins' EVS-3600, a multi-spectral imaging sensor to "see through" poor visibility and darkness better than the human eye. Historically used by military and business aircraft, the newly certified system will allow widespread adoption of EFVS by airlines for the first time. The EVS-3600 uses multiple infrared and visible light cameras providing pilots with a head-up view that exceeds natural vision. When viewed on a head-up display, EFVS increases situational awareness and enables operations in low visibility conditions.

April 2022: Collins Aerospace and FlightAware, a Collins Aerospace business, are unlocking the power of data to help operators and ground crews optimize their time and resources. ARINCDirectSM datalink customers will now receive Foresight™ ETAs through uplink via their Flight Management System (FMS) along with a suite of other FlightAware features at no additional cost. Pilots on long and complex flights may experience en route delays that can cause an estimated time of arrival (ETA) that is different from the initial FMS data. FlightAware Foresight uses predictive models to provide the most updated ETA based on current factors such as airport congestion or weather conditions. The ability to provide crews with a more accurate ETA allows flight departments to improve efficiency, better manage ground logistics, and create a smoother experience for passengers.

Counterpoint comment

Collins Aerospace is a clear leader in avionics and a key provider of various airborne systems and equipment, has significantly enhanced its market position following its acquisition by Raytheon Technologies. This strategic acquisition has facilitated the company's expansion from primarily serving the civil aerospace sector to offering comprehensive solutions for military platforms. Over the past year, Collins Aerospace has demonstrated a robust recovery, with revenues surpassing pre-pandemic levels, driven by the growth of its aftermarket sales segment.

19.1.6 CURTISS-WRIGHT

Curtiss-Wright Corporation had sales of $2.8 billion in 2023. It is a diversified, supplier of engineered products through three segments: Aerospace & Industrial, Defense Electronics, and Naval & Power. They serve three main markets: Defense; Commercial Aerospace; Power & Process; and General Industrial.

Within the company, two key divisions exist relevant to this report:

- Sensors Division (within Aerospace & Industrial)
- Defense Solutions Division (avionics subsystems solutions)

Relevant products from Commercial/Industrial segment include sensor and data recording products contribute to flight operations that monitor and communicate vital data on conditions within and surrounding the aircraft. Curtiss-Wright is one of the leading manufacturers of 'black box' data recorders used on aircraft world-wide.

Relevant products from its Defense business segment include Avionics systems including air data systems, data acquisition, data concentrators, crash protected recorders, fire & ice detection and protection systems, flight testing and space data handling systems. These systems are supplied both to the commercial and defence aerospace markets.

Historical note: The Curtiss Aeroplane and Motor Company was the world's largest aircraft manufacturer in World War 1, producing 10,000 aircraft. The company acquired a public listing in 1916. Wright Aeronautical, which was set up to make aero-engines, was founded in 1919. The two companies merged in 1929. In WW2, it was the dominant producer of aero-engines (142,840 in total) and was also a producer of 29,269 aircraft (e.g. the P-40 War Hawk and Helldiver) but never succeeded in the post war years with a jet engine. In the 1960s, it started to diversify.

Financials

FYE 31/12/23	2023	2022	2021
Aerospace Defense $m	551.6	479.7	452.7
Commercial Aerospace $m	324.9	276.5	267.7

As stated in the company's 2023 Annual Report, Aerospace & Industrial sales are mostly generated from the commercial aerospace and general industrial markets and, to a lesser extent, the defense market.

"Sales increased $51 million, or 6%, to $887 million, from the comparable prior year period primarily due to higher sales in the commercial aerospace and general industrial markets. In the commercial aerospace market, sales increased $37 million primarily due to higher demand for sensors products and surface treatment services on various narrow-body and wide-body platforms. The general industrial market benefited from sales increases of $13 million primarily due to higher demand for industrial automation products as well as higher sales of surface treatment services."

Regarding the Defence Electronics division, "sales increased $126 million, or 18%, to $816 million, from the comparable prior year periodSales in the aerospace defense market increased $16 million primarily due to higher demand for embedded computing and flight test instrumentation equipment on various domestic and international programs. Sales increases of $12 million in the commercial aerospace market were primarily due to higher demand for avionics and flight test equipment on various domestic and 34 international platforms."

We estimate that sales of avionics products in 2023 were $200m.

Locations

The Curtiss-Wright Corporate Headquarters are located in Davidson, North Carolina.

Curtiss-Wright Defense Solutions has the following facilities:

United States

- Ashburn, Virginia (33,000 ft2 facility; processing solutions for intelligence, surveillance, and reconnaissance (ISR) applications)
- Dayton, Ohio (24,000 ft2 facility; Center of Excellence for Secure Data Storage & High-Speed Data Recorders)

- East Farmingdale, New York (50,000 ft2 facility; US military electronic systems and software)
- Monsey, New York and New London, Connecticut (Strategic Subsystems Engineering and Integration Partner; analysis, design and integration of COTS, RCOTS and MIL-SPEC subsystems)
- Newtown, Pennsylvania (Aerospace Instrumentation: Data Acquisition, Recording and Transmission Systems)
- Palmdale, California (Real-Time and Post-Test Data Display and Analysis Software)
- Portland, Oregon (45,450 ft2 facility; Rugged Communications, Computing, and Networking Systems)
- Santa Clarita, California (57,000 ft2 facility; Program/Engineering Capabilities)
- Tewksbury, Massachusetts (Tactical Data Link (TDL) Processing Solutions)

Canada

- Ottawa (100,000 ft2 floor space, of which 34,000 ft2 dedicated to production; Command, Control, Computers, Communications, and Cyber)

Europe

- Cardiff, United Kingdom
- Christchurch, United Kingdom (160,000 ft2 facility; Avionics Electronics - Design, Manufacturing and Environmental Stress Screening)
- Letchworth, United Kingdom (14,000 ft2 facility; Center of Excellence for Design and Development of Computing and Video-Management Systems)
- Dublin, Ireland (Avionics Electronics - Data Acquisition, Recording, and Transmission Systems)
- Neuhausen, Switzerland (High-Speed, High-Precision Motion Control Solutions)

Capabilities

Curtiss-Wright is one of the leading manufacturers of 'black box' data recorders used on aircraft world-wide.

On military aircraft, Curtiss-Wright technologies operate, monitor and control flight systems, weapons deployment, and data analysis for nearly every US fighter aircraft program, as well as unmanned aerial vehicles.

On military helicopters, Curtis Wright provides state-of-the-art electronics, including sensors and embedded computing products. In addition, its video management system maximises the effectiveness of airborne Intelligence, Surveillance and Reconnaissance missions by enabling multiple operators to view, control and record live video and mapping information in helicopters, such as the U.S. Army's new Lakota light utility helicopter fleet. It maintains a presence on several US helicopter platforms, including the Black Hawk, Apache, Seahawk and Chinook.

In terms of specific capabilities, it provides:

- COTS (Commercial Off-the-shelf) Boards
  - Bus & Protocol Analysers
  - Direct Attached Storage
  - Graphics & Video Cards
  - I/O & Communication Cards
  - Networking (Switching and Routing) Cards
  - Processor Cards (Single Board Computers, FPGA Processors and Digital Signal Processors)
  - Radar Acquisition & Processing Cards
- Electronic Systems
  - Air Data Systems
  - Cockpit Voice & Flight Data Recorders

  - Data Concentrators
  - Data Recorders (Crash Protected, Rackmount, Rugged, Video, Quick Access and Application Specific)
  - Data Storage (Network Attached Storage and Storage Area Network Systems)
  - Radar Processing & Recording Systems
  - Rugged Switch/Router Systems and Physical Layer Switches
  - Rugged Mission Computers
  - Video Management and Display System
  - Program Specific Systems (Mission Management, Ammunition Handling, Flight Control, High Performance Embedded Computing, etc.)
- Aerospace Instrumentation
  - Antenna and Radio Frequency
  - Data Acquisition Systems
  - Ground Stations
  - High Speed Imaging & Video Systems
  - Network Switches for FTI
  - Quick Access Recorders
- Space Data Acquisition Systems
  - Data Acquisition Systems
  - Radiation Tolerant COTS Data Acquisition

Customers and contracts

Key programmes include:

- F-35 Lightning Joint Strike Fighter Program; Curtiss-Wright provides actuation equipment for the Ordnance Hoist System and Ordnance Quick Latch System as well as embedded computing and sensor electronics.
- Boeing P8-A Poseidon MMA; single board computer, data communication, sensors, and graphics and video products
- Global Hawk; flight control, sensors, mission operations and navigation are managed by Curtiss-Wright's Integrated mission and Sensor Management Systems.
- Triton (the U.S. Navy's version of the Global Hawk); Curtiss-Wright supplies the Advanced Mission Management System and the Integrated Mission Management Computer.
- Sikorsky CH-53K; data concentrator units for monitoring, processing data and controlling various subsystem components.

Strategy

From 2021 until 2023, the 'Pivot to Growth' initiative was a key part of its corporate strategy. The company states that it is "centered on a renewed drive for top line acceleration through both organic and inorganic sales growth, building on the strengths across our A&D and Commercial markets, deepening and expanding our customer relationships by driving One Curtiss-Wright to the customer, and maintaining our disciplined approach to acquisitions."

Curtiss-Wright has been strategically active in both commercial and military avionics.

In commercial aerospace in 2019, Curtiss-Wright and Honeywell announced a partnership to develop a new way for airlines to monitor and analyse flight data. The companies signed an agreement to develop the next generation of mandate-compliant voice and data recorders, using real-time connectivity. This means the aircraft data can be used

for more efficient operations, allowing for additional predictive maintenance and real-time playback of data and voice communications. Along with added connectivity, these next-generation recorders provide an easy upgrade that saves installation time and lowers costs due to being form-fit replacements for Honeywell's HFR-5 series Cockpit Voice and Flight Data Recorders (FDRs).

In defence aerospace, in September 2020, it announced the acquisition of Pacific Star Communications, Inc. (PacStar®), which is a leading provider of secure tactical communications solutions for battlefield network management, including commercial off-the-shelf (COTS)-based rugged, small form factor communications systems, as part of its strategy to position itself to benefit from the US military's investment in integrated battlefield network management.

Recent developments

July 2024: Curtiss-Wright introduced the V3-1222 DO-254 Design Assurance Level (DAL)-A safety-certifiable single-board computer for mission-critical avionics applications. The V3-1222 computer module integrates the 13th Gen Intel Core processor, offers the Intel Airworthiness Evidence Package, is housed on a rugged 3U VPX board. The single-board computer provides systems integrators with the board-level data artifacts necessary to establish a system-level avionics-certification process. The board is aligned to the Sensor Open Systems Architecture (SOSA), combines processing and graphics in one slot, and is for applications like flight control computers, mission control, and primary flight displays.

June 2024: Curtiss-Wright, in collaboration with Wind River, Ansys, and CoreAVI, is demonstrating a new digital cockpit flight display at the MOSA Industry & Government Summit & Expo. This display is built around the Curtiss-Wright 3U VPX V3-1708 DO-254 safety-certifiable NXP Layerscape LX2160A Arm processor board, which aligns with Future Airborne Capability Environment (FACE) standards. The hardware includes Curtiss-Wright's V3-717 3U VPX safety-certifiable AMD E8860 graphics board, employing CoreAVI graphics drivers to support a Multi-Touch Cockpit Display Application developed with Ansys SCADE software on the Wind River Helix Virtualization Platform. This platform is a multi-core, multi-tenant, DO-178C DAL A certifiable type 1 hypervisor-based solution.

October 2023: Curtiss-Wright and Ultra PCS are teaming up to build a new cockpit voice and data recorder that also includes health and usage monitoring of rotorcraft. The so-called "FortressHUMS," combines the typical capabilities of flight data recording with a health and usage monitoring system, or HUMS, packaged in an "easy-to-install and affordable single-box" that weighs just 13 pounds, where similar systems can weigh up to 70 pounds, Curtiss-Wright said. FortressHUMS can be retrofitted onto a helicopter optimizing the size, weight, and power investments that enhances ease of maintenance, safety, fleet management, and supply chain, the company said. Its serial communications network of sensors, connects with a single cable routed throughout the aircraft, speeding and simplifying installation. FortressHUMS can extend aircraft operational life and implement predictive maintenance programs, the company says. It can be deployed as a permanent-installed combined HUMS and recorder system for new aircraft construction, or as an upgrade for customers who install a Fortress Recorder.

October 2023: Curtiss-Wright has secured a $34-million contract to deliver data recorder technology for US and Australian manned and unmanned maritime aircraft. Under the contract, the company will supply and service its Keyed Broad Area Maritime Surveillance Airborne Recorder Network Attached Storage or K-BAR NAS. K-BAR NAS is an open architecture technology that collects flight data during test and monitoring operations. Once shipped, the recorder will be integrated into the MQ-4C Triton long-endurance drone and the PMA-290 maritime patrol and reconnaissance aircraft. The North Carolina-based company will also provide associated docking stations, chassis, removable storage modules, and laboratory cable sets.

October 2023: Curtiss-Wright has secured a five-year, $34 million firm-fixed-price indefinite delivery, indefinite quantity (IDIQ) contract with the Naval Surface Warfare Center (NSWC). The contract encompasses providing Modular Open Systems Approach (MOSA) based airborne data recorder technology. This technology is earmarked for deployment on both U.S. and Australian manned and unmanned maritime aircraft. A highlight of this agreement is the provision of Keyed Broad Area Maritime Surveillance Airborne Recorder (K-BAR) Network Attached Storage (NAS) solutions. This will include a comprehensive range of equipment such as chassis, docking stations, removable storage modules, and lab cable sets. Drawing from its stature as a premier supplier of MOSA-based encrypted, solid-state network-attached storage subsystems, Curtiss-Wright's commitment is clear: to deliver top-tier, commercial-off-the-shelf (COTS) open architecture K-BAR NAS equipment. Such equipment will bolster the capabilities of the MQ-4C Triton aircraft and the forthcoming PMA-290 aircraft models.

August 2023: Curtiss-Wright and Honeywell announced that their jointly developed Honeywell Connected Recorder-25

(HCR-25) cockpit voice recorder (CVR) and flight data recorder (FDR) variants have now been type-certified for Boeing 737, 767 and 777 production aircraft. As a result of the certification, any airline can now order the HCR-25 recorders directly from Boeing or Honeywell, and instruct Boeing to install the CVR or FDR on their aircraft. This is the first Curtiss-Wright product type-certified on 737, 767 and 777 aircraft. Based on Curtiss-Wright's compact, lightweight Fortress CVR technology and Honeywell's proven Honeywell Flight Recorder 5 (HFR5) design concept, the HCR-25 is compliant with the latest regulations and requirements to meet the mandate from the European Aviation Safety Agency (EASA) of minimum 25-hour cockpit voice recording for aircraft weighing over 27,000 kilograms. Numerous regions around the globe have issued related mandates in accordance with EASA, including Europe, Canada, Mexico and Singapore.

June 2023: Curtiss-Wright's Defense Solutions division today announced that it was selected by Airbus to provide a flight test instrumentation (FTI) system solution for use during flight tests of one of the Eurofighter Typhoon instrumented production aircraft (IPA). The Eurofighter Typhoon IPA aircraft are fitted with telemetry instruments to support dedicated flight testing and systems development. Under the contract, Curtiss-Wright will provide Airbus Defence and Space GmbH with data acquisition and encoding units (DAU) designed to capture critical test flight data, including the Axon and KAM-500 DAU product families and NSW-12GTH Ethernet switch.

June 2023: The US Air Force's Nellis AFB has awarded Curtiss-Wright a $24-million contract to provide Flight Test Instrumentation (FTI) equipment for the F-35 Technology Refresh 3 program. Technology Refresh 3 is an ongoing modernization effort for the service's hardware and software components on the F-35 Lightning II stealth multirole combat aircraft. The program aims to improve the fighter's memory, display, and computer processing capabilities and support future technology requirements. Work for the contract is being conducted at Curtiss-Wright's Teletronics Technology Corporation facility in Newtown, Pennsylvania.

February 2023: The US Air Force has awarded Curtiss-Wright a $287-million contract to deliver its High Speed Data Acquisition System. The system uses radio frequency links to collect, process, and transmit data from planes to aircrews. The platform also analyzes and displays information for users. The initial phase of the program is being funded with $123 million. Work will be conducted over five years, followed by an additional five-year option. Once delivered, the capability will support flight trials and related programs at the Edwards Air Force Base Air Force Test Center.

June 2021: Curtiss-Wright announced that it was awarded a contract by Lockheed Martin to provide its Modular Open System Approach (MOSA) computers and video processing modules to upgrade the Mission Computer and Flight Management Computer (MC/FMC) on the U.S. Navy's fleet of Sikorsky MH-60R/S Seahawk helicopters. The initial contract is valued at $24 million, with an estimated lifetime value of $70 million. Under the contract, Curtiss-Wright is providing Lockheed Martin with rugged single board computers and video processing modules. The modules result from Curtiss-Wright's Modified COTS program, which enables system integrators to upgrade individual modules in their legacy systems without having to replace the entire system, significantly speeding delivery of advanced technology to the warfighter. Shipments began in December 2020.

April 2021: Curtiss-Wright's Defense Solutions division announced that it was selected by Scientific Research Corp. (SRC) to provide a version of its Fortress flight recorder system to upgrade the T-6 Texan II trainer aircraft used by the U.S. Air Force and Navy. Under the contract, shipments began in the first quarter of 2021 and are scheduled to continue through the first half of 2023.

Counterpoint comment

Curtiss-Wright holds a strategic position within specialised niches of the avionics sector, delivering critical components in navigation and data product segment that are integral to larger system architectures. The company identifies avionics, particularly within the military domain, as a significant growth opportunity for its business. This is evidenced by a series of high-profile contracts secured in recent years, reinforcing its competitive standing in the market.

19.1.7 ENSCO, INC

Founded in 1969, ENSCO, Inc., and its wholly owned subsidiaries represent a $165 million international technology enterprise, headquartered in the Washington, D.C., area. For more than 50 years, the Ensco group of companies has been providing engineering, science and advanced technology solutions that guarantee mission success, safety and security to governments and private industries worldwide. Enco operates in the aerospace, avionics, national security, rail and cybersecurity sectors. Field offices and subsidiaries, representatives and partnerships are located throughout the United States and around the world.

In June 2022, it was announced that its national security, aerospace, avionics and cybersecurity divisions would all be merged into one business unit, the Mission Systems Group.

Financials

Ensco generated $165m in 2023 with over 750 employees.

We estimate the $23m was generated from avionics related revenues in 2023.

Locations

Ensco Inc. is headquartered in Springfield, Virginia, USA.

Ensco Avionics, a wholly owned subsidiary of Ensco Inc., is based in Endicott, NY, USA.

Ensco has US office facilities in El Segundo, CA, Colorado Springs, CO, Cocoa Beach, FL and Melbourne, FL.

Capabilities

The company possesses the following capabilities in respect to Aerospace:

- Systems Engineering & Integration
  - Launch Safety Satellite Control Systems
  - Simulation
  - Independent Verification & Validation (IV&V)
  - FAA Regulatory
  - Simulation Test & Recording System (STARS)
  - Commercial Launch Safety
  - Architex™ Enterprise Risk & Architectural Analysis Tool
- Avionics Engineering & Certification
  - Comprehensive Suite of Urban Air Mobility (UAM) Solutions
  - eVTOL Certification Services
  - Airworthiness Software Safety
  - Hardware/Firmware Engineering
  - Avionics Systems, Software, and Hardware Verification/Testing
  - Certification/Compliance Support and Consulting
  - Airworthiness Software Security
- Human Machine Interface
  - IData® Tool Suite HMI Toolkit
  - IDataMap 2D/3D Digital Mapping Toolkit
  - IGL® OpenGL® Software Graphics Renderer
- Weather
  - Weather Display Systems
  - AModeling
  - Research to Operations
  - MetWise® Weather Decision Support Tool

For more than 35 years, Ensco Avionics has developed sophisticated airborne systems for the aerospace industry to meet DO-178C/ED-12, DO-254/ED-80, DO-278A/ED-109, DO-326A, SEAL and military standards for manned and unmanned systems.

The focus of Ensco Avionics is on safety- and mission-critical software and programmable hardware engineering solutions, display application development, tailored synthetic vision applications, integration test solutions and the IData® Tool Suite.

The Ensco IData® Tool Suite is an innovative, advanced Human Machine Interface (HMI) software toolkit for creating and deploying embedded software display applications. IData offers advanced features with seamless integrations for 2D and 3D digital moving maps.

Customers and contracts

Ensco includes within its aerospace customers L3Harris, United Airlines, Alaska Aerospace Corporation.

Ensco Avionics' customers include Airbus, AVIC, BAE Systems, Boeing, Crane, Curtiss-Wright, Flight Safety, Gables Engineering Inc., GE Aerospace, Gulfstream, Honeywell, ITT, Lockheed Martin, L3Harris, Moog, Northrop Grumman, Pilatus Aircraft, Pratt & Whitney, Raytheon, Rolls-Royce, Thales, Triumph Engine Control Systems, Triumph Thermal Systems, and Unison.

The majority of its avionics related services were provided in respect to the following products;

- Avionics Displays
- Custom Software Development for Avionics Systems
- Custom Displays for Human-Machine Interfaces for Cockpit Displays (Manned/Unmanned), Battle Management, C4ISR, and Ops Centres
- Testing, Verification and Validation of Avionics Components and Subsystems
- Engineering Services
- Synthetic Vision

Strategy

The overall Ensco mission is as follows: "We partner with our customers to solve their most critical problems by delivering high performing teams and exceptionally reliable technology built to perform in demanding, mission critical environments. We provide our people exciting opportunities to advance their careers and to make the world a safer place." Their wider vision is "To transform the future safety, security, and resiliency of critical infrastructure and missions on the ground, in the air, in space, and in the information systems that connect these domains."

Creative thinking, innovation, and investment in high-technology research and development programs are the mainstay of our business.

Recent developments

July 2021: ENSCO Avionics announced that Picatinny Arsenal has chosen its IData® and IDataMap as their development tool for its Future Attack Reconnaissance Aircraft (FARA) program. The goal of the FARA program is to develop and field the next generation of tactical assault/utility aircraft as part of the Future Vertical Lift program. ENSCO Avionics IData Tool Suite accelerates the creation of mission- and safety-critical embedded display applications by providing a robust and flexible development framework to easily design, develop, prototype and deploy rich graphics for any target display application regardless of platform.

Counterpoint comment

Ensco maintains a robust portfolio of blue-chip clients within the avionics sector. The company's engineered and software services are highly specialised, and current market dynamics indicate that OEMs are not increasing the insourcing of bespoke software development. As a result, we anticipate that Ensco is well-positioned to sustain and potentially expand its growth within this specialised software market..

19.1.8 GARMIN

A global company that has traded for over 30 years and listed on the NYSE, Garmin operates in five industries: fitness, outdoor, aviation, marine and automotive OEM. It has a worldwide workforce of 19,900 associates in 86 offices in 34 countries around the world, and in 2023 recorded total revenues of $5.23 billion.

The Garmin aviation segment is a leading provider of solutions to aircraft manufacturers, existing aircraft owners and operators, as well as government/defence customers and serves a range of aircraft including business aviation, general aviation, experimental/light sport, helicopters, optionally piloted vehicles (OPV), unmanned aerial communication, flight control, hazard avoidance, weather radar, radar altimeter, datalink weather receivers and services, engine information systems, traffic collision avoidance systems, terrain awareness and warning systems (TAWS), controller-pilot data link (CPDLC), an expansive suite of automatic dependent surveillance broadcast (ADS-B) solutions, in-cockpit and cloud connectivity, wearables, portables, apps, training, simulation, flight planning/filing, premium trip services, aviation data services as well as other solutions that are known for innovation, reliability, and value.

Financials — Aviation segment

FYE 31/12/23 - USD millions	2023	2022	2021	2020	2019
Sales	846.3	792.8	712.5	622.8	735.5
Operating income	226.4	213.2	191.8	137.2	252.9
Return on sales	26.8%	26.9%	26.9%	22.0%	34.4%

Garmin's Aviation segment has continued to grow in revenue terms since 2021, since recovering from 2020's fall. With its latest results it has seen a revenue rise of 6.7%, which the company stated was "primarily due to growth in OEM product categories." In a similar pattern, operating income rose 6.2% over the previous year. In terms of the segment's contribution to overall net sales, this has remained steady at 16% (2023 and 2022).

These are quite remarkable financials that underpin the value of investing heavily in R&D in order to generate the highest levels of sector operating income.

Garmin does not report a split between OEM and aftermarket services or retrofit and upgrade usage. This we believe is because it does not have the means to track end-use given the number of stockists and distributors.

We do however believe that retrofit and upgrade revenues account for 50% of total avionics revenues.

The scope of our financial model does not include piston engine aircraft and some other services offered by Garmin. As a result, for the scope of this report, we estimate Garmin's avionics revenue to be $690m.

Locations

Garmin International, Inc. and Garmin USA, Inc. own and occupy facilities of approximately 1,990,000 ftš on approximately 107 acres in Olathe, Kansas, where the majority of product design and development work is conducted, the majority of aviation panel-mount products are manufactured, and products are warehoused, distributed, and supported for North, Central and South America.

Garmin International, Inc. leases 148,000 ftš of land at New Century Airport in Gardner, Kansas under a ground lease and occupies two aircraft hangars on this land, one of which is owned (47,000 ftš) and the other leased (53,000 ftš). Both properties serve as flight test and certification facilities that are used in development and certification of aviation products.

Capabilities

Garmin currently offers the following products, systems, and services to the global aviation market:

- Integrated Flight Decks
- Electronic Flight Displays and Instrumentation
- Navigation and Communication Products

- Automatic Flight Control Systems and Safety-Enhancing Technologies
- Audio Control Systems
- Engine Indication Systems
- Traffic Awareness and Avoidance Solutions
- ADS-B and Transponders
- Weather Information and Avoidance Solutions
- Datalink and Connectivity
- Services (e.g. web and mobile apps)

Integrated Flight Decks/Flight Displays: Garmin offers a range of integrated glass flight decks from the G1000® NXi for the general aviation and business aviation markets to the G5000® for business aviation, defence and commercial applications. Integrated capabilities include navigation, communication, flight instruments, weather, terrain, traffic, ADS-B, engine information on large high-resolution colour displays, and automatic flight control systems. Head-up display technology virtually mirrors the primary flight display instruments allowing for increased aircraft capability in adverse weather conditions. Additional features include: Garmin's 3-D synthetic vision technology (SVT™), weather, Garmin's electronic stability and protection system (ESP™), electronic flight charts, touchscreen and voice controls, CPDLC, audio and visual feedback, and animation to help pilots know exactly how the system is responding to their input.

The helicopter offerings have been optimised for rotorcraft and offer features like helicopter synthetic vision technology (HSVT™), helicopter terrain awareness and warning system with voice call outs, radar altimeter display, helicopter-specific databases that include additional heliports and low-altitude obstacles, WireAware™ wire-strike avoidance technology, as well as high resolution terrain, tailored ADS-B traffic alerting, and the ability to display video from a forward looking infrared (FLIR) camera or other video sources.

Garmin also offers all-glass integrated flight decks to the retrofit market through G950® NXi, G1000® NXi, G3000® and G5000® . Additionally, Garmin offers electronic flight display solutions that provide essential information such as aircraft altitude, attitude and heading while also displaying data from other avionics such as weather, traffic and much more. These solutions include G3X Touch™ , G500H TXi, G500 TXi, G600 TXi and G700 TXi.

Electronic Flight Instruments: To help aircraft owners with aging aircraft systems while provide modern flight display capability and preserve the integrity of their original aircraft panel, Garmin offers the G5 and GI 275 electronic flight instruments. These instruments are designed to replace existing mechanical attitude indicator, attitude directional indicator (ADI), course deviation indicator (CDI), horizontal situation indicator (HSI), engine indication system (EIS), and it can serve as a standby to a number of flight displays.

GPS/Navigation/Communication Solutions: Garmin serves the market with the GTN™ Xi series, a premium touchscreen GPS, VHF navigation and communication, and multi-function display (MFD). In addition to these core functions, this series of products combines a wealth of information for the pilot into a single display including flight planning, datalink weather, weather radar, traffic, terrain awareness and warning system (TAWS/HTAWS), charts, airport information, airspace boundaries, and much more. Additional capabilities provide advanced ADS-B "In" traffic display, including TerminalTraffic™ and patented TargetTrend™ technology as well as the ability to control the display with voice commands.

Services and Mobile Applications: Garmin Pilot™ is a premium, global app for iOS or Android mobile devices used for flight planning, filing a flight plan, in flight navigation, and automatic flight logging. It offers a comprehensive and simplified experience to access a wealth of information during any particular phase of the flight including weight and balance, performance, and trip calculations, checklists, airport information, weather, traffic, 3D Vision virtual perspective view of surrounding terrain, a digital document viewer, a scratch pad, geo-referenced sectional and approach charts, wireless database updating, ADS-B weather and traffic as well as SiriusXM radio and weather via subscription.

Garmin AUTOLAND: In the event of an emergency such as pilot incapacitation, the pilot or even a passenger on board can activate Autoland to land the aircraft with a simple press of a dedicated button. Autoland can also activate automatically if the system determines it's necessary. Once activated, the system immediately calculates a flight path to the most suitable airport and runway, while avoiding terrain and adverse weather, initiates an approach and automatically lands the aircraft.

Customers and contracts

Garmin is referred to in section 7 for its range of G1000/G3000/G5000 integrated cockpit avionic offerings together with many of its customer/platform contracts.

Garmin offers its products both as forward fit to OEMs and to end-users as retrofit/upgrades including airlines, bizjet operators, GA aircraft, and the rotorcraft market. These products include ADS-B, all glass LCD cockpits, GPS based navigation systems, FMS, auto-pilots and database services.

Garmin in referring to its Autoland device referred to "its aircraft manufacturing collaborators Piper, DAHER, and Cirrus, who shared the same vision to bring this life-saving technology to the industry."

Strategy

For Garmin's aviation product lines, Garmin considers its principal competitors to be Aspen Avionics, Avidyne Corporation, CMC Electronics, Collins Aerospace, Dynon Avionics, Genesys Aerosystems, Honeywell Aerospace & Defense, Innovative Solutions and Support Inc., L3Harris, Safran SA, Thales, and Universal Avionics Systems Corporation.

Recent developments

July 2024: Garmin announced two new slimline radios for the experimental aviation market, building upon the recently introduced GTR™ 205 COMM radio series for certified aircraft. The panel-mount GTR 205x and remote-mount GTR 205xR COMM radios have the same feature set as the GTR 205 radio plus new intercom and audio features. The 1.35-inch GTR 205x matches the bezel height of previous-generation radios, enabling easier upgrades and diverse installation opportunities in space-constrained instrument panels.

May 2024: Garmin announced it received a Best Supplier award for the ninth consecutive year by Embraer at its annual Suppliers Conference held April 30 in Gavião Peixoto, Brazil. Embraer, a leading aerospace manufacturer, recognized Garmin as the top supplier in the Electrical & Electronic Systems category for its G3000® Prodigy Touch flight deck systems in the Phenom 100EV and Phenom 300E. This annual award program honors an elite group of suppliers for their outstanding performance, continuous improvement and increased customer satisfaction among all suppliers who serve Embraer's global commercial aviation, business aviation and defense markets. This recognition validates Garmin's achievement in designing and manufacturing state-of-the-art flight deck systems while remaining responsive to market needs and preferences.

January 2024: Garmin announced it is ranked No. 1 for the 20th consecutive year in Professional Pilot's 2024 Avionics Manufacturers Product Support Survey. Garmin received top rankings in every category of the survey, including product reliability, speed in AOG service, cost of parts, manuals or CDs, technical representatives and support from manufacturers. The annual Avionics Manufacturers Product Support Survey is based exclusively on direct responses from qualified Professional Pilot readers and aircraft operators. Over 500 line evaluations were used in the survey results, rating avionics manufacturers on a scale of 1-10. Garmin received an overall score of 8.55 with the highest score being 9.27 in the product reliability category.

November 2023: Garmin announced that it received six CES® 2024 Innovation Awards, including a Best of Innovation honor, for outstanding design and engineering across a multitude of consumer technology product categories. The annual awards program, owned and produced by the Consumer Technology Associations (CTA)® , recognized the Venu® 3 advanced fitness and health smartwatch with three awards, along with the epix™ Pro, MARQ® GolferCarbon Edition and Garmin's Autoland Autonomous Aircraft Landing System Retrofit.

October 2023: Garmin announced that co-founders Dr. Min Kao and the late Gary Burrell have been named to the prestigious National Aviation Hall of Fame (NAHF). The annual awards ceremony recognises a select group of air and space pioneers for their lifetime achievements and contributions to the aviation and aerospace industry. Class of 2024 enshrinees were chosen by a voting body comprised of over 130 aviation professionals nationwide for induction into the Congressionally chartered NAHF.

September 2023: Garmin announced it was honoured with the top spot in Aviation International News' (AIN)2023 Avionics Product Support Survey for the 20th consecutive year. Garmin received top rankings in every category of the survey, including cost per hour programs, cost of parts, parts availability, AOG response, warranty fulfilment, technical manuals, technical representatives and overall avionics reliability. AIN's annual Product Support Survey is based

exclusively on direct responses from users of business jets, pressurized turboprop airplanes and turbine-powered helicopters. The survey is restricted to qualified readers of AIN meaning the results are based on unbiased professional opinions captured by over 500 respondents who represent nearly 2,000 aircraft.

May 2023: Garmin announced it recently received the 2022 Operational Excellence Award from Airbus Helicopters at their annual Supplier Conference in Marignane, France. In addition to recognizing excellence in on-time delivery and quality, the award highlights Garmin's outstanding performance amid a period of global supply chain challenges. Select Airbus Helicopters, including the H125, H130, H135 and H145, offer Garmin as standard avionics. Garmin's vertically integrated manufacturing model and agility in global operations allows products to be delivered at high rates while mitigating supply chain issues. Garmin is committed to delivering products on time with great quality globally. This marks the fourth award Garmin has received from Airbus Helicopters globally. The Garmin Aviation team was recognized with the 2018 North American Supplier of Excellence Award by Airbus Helicopters Canada and received consecutive On-Time Delivery awards by Airbus Helicopters, Inc. in 2019 and 2020.

April 2023: Garmin announced it has been named the 2022 "Best of the Best" Supplier by Embraer, a leading aerospace company, at its Suppliers Conference in Campos do Jordão, Brazil on April 18. Additionally, Garmin was recognized as the top supplier in both the Systems and Services & Support categories for its G3000® Prodigy Touch flight deck systems in the Phenom 100EV and Phenom 300E. This annual award program honors an elite group of suppliers for their outstanding performance, continuous improvement and increased customer satisfaction among all suppliers who serve Embraer's global commercial aviation, business aviation and defense markets. Embraer's supplier awards recognize Garmin's design innovation, ease of use and overall system architecture, as well as outstanding efforts in production line support, quality, and on-time reliability of the supply chain. These accolades validate Garmin's achievement in designing and manufacturing state-of-the-art flight deck systems, while remaining responsive to market needs and preferences. This is the eighth consecutive year Garmin has received a supplier award from Embraer. Over the past 13 years, Embraer has presented Garmin with 15 honors across various categories, including: Electric & Electronics Systems, Technical Support to Operators, Electro-Mechanical Systems, Material Support to Operator, Systems, Services & Support, and Best of the Best.

November 2022: Garmin announced L3Harris Technologies' selection of Garmin's G3000™ tandem integrated flight deck as part of a U.S. Special Operations Command (USSOCOM) Armed Overwatch program contract. L3Harris' Sky Warden™ platform includes the first forward-fit deployable combat aircraft featuring Garmin's G3000 tandem integrated flight deck. The G3000 provides USSOCOM with the latest communication, navigation, surveillance air traffic management (CNS/A™) capabilities with commercial-off-the-shelf (COTS) solutions based on Garmin's modern open system architecture design. L3Harris has integrated its mission management system along with a wide range of military sensors, communications equipment, and weapons systems into the G3000 touch screen human machine interface (HMI). The proven G3000 integrated flight deck will enable L3Harris to rapidly deploy new technologies quickly, provide lower life-cycle costs, and ensure access to the latest in avionic technologies.

September 2022: Garmin announced the selection of the Garmin G3000® integrated flight deck by Tactical Air Support, Inc. (Tactical Air) as part of a contract with the U.S. Department of Defense (DOD) F-5N+/F+ Avionics Reconfiguration and Tactical Enhancement/Modernization for Inventory Standardization (ARTEMIS) program. Tactical Air first selected the Garmin G3000 for their F-5 adversary aircraft training fleet in 2018. This recent award builds upon Tactical Air and Garmin's strategic relationship now serving the DOD fleet of F-5 adversary aircraft. Garmin's commercial-off-the-shelf (COTS) G3000 open architecture supports integration with a wide range of mission equipment including military sensors, helmet mounted displays, and advanced electrically scanned radar systems.

June 2022: Garmin celebrated the delivery of over 25,000 integrated flight decks, including forward-fit and retrofit solutions for general and business aviation, rotorcraft, military and government, and regional aircraft markets. Recognized for reliability, quality and innovation, Garmin flight decks have been certified on over 80 aircraft models representing 20 different aircraft manufacturersmore than any other avionics manufacturer.

March 2022: Garmin announced that it was named the 2022 Associate Member of the Year by members of the Aircraft Electronics Association (AEA) at its annual international convention and trade show in New Orleans, La., March 28-31. The prestigious Associate Member of the Year award is given to a manufacturer, distributor or service provider for its outstanding dealer support and contributions in the general aviation industry. Garmin was recognized by AEA members for many of its safety-enhancing technologies, including Garmin Autoland, the 2020 winner of the prestigious Robert J. Collier Trophy.

December 2021: Garmin announced a long-term agreement with Heart Aerospace to provide the state-of-the-art Garmin

G3000® integrated flight deck for the ES-19 electric airliner. Heart Aerospace is working to develop the new ES-19, a 19-seat electric airliner that has the potential to provide the regional air transport market with a more sustainable and environmentally friendly aircraft option as early as 2026. Additionally, United Airlines has conditionally agreed to purchase 100 ES-19 aircraft once the aircraft meets United's safety, business and operating requirements.

December 2021: Garmin announced it was named a Supplier of the Year for the seventh consecutive year by Embraer at its annual Suppliers Conference held virtually on Dec. 2. Garmin was recognized as the best supplier in the Electric and Electronic Systems category for its G3000® Prodigy Touch flight deck systems in the Phenom 100EV and Phenom 300E. Embraer honours a select group of elite suppliers annually for their outstanding performance in various categories. The 2020 and 2021 Electric and Electronic Systems award recognizes design innovation, ease of use and overall system architecture, as well as outstanding efforts in production line support, quality and on-time reliability of the supply chain. This accolade validates Garmin's achievement in designing and manufacturing state-of-the-art flight deck systems, while remaining responsive to market needs and preferences. Over the past decade, Embraer has presented Garmin with 12 supplier awards across various categories, including: Electric and Electronics Systems, Technical Support to Operators, Electro- Mechanical Systems, and Material Support to Operator.

June 2021: Garmin announced that Garmin Autoland had been awarded the 2020 Robert J. Collier Trophy for the world's first certified autonomous system designed to activate during an emergency to safely fly and land an aircraft without human intervention. The Collier Trophy has been the benchmark of aerospace achievement for over a century and is awarded annually by the National Aeronautic Association (NAA) to recognize "the greatest achievement in aeronautics or astronautics in America, with respect to improving performance, efficiency, safety in air or space vehicles, the value of which has been thoroughly demonstrated by actual use during the preceding year."

February 2021: Kansas, US: Garmin® International, Inc. announced that its revolutionary Garmin Autoland system was honoured by FLYING Magazine with a 2021 Editors' Choice Award. Part of the Garmin Autonomi™ family of autonomous safety-enhancing technologies, Autoland is the world's first certified system of its kind with the ability to activate during an emergency situation to autonomously control and land an aircraft without human intervention.

Counterpoint comment

In a relatively short period, Garmin has strategically evolved into a highly optimized and diversified enterprise, driven by robust research and development initiatives and key partnerships with GA aircraft OEMs. The company has demonstrated particular success across the business jet, helicopters, and GA sectors, both in OE and aftermarket segments, through the integration of modern and efficient avionics solutions. Several of its products have established themselves as industry benchmarks. Garmin consistently maintains an impressive operating margin in the high twenties, underscoring its strong financial performance.

19.1.9 GE AEROSPACE

GE Aerospace acquired Smiths Aerospace division in 2007 which provided it access to the avionics market in addition to power management and mechanical systems.

At the time of the acquisition Smiths generated $2.4 billion in aerospace with avionics estimated to have represented $1+ billion of this total at that time.

GE Aerospace's avionics portfolio today includes IMA, FMS, data recorders/data analytics, remote data concentrators, display products, mission and stores management. GE also provides a range of digital services including navigation databases (for FMS).

In April 2024, GE Aerospace a fully independent, publicly listed (NYSE: GE) company - began trading, solely focused on aerospace, while GE's other focus areas (energy, digital, and healthcare) forming similar companies.

GE Aerospace also has an avionic joint venture with Avic, China, (Aviage) which is reported on separately within this report.

Financials

GE's avionics is included in the 'System & Other' segment, which also includes electric power systems, turboprop engines, engine gear and transmission components, and services for commercial and defense businesses.

FYE 31/12/23 - USD millions	2023	2022	2021	2020	2019
Sales - Systems & Other	3,372	2,975	2,814	2,991	3,718
Sales - company-wide	31,770	26,050	21,310	22,042	32,875
Segment profit	6,115	4,775	2,882	1,229	6,812
Return on sales %	19.2%	18.3%	13.5%	5.6%	20.7%

Of its 2023 avionics sales, 55% came from the defence sector.

GE Aerospace has secured significant shipset values on Boeing 777, 787, and 777X; Comac 919; and Lockheed Martin F-35 in recent years which have increased its revenue base in avionics.

We therefore estimate that its avionics business generated $1,100 m revenues in 2023.

Locations

GE has a number of avionics facilities. However, its two main bases for avionics are in Cheltenham, UK, and Grand Rapids, Michigan, USA.

It is supported from other facilities including Dayton, Ohio; Florham Park, NJ, USA (service & repairs), Clearwater, Florida, USA (service and repairs).

Capabilities

GE Aerospace systems summarises its avionic capabilities as follows:

- Computing Systems - versatile and rugged embedded computing systems
- Digital Backbone - affordable and adaptable avionics system architecture
- Data Transfer Systems - design, integration and manufacture of data transfer and storage systems
- Flight Management Systems - Modular open software architecture, navigation database services
- Flight Data Voice Recorders - customizable data recorders for civil and military fixed and rotorcraft applications
- Health Awareness System - holistic picture of configuration, health, usage, and maintenance data.
- Inertial and Alternative Navigation - precision location and timing information independent of traditional RF signal-based solutions, and precision landing system for landing capability in degraded visual or dense urban environments.
- Interface Controllers - flexible remote interfacing products
- Networking Systems - versatile and rugged embedded networking systems
- Stores Management - comprehensive and safe aircraft weapon integration system solutions

FMS: GE's FMS automates in-flight tasks, enabling the pilots to file a flight plan, then safely and efficiently fly an aircraft from its origin to its worldwide destination. Simultaneously, the GE FMS will account for traffic, weather, aircraft performance and required arrival time, while optimising performance. The FMS uses a variety of sensors to determine the aircraft's current position and sends guidance commands to the aircraft control systems, which guide the aircraft along the approved flight plan. GE's innovative solutions reduce pilot workload and fuel consumption through automation of aircraft performance calculations, which aid in evaluating flight plan changes.

FMS features include the following:

- C1 Flight Management Computer (FMC) upgrade improves performance by enabling the latest U-Series FMS software
- AOC/ATC datalink communication and flight planning
- Increased availability, with single FMC part number and consistent operations across fleets

- Advanced Airspace features: RNAV/RNP 0.1, PBN, RTA, FANS 1/A, Link 2000+, PBN (RNP 0.3), either FANS A/B/C, ATN BL1, ATN BL2
- Supports FANS datalink capabilities, with integrated FANS 1/A and ATN Baseline 1 capability

IMA computing solutions: GE's contribution to the Open Flight Deck project, which is looking at next generation flight deck technologies, has been informed by its leadership in open avionics systems on Boeing 787 and Gulfstream G500/G600. GE's open avionics vision - looking at how to embody these open approaches in other areas of avionics - has led to an open-architecture platform that incorporates the hardware, software development tools and infrastructure needed to support a range of applications. Through 'Open Flight Deck' the manufacturer can partner with a range of suppliers to develop applications.

Displays: GE Aerospace has in the past supplied a range of LED displays mainly for the retrofit and upgrade market. It also has a solid state integrated standby indicator that combines heading, altitude and airspeed data. It also provides a DCDU display to the Airbus A320/A330 family, however, this is optional fit.

Remote Interface Units: The RIU-100 is a highly flexible and configurable Remote Interface Unit (RIU). RIU-100 offers a near "off-the-shelf" solution to a wide range of applications including:

- Distributed Input/Output (I/O)
- Centralised I/O
- Sub-system control (embedded or as standalone unit)

In a compact package the RIU-100 provides 100 interface channels combined with either a dual redundant MIL-STD-1553B Remote Terminal, or an ARINC 429 (2 Tx and 4 Rx channels) databus interface.

Voice and Data Recorders: The Voice and Data Recorder (VADR®) brings multiple high-speed databuses and analogue interfaces. The compact, lightweight, and affordable VADR® employs acquisition, recording, and memory protection technologies. The flexible VADR® is applicable to virtually any aircraft, and may be used as a data-only, voice only, or combined voice and data recorder to support:

- Regulatory compliance
- Aircraft maintenance
- Flight operations quality assurance
- Aircraft and component usage monitoring, limit exceedance monitoring

High speed Data Transfer: GE's (HSDTS) has been designed to handle the high volume of digital data on current and future airborne platforms, both manned and unmanned. It offers unparalleled data read/write speeds, the capability to host user developed applications and process data from its mass storage, interchangeable NVMe storage media, and user interchangeable capacity based on Commercial Off The Shelf (COTS) Solid State Drives (SSD). In addition, the HSDTS offers considerable I/O flexibility depending on user application. This high capacity, low SWaP data transfer system provides a single solution that is highly configurable for a variety of applications.

Mission computing: The GE Versatile Computing Platform (VCP) is a family of rugged embedded computers developed to satisfy a wide range of vehicle and mission computing applications. The VCP uses open architecture components and software to provide a flexible yet cost effective solution. The VCP provides standard digital avionics interfaces for vehicle or mission computer systems. The baseline VCP configuration contains a 6-slot 3U OpenVPX backplane, up to three 3U Single Board Computer (SBC) processor cards, up to eight I/O cards (3U and XMC), an Electro Magnetic Interference (EMI) filter assembly, and a power supply housed in a passive cooled chassis.

Inertial Reference Units: IRUs provide navigational grade 2-5 mils performance for platform navigation, system stabilisation, and pointing applications. This IRU is based on a proprietary inertial gyroscope technology that reduces size, weight, power, and cost (SWaP-C) when compared to units with similar performance. GE Aerospace's IRUs are utilised on land, maritime, and airborne applications; with over 5,500 units fielded worldwide. This product family is scalable to customer's specific needs.

Customers and contracts

GE Aerospace has the following avionics related contracts with the following customers:

- Airbus A320ceo/A320neo: FMS, DCDU (optional)
- Airbus A330/A330neo: FMS, DCDU (optional)
- Boeing 737: FMS, MCDU displays, air data computers, Auto/Pilot, data recorders, standby displays.
- Boeing 777X: Common Core Computing system, remote data concentrators.
- Boeing 787: Common Core Computing system, Remote Data Concentrators (Smiths also retained Wind River to assist with the development of the computing function)
- Gulfstream G500/G600: Data concentration and IMA computing platform for multiple avionics systems, advanced health and usage monitoring.
- Boeing Apache AH-64: pylon interface unit and maintenance data recorders
- Lockheed Martin F-35: Standby flight Displays.
- Eurofighter (Typhoon): Voice control system
- Boeing KC135: Integrated data acquisition recorder

Strategy

GE Aerospace is focussed upon utilising its installed base, whether it be for engines or avionics, to provide digital service support solutions that add value to its customer base.

It understands how to add value throughout the life cycle of its products with support and service as reflected within its operating margins.

Recent developments

April 2024: GE Aerospace became a publicly traded entity (NYSE: GE) as the earlier plans to split the aviation, energy/digital, and healthcare business interests came to fruition. October 2023: GE Aerospace and Hainan Airlines have signed a 10-year agreement covering systems support for the carrier's fleet of Boeing 787 aircraft. The contract will cover GE systems on the 787s, which include its avionics and other computing and networking systems. Hainan operates a fleet of 38 787s. GE says it will provide support from Singapore and its new facility in Brisbane, Australia. The company will also provide a 787 component pool at Hainan's Haikou hub.

September 2023: GE Aerospace announced the selection by Bell Textron for work on the development of a Common Open Architecture Digital Backbone (COADB), Voice and Data Recorder, and the Health Awareness System (HAS) for the Bell V-280 Valor. Following the U.S. Army's Future Long-Range Assault Aircraft (FLRAA) program contract award, the V-280 Valor will enable the U.S. Army and its allies to maintain battlefield superiority including transformational capabilities in speed, range, payload, and endurance. The GE Aerospace systems will be part of an open, scalable, high-speed data infrastructure consistent with the U.S. Army's Modular Open Systems Approach (MOSA) that enables rapid testing, verification, and fielding of mission-focused capabilities for future vertical lift programs.

July 2023: GE Aerospace announced that its Cheltenham, England facility had been recognised as part of an elite group of top-performing suppliers by Lockheed Martin Aeronautics as a recipient of the Mission Focused Award. The recognition is based on GE Aerospace - Cheltenham having achieved outstanding performance levels in quality and delivery throughout 2022. GE Aerospace in the U.K. has been supplying the Electrical Power Management Systems, Standby Flight Displays and Remote Input Output Units to a global customer base for many years, supporting a broad range of major commercial and military aerospace programs.

June 2023: GE Aerospace was selected by Korea Aerospace Industries (KAI) to supply the Health and Usage Monitoring System (HUMS) for the Korean Marine Attack Helicopter (KMAH). HUMS shipset deliveries will commence in 2024 and will include: Data Acquisition and Processing Unit (DAPU); Optical Blade Tracker (OBT); Multi-Platform Ground Station (MPGS). GE Aerospace sites in Southampton (UK) and Grand Rapids (MI USA) will develop and supply the HUMS to KAI. This follows an award KAI has received from the Korean Government to develop and supply the Korean Marine Attack Helicopter (KMAH).

June 2023: GE Aerospace delivered the 1,200th shipset system for the F-35 for each of the seven avionics and power systems across their global manufacturing and support network. GE Aerospace has the following systems onboard

the aircraft: Electrical Power Management System: Cheltenham, UK; Standby Flight Display: Cheltenham, UK; Remote Input Output Unit: Cheltenham, UK; Fuselage Remote Interface Unit: Grand Rapids, MI USA; Missile Remote Interface Unit: Grand Rapids, MI USA; Engine Distress Monitoring System: Southampton, UK; Ingested Debris Monitoring System: Southampton, UK.

April 2023: GE Aerospace has signed an agreement with AJW Group (aircraft component parts, repair, and supply chain solutions provider) to support avionics and electrical power systems across the B777, B737 and A320/330/340 family of aircraft. The contract will start this year and will cover all AJW Group's Europe, Middle East, and Africa (EMEA) customers that fly the B777, B737 and A320/330/340 family of aircraft. GE Aerospace was selected for the three-year agreement based on turnaround time (TAT) and repair capability. GE Aerospace will service the systems at their repair and maintenance location in Cheltenham, United Kingdom. Some of the systems included in the agreement are Electrical Load Management Systems, Flight Management Systems and Data Control Display Units.

April 2023: GE Aerospace has signed an agreement with Lockheed Martin to support avionics and electrical power systems on the F-35 globally. The four-year agreement entails maintenance, repair, and overhaul for GE Aerospace systems on the F-35 Lightning II aircraft. GE Aerospace will service the F-35 systems at their repair and maintenance locations in California, Georgia, and Utah as well as GE sites at Grand Rapids, Michigan, Long Island, New York and Cheltenham, United Kingdom.

December 2022: With Boeing asked to build two KC-46 tanker aircraft for the Japanese military, GE Aviation Systems will be providing mission control system avionics and flight management system (FMS), from their facilities in Grand Rapids, MI, and Clearwater, FL.

November 2021: GE Aviation is supplying the data concentration network, advanced power management system and health management system for the recently unveiled Gulfstream G400 and Gulfstream G800 business jets. The data concentration network for the G400 and G800 is common from the G500 and G600 and builds on GE's common core system from the Boeing 787. The system provides a highly configurable integrated data network for the aircraft and offers a way to seamlessly connect avionics and manage aircraft functions. Using GE's tool suite, the data concentration network can be rapidly re-configured, enabling efficient integration and significantly reducing cost of change over the life of the airplane.

November 2021: General Electric announced plans to split its aviation, energy, power and digital, and healthcare interests into three distinctive public companies, in order to focus solely on aviation in the coming years.

Counterpoint comment

GE Aerospace is a leading avionics supplier played a significant role in the establishment of the Aviage joint venture with AVIC. However, the current performance of this JV remains uncertain, particularly in light of heightened tensions between the US and China, as well as growing concerns surrounding the protection and potential exploitation of intellectual property.

While GE Aerospace demonstrates robust capabilities in specific domains such as Integrated Modular Avionics (IMA), computing infrastructure, Flight Management Systems (FMS), and data solutions, its portfolio lacks the comprehensive suite of integrated avionics systems offered by competitors like Collins, Honeywell, and Garmin. Notably, GE Aerospace's presence in communication products is relatively weak, highlighting its limited positioning in this segment..

19.1.10 GENERAL DYNAMICS

General dynamics operates via four divisions as follows:

- Aerospace - (Gulfstream and Jet Aviation)
- Marine Systems - (NASSCO, Bath Iron Works, Electric boat)
- Combat Systems - (European Land Systems, Land Systems, Tactical and Ordnance)
- Technologies - (Mission Systems, Information Technology)

General Dynamics is not a major avionics provider, but it does have airborne mission systems capabilities within its Technologies division.

Financials

FYE 31/12/23 - USD millions	2023	2022	2021	2020	2019
Revenue	42,272	39,407	38,469	37,925	39,350
Operating Earnings	4,245	4,211	4,163	4,133	4,570
Return on sales %	10.0%	10.7%	10.8%	10.9%	11.6%
Technologies segment revenue (excluding IT services)	4,463	4,297	4,388	4,756	4,937

General Dynamics reports by segment and Technologies division revenues includes airborne mission, cyber, sensor and data products. In 2023, Technologies had sales of $12,922m (inclusing IT services sales) compared with $12,492m in 2022. Gernal Dynamics commented that "As a group, earnings were down 2% as Mission Systems navigates a transition from legacy programs that began to phase out to newer programs coming online at somewhat lower initial margins."

We estimate that General Dynamics generated $300m of avionic related revenues in 2023.

Locations

General Dynamic's Mission Systems is headquartered in Fairfax Virginia, USA.

Other Mission Systems facilities are located as follows;

- Cullman, Alabama
- Scottsdale, Arizona
- San Jose, California
- Groton, Connecticut
- Orlando, Florida
- Dedham, Pittsfield, Quincy and Taunton, Massachusetts
- Bloomington, Minnesota
- Florham Park, New Jersey
- Greensboro and McLeansville, North Carolina
- Canonsburg, Charleroi, and Pittsburgh, Pennsylvania
- San Antionio, Texas
- Marion and Manassas , Virginia
- Calgary, Halifax and Ottawa, Canada
- Tallinn, Estonia
- Oakdale and St. Leonards, United Kingdom

General Dynamics has a subsidiary Mission systems business in Rome, Italy, however this does not include airborne equipment.

General Dynamics also has a Mission systems subsidiary located in Ottawa, Ontario, Canada that provides data Management Systems.

General Dynamics' Mission systems had a total of 8,100,000 ft^2 of facility space in 2019.

Capabilities

Stores Management: DSMS is a standards-based MIL-STD-1760 weapons control system that provides selection, arming, release and post launch control of modern precision guided weapons. DSMS is expandable — After DSMS is installed, new MILSTD-1760 stores can be integrated with software modification only and no additional hardware.

Identification Friend or Foe: The IFF crypto solutions developed are being integrated into the world's newest, most advanced military aircraft and aboard ships. They are also being incorporated into the upgrades of legacy IFF systems in operational aircraft.

ISR software: TAC-MAAS is advanced motion imagery Processing, Exploitation and Dissemination (PED) software, which delivers significant productivity and intelligence benefits for Intelligence Surveillance and Reconnaissance (ISR) operations. TAC-MAAS has an operationally proven track record and boasts demonstrated plug and play interoperability with STANAG 4609/NGA MISP compliant manned and unmanned ISR platforms. It has low training and operational support requirements delivering a cost-effective solution for leveraging intelligence from airborne sensor imagery.

Mission Computing: (AMC) is an integrated information processing system, providing complete hardware and software solutions. It is built on a well-defined open systems architecture allowing for rapid insertion of emerging technologies. General Dynamics supplies system design and integration services to ensure a precise fit to the requirements of each specific user platform. The AMC is a set of digital computer hardware and software that performs general purpose, I/O, video, voice, and graphics processing.

- Communication is over multiple buses, including 1553, Fibre Optic Fibre Channel, and Local PCI, and all modules integrate in an industry standard 6U VME backplane
- I/O configuration may be tailored with PMC mezzanine modules
- Design is scalable and expandable, with a clear and built-in path for technology upgrades and insertion
- Well-defined avionics Application Programming Interface (API) abstracts the application software from the underlying hardware, affording system evolution to ever increasing performance standards, while effectively managing obsolescence
- Ethernet interface supports software development and system maintenance.

Data Management Systems: The Data Management Systems (DMS) enables an aircraft to collect and present integrated tactical situational awareness data gathered by:

Multi-mode radars, electro-optic sensors, electronic support measure systems, acoustic processing systems, self—defence suites, magnetic anomaly detector systems, weapons/stores management suites, SATCOM systems, tactical datalinks, Automatic Identification Systems (AIS), Navigation and Flight Management Systems

SATCOM On-the-Move® antennas provide secure, beyond-line-of-sight communications for U.S. and coalition troops operating in remote locations. Designed for the rugged tactical environments, these antennas can be mounted on a fast moving vehicles, high speed boats, aircraft and UUVs. These antennas provide reliable X, Ku, or Ka Mil and commercial band satellite communications.

Customers and contracts

Specific contracts are as follows:

- General Dynamics Advanced Mission Computer (AMC) is the nerve centre of the U.S. Navy's F/A -18 Super Hornet and the U.S. Marine Corps' AV-8B Harrier.
- P3 Orion: Digital Stores Management System (DSMS) is a weapons control system enabling the launch and control of modern precision guided weapons.
- U.S. Navy's P-3C: Stores Management System.
- General Dynamics Canada Mission Systems is prime integrator of the mission sensors and systems for the CP-140 Aurora and the CH-148 Cyclone
- NATO AWACS Boeing EC-3: Data and mission computing console upgrade

Strategy

General Dynamics has strength in Mission Computing, Stores Management, IFF sensing and data management for military airborne applications. However, it is heavily dependent upon the F/A-18 programme along with AV8B which are both in mature life cycle mode of operation and support.

Recent developments

None that we can see.

Counterpoint comment

General Dynamics has strength in land, marine and space applications but has not secured any new airborne business in recent years (other than F/A-18 follow on contract awards and service support).

19.1.11 GENOVA TECHNOLOGIES

Founded in 1993, Genova Technologies is third party software development company, which works across a number of diverse sectors. In aerospace, Genova Technologies is an engineering services company, providing outsourced avionics software development and verification.

Financials

Counterpoint estimates Genova's avionics-related sales were $9m in 2023.

Location

Genova's headquarters is in Cedar Rapids, IA.

Capabilities

Genova Technologies provides commercial and military avionics and aerospace manufacturers and federal government customers with solutions to meet mission-critical application development, web development, mobile technologies, information technology, and testing and validation needs.

It has expertise in the following stages of the software life cycle:

- System Validation
- Software Development
- Independent Software Verification
- Test Automation
- Software Tools Development and Qualification

Genova has over 20 years' experience with DO-178B/C and DO-254 processes.

Customers and contracts

Projects include a DARPA program to demonstrate a tactical airborne network. It also performs commercial aerospace work but in common with many such companies it does not generally reveal the identity of its clients.

Counterpoint comment

A relatively small player with focus on aftermarket.

19.1.12 GREEN HILLS SOFTWARE

Green Hills Software was founded in 1982, is privately held, and has been profitable since its inception. Green Hills Software has averaged nearly 30% per year revenue growth and is now the world's largest independent real-time operating systems (RTOS) company. It competes in several markets, namely: Aerospace & Defence; Automotive; Consumer; Industrial; Medical; Networking & Telecomms; and Software Defined Radio.

Green Hills Software offers the safest and most secure RTOS and development tools for aerospace and defence. Its safety and security pedigree goes back to 1997 with the Boeing B1-B avionics upgrade and the Sikorsky Helicopter S-92 Avionics Management System from Rockwell Collins, which was later certified to DO-178 DAL A. Since then, Green Hills Software products have been deployed on almost every commercial and military aircraft. Its in-house group of certification experts has provided certification evidence for over 80 safety and security certifications across all the key processor architectures, reducing time, cost, and risk of certification.

In March 2021, the company raised $9.3 million of venture funding from undisclosed investors. Previous venture funding was raised in 2019 ($150 million) and 2005 ($1.32 million) respectively.

Financials

We estimate that Green Hills generated $120m of revenues in 2023.

We further estimate that $16m of revenues were related to avionics product solutions.

Locations

Green Hills Software is headquartered in Santa Barbara, California. Its European headquarters is located in Eastleigh, United Kingdom, while its Safety and Security Critical Products office is in Palm Harbor, Florida.

The company has a global presence, with offices responsible for key areas within the region: EMEA

- Aylesbury, United Kingdom (UK)
- Paris, France (France, Spain, Portugal)
- Bonn, Germany (Germany, Austria and Switzerland)
- Torino, Italy (Italy)
- Herzelia, Israel (Israel)
- Leusden, The Netherlands (Benelux and Eastern Europe)
- Uppsala, Sweden (Sweden, Finland, Norway and Denmark)
- Madrid, Spain (Spain)

APAC

- Melbourne, Australia (Australia, New Zealand Direct Sales Office)
- Tokyo, Japan (Japan Direct Sales Office)
- Kyeonggi-do, Korea (Korea Branch Office)
- In addition, there are distributors within China, India, Korea and Taiwan.

Americas (Sales offices)

- Danvers, MA (New England & Eastern Canada)
- Mahwah NJ (Mid-Atlantic)
- Columbia, MD (Government Programs)
- Frisco, TX (South Central)
- Phoenix, AZ (Southwest)
- Bothell, WA (Northwest)

- Santa Clara, CA (Northern California)
- Santa Barbara, CA (Southern California)

Capabilities

Within the aerospace and defence sphere, the company's areas of expertise are twofold: Airborne Safety-Critical Systems, and High Robustness Security Systems. Airborne Safety Critical Systems

- Flight control electronics
- Flight management system
- Engine control systems
- Traffic Collision Avoidance Systems (TCAS)
- Cabin pressure control systems
- Fuel management systems
- Mission computers
- Positioning, Navigation, and Timing (PNT)
- Terrain warning systems
- Weather radar
- EW radar warning systems
- Primary Flight Displays (PFDs)
- Multi-Function Displays (MFDs)
- Data radios
- Voice radios
- Air data inertial reference units (ADIRU)

High Robustness Security Systems

- Communication, navigation, and identification (CNI)
- Software-Defined Radios
- MLS data displays that include input devices
- Military satellites
- Military communications system
- Standalone cross-domain solutions such as a downgraders
- Joint and coalition combat training systems
- Weapon systems
- Integrated control processors with MLS requirements

The INTEGRITY-178 tuMP real-time operating system (RTOS) provides benefits for safety and security-critical systems in aerospace and defence systems. For DO-178C airborne safety applications, INTEGRITY-178 tuMP is the only RTOS that supports multi-processing of ARINC 653 partitions across multicore cores in symmetric multi-processing (SMP) and bound multi-processing (BMP) mode. It is also the only RTOS to provide a general solution to multicore interference mitigation. Managing the shared resource contention that causes multicore interference can benefit all types of real-time systems by decreasing worst-case execution times.

For security-critical applications, INTEGRITY-178 is the only commercial operating system certified to Common Criteria EAL6+ and NSA High Robustness, and INTEGRITY-178 tuMP extends that pedigree to multicore processors. High

robustness enables hosting multi-level security (MLS) applications, and INTEGRITY-178 tuMP is the only commercial RTOS capable of hosting cross-domain solutions (CDS). There is no reason to choose between safety and security when you can have the best of both in the same solution with the INTEGRITY-178 tuMP RTOS.

Customers and contracts

Green Hills supported the Boeing B1-B avionics upgrade and the Sikorsky Helicopter S-92 Avionics Management System from Rockwell Collins.

They have also supported the following customer platforms:

- Boeing 787 Dreamliner
- Northrop Grumman Bell UH-1Y
- Lockheed Martin F-22 Raptor
- Aselsan T-70 Blackhawk program
- Lockheed Martin C130J
- Northrop Grumman Bell AH-1Z
- Saab Skeldar UAV
- Lockheed Martin F-35
- Airbus A380
- Rockwell Collins Avionics Management
- Airbus Military mission Management Computer
- Lockheed Martin F-16 fighter

Strategy

Green Hills Software is a worldwide leader in embedded safety and security. It covers seven sectors including aerospace and develops industry standard products where criticality, security and reliability are key requirements.

Within aviation avionics it is clearly focussed upon supporting many lead OEM specifiers.

Recent Developments

April 2024: Triumph Group chose the Green Hills INTEGRITY-178 real-time operating system (RTOS) for the engine-control units in U.S. helicopters including the AH-64D Apache, CH-47D/F & MH-47D/F/G Chinook, UH-60L/M/V Black Hawk, HH-60 Pave Hawk, MH-60 Jayhawk, and SH-60 Sea Hawk.Inc. in Radnor, Pa., needed real-time software for a wide variety of U.S. military helicopter avionics. Safety-critical engine-control units running INTEGRITY-178 have been developed to RTCA/DO-178B design assurance level A (DAL A) avionics safety-assurance standard. Triumph also has selected the INTEGRITY-178 tuMP multicore RTOS for the company's next generation of engine-control units, which has applications running concurrently on all cores of a quad-core processor.

March 2023: Green Hills Software announced that Merlin, the leading developer of safe autonomous flight technology for fixed-wing aircraft, has selected the INTEGRITY® -178 tuMP™ safety-critical real-time operating system (RTOS) for its autonomous flight solution. INTEGRITY-178 tuMP will run on the PU-3000 multicore avionics computer from CMC Electronics, which will host the flight control software that enables autonomous flying.

July 2022: Green Hills Software announced that its INTEGRITY® -178 tuMP™ safety-critical real-time operating system (RTOS) will be used in the Replacement Multi-Function Controls and Displays (RMCD) on the C-5M Super Galaxy transport aircraft. INTEGRITY-178 tuMP will run on the PU-3000 multicore avionics computer from CMC Electronics, which will be combined with the VDT-1209 video display terminal from Intellisense Systems to form the full C-5M cockpit display system, including the primary flight displays.

December 2021: The U.S. Air Force have chosen the Green Hills INTEGRITY-178 RTOS for the Special Mission Display Processor (SMDP) aboard the Air Force Lockheed Martin C-130J to replace outdated equipment. The SMDP requires

the RTOS to meet the U.S. National Security Agency (NSA)-defined separation kernel protection profile (SKPP) for high robustness security, which provides the ability to host multi-level security (MLS) software applications. Security is a top priority for the SMDP because it controls the flow of secure and unsecure information between aircraft systems, and incorporates Link 16 situational awareness into the C-130J.

Counterpoint comment

Green Hill maintains an extensive portfolio of blue-chip clients across multiple industries. This success is largely driven by its proprietary software solutions in the RTOS space, an area where many OEMs prefer outsourcing rather than handling in-house development.

There is a sustained trend toward outsourcing high-end software development, as OEMs increasingly find this approach more cost-effective than investing in bespoke internal capabilities. Given these dynamics, we anticipate that Green Hill will continue to experience growth exceeding industry averages.

19.1.13 HONEYWELL

Honeywell Aerospace began in 1914. Over a century, through various acquisitions, mergers and name changes, Honeywell Aerospace combined legacy companies Sperry, Bendix, Garrett AiResearch, Pioneer, Lycoming, Grimes, King Radio and Allied Signal.

Honeywell Aerospace is a global supplier of products, software and services for aircraft. Products include aircraft propulsion engines, auxiliary power units, environmental control systems, integrated avionics, electric power systems, hardware for engine controls, flight safety, communications and navigation, satellite and space components, aircraft wheels and brakes, and thermal systems. Software includes engine controls, flight safety, communications, navigation, radar and surveillance systems, internet connectivity and aircraft instrumentation. Services are provided to customers for the repair, overhaul, retrofit and modification of propulsion engines, auxiliary power units, avionics and mechanical systems and aircraft wheels and brakes.

Honeywell Forge for aircraft connected solutions, software and data services designed to improve customers' efficiency and enable improved operations.

Honeywell's Aerospace division is comprised of the following businesses:

- Electronic Systems
- Engines and power Systems
- Mechanical Systems and Components
- Services and Connectivity

Honeywell's avionics products sits within its Electronic Systems (ES) division and it generates some avionic related revenues from Services and Connectivity.

Financials

FYE 31/12/23 $ millions	2023	2022	2021	2020	2019
Commercial original equipment	2,397	2,069	1,720	1,932	2,997
Commercial aftermarket	6,241	5,108	4,155	3,786	5,731
Defence and space	4,986	4,630	5,151	5,826	5,326
Total aerospace sales	13,624	11,827	11,026	11,544	14,054
Aerospace segment profit	3,741	3,228	3,051	2,904	3,607
Aerospace profit margin	27.5%	27.3%	27.7%	25.1%	25.7%

Honeywell commented: "Sales increased $1,797 million due to higher organic sales of $1,148 million in Commercial Aviation Aftermarket driven by higher sales volumes in air transport due to an increase in flight hours, higher organic

sales of $361 million in Defense and Space driven by higher sales volumes due to increased shipments, and higher organic sales of $315 million for Commercial Aviation Original Equipment driven by higher sales volumes due to increased shipments. Segment profit increased $513 million and segment margin percentage increased 20 basis points to 27.5% compared to 27.3% for the same period of 2022."

In arriving at an estimate for Honeywell's avionic revenues we believe that a significant proportion of its Electronic Systems sales are avionic-related (having made some reduction for satellite products).

The last time that Honeywell provided a breakdown by business unit was in 2022. The numbers at that time were:

- Electronic Systems – $4.1 billion
- Engines and power Systems – $3.9 billion
- Mechanical Systems and Components – $3.2 billion
- Services and Connectivity – $0.6 billion

We therefore estimate that in 2023 Honeywell generated revenues of $3,200m in respect to avionics product and services.

Locations

Honeywell Aerospace is headquartered in Phoenix Arizona, USA.

All of Honeywell's surveillance products including TCAS and Weather Radar are designed in their facility located in Phoenix, USA.

Honeywell also has an engineering software facility in Tempe Arizona that produces avionic software.

Their inertial measurement units are designed in Minneapolis, Minnesota, USA, however, in 2020 Honeywell announced that they would close this facility.

Honeywell has had a strong avionic engineering presence in Redmond, Washington but has reduced this facility from circa 1,000 engineers to around 350 in recent years.

Honeywell Avionics has a support centre in Westeville, Ohio, USA.

Capabilities

Honeywell summarises its avionics capabilities as follows:

- Airplane Information Management System
- Augmented Reality
- Autopilots & Indicators
- Cockpit Displays
- Control Display Units
- Flight Management Systems
- Image Processing Module
- Integrated Flight Decks
- Maintenance
- Synthetic Vision Systems

One of Honeywell's latest initiatives is Anthem, described as "the first clean-sheet next generation core avionics cockpit systems computing architecture introduced by Honeywell Aerospace in more than two decades..." Utilising Honeywell Forge, the SAAS cloud platform introduced in 2019, Anthem embeds processing inside smart displays rather than requiring separate equipment in an aircraft's electrical equipment bay.

Honeywell Primus Epic Avionic suite: Primus Epic is built around field-removable modular avionic units (MAUs) which are the building blocks of the Primus Epic. Modules for computing, database storage, input/output, network communication, and power supply are plugged into a hardware cabinet called the modular avionics unit (MAU). Primus Epic applications will typically require between one and four MAUs, each with four to 24 module slots, connected by the latest version of Honeywell's ASCB databus which provides a throughput capacity of 20 megabits/s. Honeywell has developed its own software operating-system for the MAUs and "smart" liquid-crystal displays. The Digital Engine Operating System provides standard interfaces and services for all the resident functions and allows one function to be changed without affecting others. Software for multiple critical, essential and non-essential functions can be run on the same processor. The MAUs can be configured to perform many avionics functions within one box, including autoflight system, fault-warning computer, flight-management system, aircraft utility-systems control and another new feature, the integrated sensor suite. This is a complete primary-sensor system consisting of global-positioning and air-data modules, and a small inertial-measurement unit combining ring-laser and fibre-optic gyro technology in one sensor.

Combining computing and sensing functions has helped Honeywell to reduce acquisition cost by 30%, size and weight by 40% and application cost by 50%, while increasing maintainability by 60% and both dispatchability and reliability by 100%. In the Hawker Horizon, Honeywell reduced weight by some 45kg compared with its SPZ-8000 system in the Hawker 1000, eliminating 23 line-replaceable units and at least doubling system reliability.

Flight Management Systems: Next Generation Flight Management Systems (NGFMS) meets the needs of all aircraft sizes. The NGFMS is optimised for future Air Traffic Management (ATM) functionality and deliver improved fuel efficiency, reduced direct operating costs, reduced pilot workload and improved safety. With a redesigned architecture, the NGFMS software utilises a modular design that allows for aircraft specific adjustments in hardware, operating systems, Input/Output (IO) and other features. The system can run the same core functionality on multiple platforms with little modification from the core FMS functionality.

Primus Epic integrated cockpit: Honeywell is a leading provider of navigation, display systems, flight controls and flight management systems, developing a broad and scalable portfolio of hardware and software products that provide value for a wide range of aircraft configurations. Honeywell continues to develop advanced cockpit solutions, including the Primus Epic 2.0 and Epic 2.0+ integrated avionics systems, the latest evolution of the Primus cockpit family.

Air Data Inertial Reference Systems: Honeywell's third-generation air data inertial reference system with digital gyros provides high system reliability and performance with reduced operation and maintenance in a 4 modular concept unit package. It is interchangeable with earlier 4 modular concept unit (MCU) air data inertial reference system (ADIRS) and 10 MCU ADIRS (with a tray adapter).

Enbedded GPS/INU navigation: Honeywell has produced and delivered more than 60,000 embedded global positioning system inertial navigation systems (EGI). Honeywell's EGIs provide a robust civil certification to DO-178 and DO-254, enabling much easier certification at the aircraft level for features such as automatic dependence surveillance-broadcast (ADS-B), required navigation performance (RNP) / area navigation (RNAV), wide area application services (WAAS).

Traffic Avoidance Systems: The SmartTraffic collision avoidance system (CAS) 100 system offers three models of commercial traffic alert and collision avoidance system (TCAS). The TPA-100 TCAS processor has sufficient processing capacity to incorporate future automatic dependent surveillance broadcast (ADS-B) IN functionality. Honeywell offers three versions of commercial TCAS within the TPA-100 TCAS processor family and they are available in both 6 modular concept unit (MCU) and 4 MCU ARINC form factors.

Enhanced Ground Proximity Warning Systems (EGPWS): The Honeywell EGPWS reduces the risk of controlled flight into terrain by providing flight crews with timely, accurate information about terrain and obstacles in the area. The system uses various aircraft inputs and an internal database to predict and warn flight crews of potential conflicts with obstacles or terrain. EGPWS software enhancements include SmartRunway and SmartLanding systems, developed to help flight crews avoid potential runway incursions and excursions.

Weather radar system IntuVue RDR-7000: Provides business aviation and helicopter pilots the information needed to make safer, faster and informed decisions before flying in bad weather and challenging environments. Engineered to provide far superior reliability, accuracy and durability than legacy magnetron-based radar systems, the RDR-7000 offers customers to remotely enable advanced software features.

JetWave™ Honeywell's JetWave™ system exclusively powers Inmarsat's GX Aviation global highspeed Ka-band service.

Designed to deliver 'home equivalent' connectivity, Honeywell can help airlines provide a consistently outstanding passenger experience all over the world.

Honeywell Forge: Honeywell Forge for Airlines is the most advanced analytics platform that has been helping over 100 airlines identify, implement, and optimise dozens of initiatives to improve flight and maintenance operations. Currently, Honeywell Forge is being used to process data from more than 10,000 aircraft. Major airline groups like Lufthansa, IAG, Etihad, KLM, Japan Airlines are using the platform to improve operational efficiency.

Honeywell also provide a range of mission and vehicle management computers that are developed for numerous space applications (outside of the scope of this report).

Customers and contracts

Honeywell's Primus Epic family of avionic suites and their associated customers/platforms is covered in section 9 of this report.

- A320: FMS, Data management unit, air data inertial ref units, MMR.
- A330: FMS, data management unit, air data inertial reference system, integrated multi-mode receiver.
- A350: Airborne Communication Unit, JetWave ka-band satellite connectivity.
- A380: FMS, Air Data inertial reference system.
- Boeing 737: Radio comms equipment, Airborne comms equipment, FMS, SATCOM systems, Flight data acquisition unit, Flight recorders, Cockpit voice recorder, Air data computers, HF data link, EFIS display system, Flat panel LCD displays (737-700.737-800,737-800.737-900), Multi-mode receiver, Terrain Awareness Warning system, EGPWS on BBJ variant.
- Boeing 747: FMS, Cockpit Control Systems, Cockpit indicators, Autopilot flight director, FANS system.
- Boeing 767: EFIS system, -700 display system, VOR, receivers.
- Boeing 777: SATCOM, Airplane Information Management (AIMs) system, Aircraft Environmental Surveillance System (AESS), flat panel LCD cockpit display system, MMR, high speed digital voice and data comms system.
- Boeing 787: FMS, Inertial navigation systems, autopilot, EGPWS, air data sensors, MMR.
- Airbus CN295: Flight recorders, Weather radar, IFF interrogators, FDR.
- Airbus H145M/EC145: Radar/radio altimeter, DME, VOR receivers, ILS.
- Boeing AH Apache: GPS/INS, SATCOM.
- Boeing F-15 Eagle: IFF transponder, Air data Computers, AHARS, Inertial Navigation Systems.
- Comac C919: Air data computers, Inertial reference systems
- Dassault 50EX: Laseref gryo inertial system, TAWS, EGPWS
- Dassault 7X/8X: Primus Epic (EASy flight deck), radio comms systems, JetWave-ka band satellite connectivity.
- Dassault 900LX: Primus Epic EASy flight deck, JetWave ka-band satellite connectivity.
- Embraer 170/190: Airborne comms system, ka-band satellite connectivity, Primus Epic avionic suite, DU-1310 Display unit, KDU-180 display unit, EGPWS, Integrated Navigation service. Next Gen FMS (option)
- Embraer E2 Gen jets: Primus Epic avionic suite, Next Gen FMS, SmartView Synthetic vision systems, DU-1310 Display units, MFCDU, Radar altimeter
- Gulfstream G280: Planeview flightdeck developed with Gulfstream.
- Gulfstream G500/550: Primus Epic avionic suite, EVS system, Weather mapping radar, LCD display suite, TCAS system, moving maps, ADS-B display capability.
- Gulfstream G600/650: Primus Epic avionic suite, EVS system, LCD display suite, TCAS, ADS-B display capability, 3D weather radar, EGPWS, NextGen FMS system.

- Gulfstream G700: Primus Epic based Symmetry avionic suite, NextGen FMS system, 3D Weather radar
- Leonardo AW139: Primus Epic avionic suite. EFIS displays.
- Lockheed Martin C-130J: Dual GPS/INS navigation system, military TCAS, Radio Altimeters, EGPWS, Weather radar system (option).
- Lockheed Martin F-35: Radar Altimeters
- Sikorsky UH-60 Black Hawk: Radar altimeter, Weather radar, GPS/INS navigation, Aspire 200 SwiftBroadband channels provide up to 650 Kbps per channel.

Strategy

Honeywell is a market leader in avionics with a complete range of offerings including key growth drivers such as integrated avionics, surveillance, autonomy and service offerings (i.e. Honeywell Forge).

As such it continues to invest in developing new technologies across a broad number of sectors (all of which requires heavy investment).

Aerospace has been the target of takeover on more than one occasion and Honeywell corporate has considered divesting its Aerospace division in recent past.

Recent developments

July 2024: Honeywell has signed a deal with United Airlines to supply a suite of avionics tech for the company's incoming Boeing 737 MAX aircraft over the next ten years. The US company will supply five technologies for the planes, including a 3D weather radar and 'intuitive' display for pilots, a 25-hour flight data recorder, and a radar altimeter to assist instrument landings and filter out 5G interference.

March 2024: Honeywell has agreed to acquire Italy's Civitanavi Systems S.p.A., a provider of position, navigation, and timing (PNT) technology to the aerospace, defense, and industrial markets, a deal that adds new technology to its product portfolio that will strengthen its ability to help customers for autonomous operations. The $217 million deal is expected to close in the third quarter subject to clearing anti-trust authorities, approvals in Italy, the United Kingdom, and Canada related to foreign direct investment regulations, and the tender of at least 95 percent of Civitanavi's outstanding shares. Honeywell said Civitanavi's controlling shareholder, which owns 66 percent of the company, has agreed to the deal. Civitanavi specializes in fiber optic gyro technology that currently is not part of Honeywell's navigation product suite. Honeywell said that Civitanavi's inertial navigation, geo-reference, and stabilization systems will complement its existing navigation and sensors business.

February 2024: Honeywell aerospace is investing $84 million to expand its avionics manufacturing facility in Olathe, Kansas. According to the company, the expansion is expected to generate $47 million in total gross domestic product and contribute $18.3 million to state and local taxes in the first six years. It expects the expansion to employ an additional 153 employees at the site and create more than 200 other supported jobs across Kansas. The current 560,000-sq-ft is used for manufacturing components for Honeywell's avionics, safety and flight control systems, and radio frequency systems for traffic collision avoidance, radar altimeters, and weather radar.

February 2024: At Singapore Airshow 2024, Honeywell announced a Memorandum of Understanding (MOU) with PT Dirgantara Indonesia (PTDI) to jointly elevate the overall performance, reliability, and mission readiness of the Indonesian Armed Forces' S-70M helicopter fleet. Honeywell and PTDI will explore opportunities around the procurement of Honeywell's avionics and mechanical products on S-70M helicopters designated for the Indonesian Army. The MOU also outlines potential areas of collaboration in the localisation of Maintenance, Repair, and Overhaul (MRO) capabilities for Honeywell's avionics and mechanical systems on the helicopters, as well as the manufacturing and supply of the Harness Assembly by PTDI for Honeywell.

February 2024: The U.S. Air Force is ordering advanced multicore avionics data processors for upgrades to the F-15 jet fighter aircraft under terms of a $61.2 million order, involving Honeywell and Boeing. Boeing has been asked to build full-rate-production versions of the F-15 Advanced Display Core Processor II (ADCP II) for integration into the Air Force F-15 aircraft fleet. The ADCP II flight computer comes from the Honeywell Inc. Aerospace segment in Phoenix. The avionics computer is based on commercial technology and provides multicore processor capabilities. Its high-speed processing and interface designs enable advanced systems integration, increased mission effectiveness, augmented

fault-tolerance, enhanced system stability, and aircrew survivability, Air Force officials say. Boeing will oversee production and integration of the ADCP II boxes and related equipment into the aircraft.

December 2023: Boom Supersonic has selected the Honeywell Anthem integrated flight deck for its Overture aircraft. As part of the agreement between the two companies, Honeywell's next-generation flight deck and its modular avionics platform will be incorporated into Overture. The Honeywell Anthem flight deck will be tailored for Overture's specific mission requirements, helping to enable exceptional situational awareness and enhanced safety. The advanced avionics interface provides continuity to Overture pilots from initial simulator-based flight training through to actual flights. Honeywell successfully completed the first flight of its Anthem integrated flight deck using its Pilatus PC-12 test aircraft in May 2023, paving the way for Federal Aviation Administration certification.

July 2023: Honeywell and Swedish aerospace and defense company Saab reached an agreement regarding the acquisition of Saab's heads-up display (HUD) assets. The HUDs will be integrated into the Honeywell Anthem flight deck (following a three-year collaboration) and will be available as an option for Honeywell's Primus Epic flight deck as well.

June 2021: Lilium has engaged with Honeywell to develop the 7-Seater Lilium Jet's avionics and flight control systems. Honeywell's Compact Fly-by-Wire System will act as the flight control system on the all-electric 7-Seater Lilium Jet, responsible for controlling its moveable parts, including the 36 control surfaces and ducted fans that will provide its high levels of manoeuvrability in every stage of flight. Alongside the flight control system, Honeywell will deliver the next generation integrated avionics system, which will provide a simplified user interface for the pilot to fly the Lilium Jet. The selection of Honeywell's next-generation UAM avionics system is the result of ongoing collaboration between Lilium and Honeywell to converge on the specific technical requirements suitable for the Lilium Jet. The avionics system is designed to reduce training time and will support operation by a single pilot, freeing up greater passenger capacity.

May 2021: Honeywell's flight deck technologies will act as core systems on Dassault's all-new Falcon 10X jet. The newest model from Dassault features a range of 7,500 nautical miles, which allows it to fly from Los Angeles to Sydney or Hong Kong to New York with nary a stop. Along with the extended range, the aircraft will offer enhanced comfort and safety to optimize the passenger experience. Furthermore, Honeywell's advanced flight deck technologies will bring a user-friendly experience for future pilots of the Falcon 10X.

Counterpoint comment

Honeywell has sustained its leadership position as a preeminent integrated avionics system supplier despite the competitive pressures from acquisitive entities such as Raytheon, Safran, Lockheed Martin, and L3Harris. The companys contractual engagements encompass a broad spectrum of both commercial and military platforms. Notably, Honeywell continues to achieve robust profit margins in the high twenties, even in the post-pandemic environment.

19.1.13.1 BENDIXKING

Vincent Bendix started the Bendix organisation with an idea for an automatic starter for automobiles in 1911. Bendix Corporation was renamed the Bendix Aviation Corporation in 1929 to signify a new direction for the company. Bendix formed its radio division in 1937 to make avionics and radio transmitters/receivers for aircraft.

Ed King formed the King Radio Corporation and created the first low-cost, crystal controlled, 90 channel, VHF transceiver for smaller aircraft, dubbed the KY 90. King Radio released the KTR 900, the first all solid state transceiver, for airlines in 1966. King Radio released the KDF 800, the first digital automatic direction finder (ADF) for general aviation, in 1969. King Radio released the KX 175, the first low cost all solid state VHF navigation and communications unit with TSO design approval, in 1970.

In 1999, AlliedSignal merged with Honeywell and adopted the Honeywell name to take advantage of the company's universal recognition throughout the industries it serves, as well as in households around the world. Shortly after the merger was completed, Honeywell announced that due to pilot recognition and loyalty, it would retain the BendixKing brand for its general aviation avionics.

In 2011, BendixKing established its new headquarters in Albuquerque, New Mexico. The tradition of leadership and innovation continues with BendixKing.

Financials

Based upon historical reported revenues we estimate that BendixKing generated $25m in revenues in 2019, and $20m in 2020.

Locations

BendixKing has its main facilities in Albequerque, New Mexico, where it owns a 40,000 ftš facility and employs 140 personnel.

Capabilities

BendixKing designs, develops, sells, and supports a full suite of avionics, including integrated flight decks, navigators, audio panels, radios, transponders and ADS-B transceivers, autopilots, radar-based storm sensors, and in-flight and on-ground connectivity.

BendixKing avionics are offered on a variety of aircraft in the general aviation market, including single-engine and twin-engine piston and turboprop airplanes, business jets, helicopters, and military trainers.

Customers and contracts

BendixKing's products are found on aircraft manufactured by Cessna, Piper, Mooney, Beechcraft, Diamond, Cirrus, Pilatus, Hawker, Lear, Textron, Dassault and many others.

Their products are marketed, installed and supported by a globally distributed team of sales professionals and over 500 authorised dealers located throughout the North and South America, Europe, Middle East, Africa, Asia and the South Pacific.

Strategy

BendixKing offers lower cost products and it focus upon the lower priced tiers of the Aerospace & Defence sector should continue to serve it well.

Bendix King states that its strategy is focussed upon developing networked connectivity within all aircraft and is promoting subscription services via satellite accordingly.

Bendix King is offering its business commuters/operators satellite wi-fi connectivity for $39 per hour of $399 per month.

Recent developments

None that we can see.

Counterpoint comment

For many years BendixKing suffered neglect as a business brand where it was part of the much larger Honeywell Aerospace business. Much of its market share had been eaten away by the likes of Garmin, Universal Avionics, Astronics and others.

However the move to a low cost location, and its independence as a brand has allowed it to continue to service the GA, small bizjet and rotorcraft market sector.

We believe that Honeywell could dispose of BendixKing at some point as it does not appear to be a core part of their future and they are becoming stretched for investment over a wide range of systems.

19.1.13.2 CAES

CAES (formerly known as Cobham Advanced Electronic Solutions) is a leading supplier of high-performance avionics and electronic solutions for aerospace, defense, space, and industrial applications. With a rich history of innovation and technological excellence, CAES offers a comprehensive portfolio of advanced electronics, including mission-

critical systems, radio frequency (RF) and microwave components, and subsystems that power a wide range of platforms from satellites to fighter jets.

The company was founded in 1934, and made its first acquisition of Atlantic Microwave Corporation in 1994, which become part of what is known today as Cobham Advanced Electronic Solutions (CAES). In the following years CAES expanded significantly following its acquisition strategy. The acquisitions made are:

- 1996: Acquisition of Continental Microwave Tool & Co. and Kevlin Corporation
- 1997: Acquisition of Nurad Technologies Inc.
- 1998: Acquisition of Premier Microwave
- 2001: Acquisition of Litton Airtron Microwave Product Line
- 2005: Acquisition of Microwave Development Company (MDC) as well as REMEC Defense and Space Inc.
- 2008: Acquisition of BAE Systems' Sensor and Antenna Systems Lansdale Inc.
- 2008: Acquisition of Tyco Electronics' M/A-COM Radio Frequency Components and Subsystems business (Whose portfolio consisted of acquired solutions from Microwave Associates as well as Stellex Microwave/Watkins Johnson and Adams-Russell)
- 2011: Acquisition of Trivec Avant Corporation
- 2014: Acquisition of Aeroflex
- 2023: Acquisition of Colorado Engineering Inc. (CEI)
- 2023: Acquisition of Herley (the specialist RF portion of Ultra)

In 2020, Cobham was acquired by Advent International, a private equity investor. Advent completed its buyout of the then Cobham Advanced Electronic Solutions for $5 billion in 2020 and later carved out CAES as a standalone entity in 2021.

In September 2024, Honeywell completed the acquisition of CAES from Advent International for approximatly $1.9 billion in an all-cash transaction. By the time of the acquisition, the company had around 2,200 employees.

Financials

The following financials are for AI Convoy (Luxemborg) S.a.r.l, the parent company of Cobham Limited. The CAES RF revenues relate to the entity that was sold to Honeywell.

FYE 31/12/23 - £millions	2023	2022
Sales - Communications and connectivity	223	211
Sales - CAES RF	704	662
Sales - total	927	874
Operating profit	24.7	(18.9)
Operating margin	2.7%	(2.2)%

Honeywell estimated to investors that 2024 run rate revenue for CAES would be $800m and that the purchase price of $1.9billion was 14x 2024 estimated EBITDA, implying an EBITDA of around $140m.

Locations

Cobham Advanced Electronic Systems is headquartered at Arlington, VA, USA and has 13 facilities in the United States including Colorado Springs, USA, Plainview NY, USA, San Diego, CA, USA and Exeter, NH, USA. CAES has about 2,200 employees by the time of the Honeywell acquisition in 2024.

Capabilities

CAES provides:

- Low-band Transmitters for Communications Countermeasures: The EA-18G Growler carries the CAES Integrated Antenna/Radome and Low-Band Transmitter, which is designed to protect strike aircraft, ships and ground troops by disrupting enemy radar and communications.
- Electronic Warfare Self Protection (EWSP) products and services offer a suite of countermeasure solutions to protect land, sea and air platforms from weapons fire. CAES EWSP products and services include an extensive suite of radar warning receivers (RWR) fitted to fixed- and rotary-wing aircraft.
- Electronic Surveillance products enable threat recognition, targeting and other tactical actions such as threat avoidance and homing. CAES products are also used for Signals Intelligence (SIGINT) to analyse intercepted frequencies and identify traits such as frequency, bandwidth, modulation and polarisation. CAES has developed and deployed electronic surveillance subsystems on multiple fixed- and rotary wing aircraft, attack-class submarines, missiles and ground vehicles.
- Provides data links and telemetry modules for use in UAV systems, missiles and munitions.
- Offers a variety of custom advanced electronics for transmit and receive functionality such as transmit/receive (T/R) modules, transmitters, receivers and AESA radars.

Customers and contracts

CAES has known contracts on:

- F-35
- EA-18G Growler
- AIM-120 Advanced Medium-Range Air-to-Air Missile
- GMLRS

84% of Cobham Advanced Electronic Systems' revenues are defense related with 60% in total generated within the US.

Strategy

It is unclear what CAES's strategy will be under the new ownership, but Honeywell commented that "This acquisition will enhance Honeywell's defense technology solutions across land, sea, air and space, including new electromagnetic defense solutions for end-to-end radio frequency (RF) signal management. With CAES' scalable offerings and Honeywell's current defense and space portfolio, the combined company will grow Honeywell's established production and upgrade positions on critical platforms that include F-35, EA-18G, AMRAAM and GMLRS, while also introducing offerings on new platforms like Navy Radar (SPY-6) and UAS and C-UAS technologies. Based on current and anticipated demand, these programs are expected to grow significantly in the years to come, creating a favorable tailwind for revenue growth of Honeywell's Aerospace Technologies business.". "Looking ahead, Honeywell sees attractive opportunities to expand the combined solutions internationally, capitalizing on accretive growth spaces with select defense customers."

Recent Development

July 2024: CAES received an award of $172.7 million from Raytheon Technologies in support of a major international missile program. This award covers the next three lots of follow-on production for the missile data-link assembly.

January 2024: CAES announced that it has expand its product offerings with a new direct-to-digital RF converter designed to optimally meet the bandwidth and form factor requirements of radar, electronic warfare, and C4ISR mission applications. The CAES TORNADO converter, the latest in CAES' investment in direct RF sampling architectures, has 8x transmit and 8x receive channels paired with the Intel Agilex® 9 FPGA Direct RF Series in a 3U, SOSA-aligned configuration. CAES is providing early access to design a product based on Intel's advanced technology. The CAES TORNADO converter is the first product of its kind to combine CAES's reliable engineering and 3U board with Intel's flexible and scalable RF-Series FPGA. The CAES TORNADO converter will be ready for delivery in 2024.

Feburary 2024: CAES announced that its Autonomous Flight Termination Unit (AFTU) performed flawlessly on a recent flight of a hypersonic test platform. The flight test was part of a program to validate payload performance in a very challenging, operationally-relevant hypersonic environment. This live flight success signifies a major milestone in product development.The CAES AFTU is a fully configurable termination unit that employs the latest software, technologies, and manufacturing processes to provide a high-performance, long-life product. It is extremely low SWAP and is capable of handling the harshest operational environments.

October 2023: CAES has been awarded a contract from the U.S. Navy for production of the AN/ALQ-99 Low Band Consolidation (LBC) transmitter. Total funding through 2025 to support both the U.S. Navy and Royal Australian Air Force (RAAF) is expected to exceed $55 million, if all options are exercised. This award also includes new special test equipment and follows a contract for the initial pre-production phase of the LBC.

June 2023: CAES is investing in the future with a new automated tuning process that is bringing enhanced accuracy, consistency and competitiveness to its San Jose manufacturing facility. Machine learning was a key technology capability CAES utilized in the development of the new automated tuning process. CAES San Jose has implemented the Automated Robotic Tuning (ART) system on one of its current missile programs of record since December 2022 and is looking to expand the application to other programs. By automating the tuning process, CAES is able to manufacture a much more consistent product in significantly less time.

April 2023: CAES has been awarded a contract from the US Navy for the initial pre-production phase of the AN/ALQ-99 Low Band Consolidation (LBC) transmitter. The LBC is a modification to the AN/ALQ-99 Low Band Transmitter.

March 2023: CAES announced that Herley has joined CAES, further expanding the company's footprint in the RF market. Herley delivers high-integrity, small Size, Weight and Power (SWaP) and application specific RF and electronic warfare assemblies, tactical RF products and missile flight instrumentation solutions. With facilities in Woburn, Massachusetts; Whippany, New Jersey; and Lancaster, Pennsylvania, the company brings an experienced team, strong customer relationships and new strategic programs to CAES. With the combination, CAES grows its portfolio of solutions with added capabilities in missile flight instrumentation, customized RF solutions for microwave assemblies and tactical radio frequency.

March 2023: CAES announced that its 3U converter was selected for inclusion in the US Air Force's MIRAGE airborne Electronic Warfare (EW) pod demonstration. The new SOSA-aligned 3U wideband RF converter was recently sent to Georgia Tech Research Institute for integration into the demonstration. The converter leverages the Government-Owned Modular Open System Approach (MOSA) as well as polarization-diverse cross-notch antennas."The MIRAGE Pod will provide the USAF a flexible platform to mature and assess, in operationally relevant environments, EW/EMS capabilities aligned to Open Architecture Standards. The ultimate goal is to enable rapid fielding of capabilities to Programs of Record. Initial pod experiments will begin on multiple aircraft starting this summer," said Jacob Hardegree, Tech Advisor EW and Avionics Division, Agile Combat Support Directorate, Air Force Life Cycle Management Center. "CAES' 3U wideband converter was selected because it is high performance and SOSA-aligned, allowing for direct integration into the existing USAF ruggedized SOSA chassis. CAES was selected after an analysis of available industry offerings and was determined to have the best solution for the initial MIRAGE experiment."

January 2023: CAES announced that it has been awarded a Low Rate Initial Production Phase 2 (LRIP2) contract from Lockheed Martin Corporation. Under the contract, CAES will supply its high performing Phased Array Antennas to support Lockheed Martin's Advanced Off-Board Electronic Warfare (AOEW) system. Lockheed Martin's AOEW Active Mission Payload (AMP) AN/ALQ-248 system, is a self-contained EW pod hosted by an MH-60R or MH-60S Seahawk helicopter, which provides the Navy advanced ASM detection and response capabilities. The announcement follows the Low Rate Initial Production Phase 1 (LRIP1) Contract that CAES was awarded earlier 2022.

November 2022: CAES announced that it has been chosen by Argotec, an Italian aerospace engineering company, to provide its radiation hardened GR712RC dual-core LEON3FT SPARC V8 Microprocessor on several key space missions. The GR712RC is a dual-core LEON3-FT SPARC V8 processor, with advanced interface protocols, dedicated for high reliability rad-hard aerospace applications.

May 2022: Criteria Labs, an industry leader in high-reliability RF components and semiconductor engineering solutions has partnered with CAES to consult on systems development and production of die carrier assemblies in support of the U.S. Navy's Advanced Offboard Electronic Warfare program (AOEW). The AOEW program will deliver persistent electronic surveillance (detection) capability against naval threats like anti-ship missiles (ASM). Criteria Labs will support in the delivery of low rate initial production (LRIP) lots before the start of full-rate production (FRP) in 2023 or 2024.

April 2022: CAES announced that it has been awarded a Low Rate Initial Production Phase 1 (LRIP1) Contract by Lockheed Martin Corporation for Phased Array Antennas to support its Advanced Off-Board Electronic Warfare (AOEW) system. The AOEW program delivers persistent electronic surveillance and attack capabilities against potential threats such as anti-ship missiles, thereby allowing naval warfighters to not only see incoming threats, but respond to them in real-time.

December 2021: CAES introduced a wideband, Gallium Nitride (GaN) based, high-power wideband RF amplifier. The ruggedized RF amplifier features the industry's best RF output power-to-weight ratio and enables long distance stand-off jamming and self-protection applications for a wide range of assets, including airborne platforms with stringent SWAP requirements such as UAVs and EW pods.

November 2021: CAES released the industry's smallest 0.5- to 18-GHz single-3U-slot wideband up/down converter with integrated local oscillator (LO) and preselection. The high-performance frequency converter is designed for the most challenging RF-based electronic warfare (EW) applications, including electronic intelligence and electronic support, surveillance and attack systems. The modular converter conforms to the SOSA technical standard, which facilitates system interoperability and alternate band configurations in small-form-factor embedded computing systems.

October 2021: CAES announced that it has acquired Colorado Engineering, Inc. (CEI), a leading Radio Frequency (RF) and high-performance computing (HPC) solutions provider in Colorado Springs, Colo. CEI's cutting-edge advancements in providing solutions to complex defense and commercial systems, along with their extensive experience in RF, digital, analog hardware and software solutions, complement CAES' leading RF, microwave and millimeter wave expertise and manufacturing capabilities across advanced electronics that serve the Aerospace and Defense industry.

Counterpoint comment

CAES is a prominent entity specializing in advanced RF and EW technologies, with substantial investments in research and development. Despite these investments, the company's profit margins are comparatively lower than those of its competitors. Additionally, CAES has pursued growth through strategic acquisitions. We anticipate assessing the company's performance and strategic direction under Honeywell's ownership moving forward.

19.1.14 INNOVATIVE SOLUTIONS AND SUPPORT

Innovative Solutions and Support, Inc. was incorporated in Pennsylvania on February 12th, 1988. The company operates in one business segment as a systems integrator that designs, develops, manufactures, sells and services air data equipment, engine display systems, standby equipment, primary flight guidance, auto-throttles and cockpit display systems for retrofit applications and original equipment manufacturers. The Company supplies integrated Flight Management Systems, Flat Panel Display Systems, air data equipment, Integrated Standby Units, and advanced Global Positioning System receivers that enable reduced carbon footprint navigation.

In June 2023, IS&S acquired certain assets and was granted perpetual license rights to manufacture and sell licensed products related to Honeywell's inertial, communication and navigation product lines.

Financials

FYE 30/09/23 - USD millions	2023	2022	2021	2020	2019
Net Sales	34.8	27.7	23.0	21.6	17.6
Operating income	7.4	7.2	3.9	2.7	1.5
Return on sales	21.2%	26.0%	17.0%	12.5%	8.5%

Commenting on the latest results, the company stated: "Net sales in fiscal 2023 increased $7.1 million, or 25.5%, to $34.8 million from $27.7 million in fiscal 2022. Product sales in fiscal 2023 increased $0.2 million compared to fiscal 2022. EDC sales increased $0.7 million, or 146.8% compared to fiscal 2022, reflecting increased EDC business. Customer service sales increased $6.2 million, or 127.2% from fiscal 2022. The increase in customer service sales primarily reflects customer service sales of $5.8 million due to the Honeywell Agreement. The increase in product sales primarily reflects increased shipments of displays to general aviation customers and commercial transport customers of $0.7 million and $0.6 million, respectively. Military product sales decreased $1.1 million due to reduced business volume."

Operating income for FY23 increased by 2.8%, compared with an 85% increase reported in the preceding twelve-month period. Scrutiny of the latest financial accounts however, reveals a notable increase 60% - in selling, general and administrative expenses from 2022 to 2023, compared with only 8% during 2021 to 2022.The company noted that "SG&A expense in fiscal 2023 was primarily the result of increased stock compensation expense and legal fees, professional fees, audit fees and amortization expense primarily related to the Transaction and increased board director fees."

We estimate that Innovative Solutions and Support generated revenues of $24m in respect to avionics products in 2023.

Locations

In 2001, Innovative Solutions and Support purchased 7.5 acres of land in the Eagleview Corporate Park in Exton, Pennsylvania. The company constructed a 45,000 ftš design, manufacturing and office facility on this site. Land development approval allows for expansion of up to 20,400 ftš. Such expansion would provide for a 65,400 ftš facility which the Company believes is adequate to meet the needs the foreseeable future.

The Company also occupies 8,358 ftš of office and warehouse space in Exton, Pennsylvania under a lease expiring in March 2021.

Capabilities

Flight Management Systems: The FMS offers full performance navigation and mission planning capabilities, storage for up to 128 Waypoints, storage for up to 100 Flight Plans, the ability to store a Global Nav Database on a 32 GB Solid State Drive, a common ARINC 424 Database, and integration with existing IRU/AHRS equipment. Flight crews will utilise the data in the navigation database to create, edit and modify flight plans. Navigation data includes airways, jet routes, SIDS, STARS, user stored routes and more. The FMS interfaces with the Innovative Solutions and Support's SBAS GPS receiver to provide a WAAS/Global Positioning System (GPS) based navigation solution. The GPS receiver is located remotely depending on space availability.

Auto-throttle: The Innovative Solutions and Support ThrustSense Autothrottle is the first ever full regime auto-throttle system to be certified for the King Air. ThrustSense allows the pilot to automatically control the power setting of the engines from take-off to landing phases of flight, including go-around. The autothrottle computed and controls power levels reducing pilot workload.

Displays: Innovative Solutions and Support offer a range of LCD display formats from 10 inch up to 20 inch. The displays typically have an 80-degree viewing angle, NVIS compliant display lighting, and a non-glare, anti-reflective display surface.

ADAHRS: Air Data, Attitude and Heading Reference System (ADAHRS) replaces DG/VG's, AHRS and air data computers in a single, compact, light-weight unit. Coupled with the Innovative Solutions and Support Beta-3 GPS Receiver it can provide INS grade performance to 25-foot 3D positional accuracy. The Innovative Solutions and Support ADAHRS outputs in Digital and Analog in format aircraft attitude, heading, altitude and air speed to interface with existing autopilot and display systems at a fraction of the cost of comparable AHRS alone.

Air Data Modules: The Innovative Solutions and Support Air Data Module (ADM), is a self-sensing, RVSM compliant, digital air data computer (DADC). The ADM inputs static (Ps) and pitot (Pt) pressures, total temperature (Tt), and installation configuration data. Air data is output on ARINC 429 and RS422 data formats. The ADM receives barometer setting number and Selected Altitude via ARINC 429 input. The ADM has an altitude range of -1000 to 53,000 feet (16,154 meters), an airspeed range of 40 to 400 knots, and a barometer setting range (via ARINC 429) of 22.00 to 31.00 in Hg (745 to 1050 hPa).

RNP Navigator: Innovative Solutions and Support designed its RNP/LPV Navigator to allow for RNP operations without having to modify the existing FMS in older aircraft. This saves many operators from performing costly FMS and MMR upgrades. The solution is easily integrated into our Flat Panel Display System or Integrated Navigation Standby Unit increasing operator flexibility while minimising aircraft downtime.

Integrated Standby Unit: The Innovative Solutions and Support Integrated Standby Unit (ISU) calculates, processes and displays altitude, attitude, airspeed, slip/skid, and navigation display information into a logical and concise single instrument display. The unit is designed to support Radio Management and Alternate navigation functionality. The

ISU includes MEMS Gyro technology coupled with IS&S air data, RVSM and Flat Panel Display System (FPDS) product experience. The result is a highly reliable and accurate standby display system for retrofit and OEM applications.

Customers and contracts

The company's website lists over fifty customers, including airlines, air forces, OEM's, and other aerospace companies.

Customers of IS&S include the U.S. government (including the DoD, the Department of Interior and the Department of Homeland, Security), Air Transport Services Group Inc. ("ATSG"), Amazon.com, Inc., American Airlines, Inc. ("AAL"), Boeing, Deutsche Post, DHL Group, FedEx Corporation ("FedEx"), Icelandair, L3Harris Technologies, Inc. ("L3Harris Technologies"), Lockheed Martin, Corporation ("Lockheed Martin"), Pilatus, Sierra Nevada Corporation, Textron, and the Department of National Defense (Canada), among others. A limited number of customers make a significant contribution to overall sales. In FY 2023, the three largest customers, Pilatus, ATSG and Textron accounted for 23%, 12% and 10% of total revenue, respectively.

Known programmes include:

- Boeing 737NG Flight Deck Upgrade (aftermarket only)
- (K)DC-10 Cockpit/IP (aftermarket only)
- Boeing757/767 Cockpit/IP (757 aftermarket only)
- Cessna Citation AdViz Flat Panel Display
- Eclipse 500 Avio IFMS (aftermarket only)
- Eclipse 550 Vantage Cockpit/IP Flat Panel Display System (aftermarket only)(aftermarket only)
- Lockheed Martin C-130 EIDS and Cockpit/IP
- P-3 Cockpit/IP — (aftermarket only)
- McDonnell Douglas MD-80 (aftermarket only)
- Pilatus PC-12

Company's principal competitors include Honeywell, Collins Aerospace, L3Harris, GE Aerospace

Strategy

As stated in their 2023 Annual Report, the Company's objective is to become a leading supplier and integrator of cockpit information.

The company identify a number of key elements that contribute to their strategy for achieving this:

- Continue to drive the market toward the performance, situational awareness and safety advantages of equipping the ThrustSense® Autothrottle on both aftermarket and OEM aircraft
- Continuation of ThrustSense® Autothrottle STC Installations
- Focusing on retrofits
- Expand presence in the flat panel display market
- Continuing development of innovative products
- Maintaining focus on air data markets
- Increasing sales to DoD, other government agencies, defense contractors, commercial air transport carriers and corporate/general aviation markets
- Expanding international presence
- Acquisitions, investments, strategic partnerships or other ventures

Recent developments

June 2024: As reported in its investor relations, "Innovative Solutions & Support announced its response to the unsolicited, non-binding indication of interest to make a proposal from Christopher Harborne (the /"Non-Binding Indication of Interest"). The Non-Binding Indication of Interest contemplates a transaction in which Mr. Harborne would acquire all of the shares of the Company's common stock not already owned by Mr. Harborne at a price of $7.25 per share in cash. Per its terms, the Non-Binding Indication of Interest is also subject to negotiation, due diligence, execution of definitive agreements, and clearance under applicable antitrust and other laws, among other contingencies. After careful review and consideration consistent with its fiduciary duties, and in consultation with its financial, legal and other advisors, the Board of Directors of the Company unanimously determined that the Non-Binding Indication of Interest undervalues IS&S, lacks certainty, and is not in the best interests of the Company and its stakeholders. "

June 2023: IS&S entered into an Asset Purchase and License Agreement with Honeywell International, Inc. pursuant to which Honeywell sold, assigned or licensed certain assets related to its inertial, communication and navigation product lines, including a sale of certain inventory, equipment and customer-related documents, an assignment of certain contracts and a grant of exclusive and non-exclusive licenses to use certain Honeywell intellectual property related to its inertial, communication and navigation product lines to repair, overhaul, manufacture sell, import, export and distribute certain products to the Company for cash consideration of $35.9 million.

May 2023: Innovative Solutions & Support announced that it is providing its Utilities Management System (UMS) for the recently announced Pilatus PC-24 under a multi-year production contract. The IS&S UMS integrates multiple aircraft utility functions commonly supported by multiple individual controllers and monitors. The UMS-24 will monitor aircraft sensors and control aircraft systems as required achieving the system functions. This open architecture system will allow Pilatus to design and/or refine control and monitoring algorithms, in-house. The UMS-24 consists of four identical LRUs each one servicing up to 334 signals and controls. The four LRUs are data-linked through a high speed multi-line Ethernet ring. The interconnected system will integrate the PC-24 mechanical and electrical systems with the main avionics suite. Each unit contains two channels with dissimilar hardware and software.

March 2023: Avidyne and Innovative Solutions & Support have announced the debut of the Helix integrated flight deck for helicopters, with an initial application in the Sikorsky S76++. The Helix uses IS&S's 10.4-inch flat panel displays in concert with Avidyne's Helios flight management system to modernize legacy helicopters. Other features include 3D synthetic vision, electronic charts, ADS-B weather and traffic, and SBAS/LPV capability.

January 2022: Innovative Solutions & Support appointed president Shahram Askarpour to CEO following founder, chairman, and CEO Geoffrey S.M. Hedrick's death that was announced last week. Askarpour joined IS&S as VP of Engineering in 2003 and in March 2012 was promoted to president. He has more than 40 years of aerospace industry experience and before joining IS&S worked at Smiths Aerospace, Instrumentation Technology, and Marconi Avionics. Askarpour holds an undergraduate degree in electrical engineering from Middlesex University in the UK, a postgraduate certificate in systems engineering, and a Ph.D. in automatic control from Brunel University London.

Counterpoint comment

As a provider of discrete boxes, Innovative Solutions and Support is exposed to both the integrators and low cost providers such as Garmin and Universal Avionics. Innovative Solutions and Support's limited size may make it difficult for them to grow in this challenging sector.

19.1.15 JEWELL INSTRUMENTS

Jewell Instruments is a world leader in the manufacture and distribution of acceleration and tilt sensors as well as electronic compasses, avionics components, solenoids and panel meters. It provides custom solutions for a diverse group of industries, including aerospace.

Financials

We estimate that Jewell Instruments generated $28m of revenues in 2023.

In terms of avionics instruments we further estimate that Jewell generated $5m of revenues in 2023.

Locations

Jewell has two, fully modernised manufacturing facilities, one in Manchester, New Hampshire, and one in Barbados, West Indies. Both are fully capable of handling the most stringent manufacturing requirements while our Barbados facility also provides the extremely cost-competitive advantage of an offshore manufacturer.

60,000 ftš headquarters facility features R&D, engineering, and manufacturing personnel dedicated to Jewell's products and Partnership Manufacturing

The 20,000 ftš offshore manufacturing facility features a dedicated Jewell team experienced at providing low-cost, high-quality manufacturing.

Capabilities

Jewell Instruments is a leading provider of traditional electro-mechanical avionic meter mechanisms and instruments.

Applications include the following:

Their custom avionics assemblies can be manufactured for:

- Automatic Flight Control
- Ground Velocity Reference
- Tactical Air Navigation Beacon Systems
- Visual Omni Range
- Pilot Steering Indicators
- Hover Indicators
- Autopilot Systems
- Inertial Guidance Systems
- Horizon Situation Indicators
- Attitude & Direction Indicators
- Fuel Gauges
- Global Positioning Systems

Customers and contracts

Jewell does not list or identify its end customers, largely, we suspect, because it supplies to Tier2/3 suppliers and via distributors/stockists. It therefore may not always know on which platforms its products are installed.

These stand-alone discrete instruments and sensors are likely to be used for small business jets, GA, rotorcraft and UAV platforms.

Strategy

Jewell is largely a component provider offering older mechanical instruments in addition to solid state sensors. It operates in a niche market in terms of avionics with growing sales in other areas e.g. rail in China.

Recent developments

No recent developments

Counterpoint comment

A small independent niche provider of avionics components with limited exposure to aerospace.

19.1.16 L3HARRIS

Harris was incorporated in Delaware in 1926 as the successor to three companies and subsequently listed on the New York Stock Exchange. In 2019 Harris and L-3 entered into a merger agreement creating L3Harris Technologies, Inc. Harris today is a global aerospace and defense technology innovator, delivering end-to-end solutions for customers' mission-critical needs. They provide advanced defense and commercial technologies across air, land, sea, space and cyber domains. They support government and commercial customers in 130 countries, with its largest customers being agencies of the U.S. Government and their prime contractors. Harris's products, systems and services have defense and civil government applications, as well as commercial applications.

The company's activities are currently split into the following segments:

- Integrated Mission Systems (IMS): prime systems integration across the following segments:
  - ISR
  - Maritime
  - Electro-optical
  - Commercial Aviation Solutions (including integrated avionics, pilot training and data analytics services)
- Space and Airborne Systems (SAS): a provider of full missions solutions as a prime and subsystem integrator for the following segments:
  - Space systems
  - Intel & Cyber
  - Mission Avionics (including sensors, processors, hardened electronics, release systems and antennas for aircraft platforms)
  - Mission networks
  - Airborne combat systems
- Communication Systems (CS): enables warfighters across all domains and includes:
  - Tactical communications
  - Broadband communications
  - Integrated vision solutions
  - Public safety
- Aerojet Rocketdyne (AR): acquired in 2023, AR provides propulsion systems to the US government and is divided into two categories:
  - Missile Solutions
  - Space propulsion

Harris has a JV with Thales France titled Aviation Communications and Surveillance Systems (ACSS) which is responsible for marketing a range of products including its autonomous solutions (ADS-B) products and a wide range of its data products. It is covered separately within this report under section 18.1.

At the beginning of 2023, the company acquired Viasat Inc.'s Tactical Data Links product line commonly known as Link 16 for approximately $1.96 billion, subject to customary adjustments. Later in the year it acquired the technology-based engineering and manufacturing company, AJRD (Aerojet Rocketdyne), which specialises in missile solutions, and, space propulsion and power systems.

Recently, to improve business alignment the Agile Development Group ("ADG") business was moved from IMS to the SAS segment. Additionally, in October 2023 their Electronic Warfare sector and the majority of the Agile Development Group (ADG) business within the SAS segment was combined to create a new sector, Advanced Combat Systems ("ACS"). The remainder of ADG was combined with the Space Systems sector within the SAS segment. Furthermore, it was announced in November 2023 that the Commercial Aviation Solutions division with IMS, providing integrated avionics, pilot training and data analytics services for the commercial aviation sector, was to be sold.

L3Harris employed approximately 50,000 personnel at the end of 2023.

Financials

FYE 29/12/23 - USD millions	2023	2022	2021	2020	2019
Full year Revenue	19,419	17,062	17,814	18,194	18,074
Integrated Mission Systems revenue	6,630	6,626	5,839	5,538	5,400
Space and Airborne Systems revenue	6,856	6,384	5,093	4,946	4,700
Communication Systems revenue	5,070	4,217	4,287	4,443	4,300
Aerojet Rocketdyne	1,052	N/A	N/A	N/A	N/A
Aviation Systems revenue	N/A	N/A	2,783	3,448	3,900
EBIT	1,221	1,273	2,283	1,322	2,995
EBIT Margin	6.3%	7.5%	12.9%	7.3%	16.6%

Overall revenue rose by nearly 14% from the previous year, while EBIT fell by 4%. Commenting on revenue performance in IMS in the latest Annual Report, the company stated: "The flat IMS revenue in fiscal 2023 compared with fiscal 2022 was primarily due to lower revenue of $179 million in ISR largely from lower aircraft missionization volume, offset by higher revenues of $69 million in Electro Optical from higher volume in space and sensors, $63 million in Maritime largely from volume in classified programs, power and energy solutions and international and $61 million in Commercial Aviation Solutions from volume. The decrease in IMS operating income and operating margin in fiscal 2023 compared with fiscal 2022 were primarily due to a net change in EAC adjustments of $103 million, principally in ISR and in Maritime from net unfavorable EAC adjustments in fiscal 2023 due to program execution, and the sale of $33 million of end-of-life inventory in Commercial Aviation Systems during fiscal 2022. Such decreases were partially offset by $64 million of lower R&D expenses and $59 million of lower non-cash charges for impairment of goodwill and other assets in fiscal 2023."

Reviewing SAS performance, the company stated: "The increase in SAS revenue in fiscal 2023 compared with fiscal 2022 was primarily due to higher revenue of $445 million from program growth in Space Systems, Mission Networks and Intel and Cyber. The increases in SAS operating income and operating margin in fiscal 2023 compared with fiscal 2022 were primarily due to higher volume, $66 million of lower R&D expenses, $53 million of lower non-cash charges for impairment of goodwill and other assets, lower overhead costs and favorable mix in Space Systems due to a nonrecurring license sale during fiscal 2023. Such increases were partially offset by $40 million change in EAC adjustments from program execution during fiscal 2023."

The US Government is by far the largest customer. Whether the various departments and agencies of the U.S. Government, or foreign military sales funded through the US Government, revenue derived was 76% (74% in 2022).

Company backlog was $32.7 billion at the end of 2023, of which $22.0 billion was funded backlog.

We estimate that L3Harris generated $1,250m of avionics-related revenues in 2023.

Locations

L3Harris's principal executive offices are located at 1025 West NASA Boulevard, Melbourne, Florida, USA. Many of its avionics products are designed and manufactured within its Melbourne, Florida facility. As of December 2023, the company operated around 300 locations in the U.S., Canada, EMEA, APAC and South America.

Key locations for

Aviation Systems Melbourne, Florida; Muskegon and Grand Rapids, Michigan; Torrance, Menlo Park and Anaheim, California; Arlington and Plano, Texas; Cincinnati, Ohio; Hauppauge, New York; Herndon, Virginia; Tewksbury, Massachusetts; and Phoenix, Arizona.

L3Harris has 15 locations within the UK (part of the L3 merger) but does not produce airborne equipment in the UK.

Capabilities

Displays: L3Harris' 10.4-inch Multi-Function Display — Technology Refresh (MFD-TR) is a next-generation display system providing a superior sunlight readable image area with exceptional bezel functionality in a physical format that can be applied to fixed-wing aircraft, rotorcraft, ground vehicles, and shipboard systems. The AH-64 6.25" x 6.25" Multi-Purpose Display (MPD) is a high-resolution display that provides both colour and monochrome video with colour symbology that supports flight, mission operations and situational awareness to the crew.

Of particular note is Harris's contract for the panoramic wide integrated LCD display for the F-35 upgraded cockpit due to enter service in 2022/23.

Harris also offers a range of integrated standby displays for secondary/back-up navigation.

Antennas: The 1501341 Series (Batwing) antenna design provides high performance satellite communications for satellite elevation intercept angles of +35ř above the horizon through the aircraft zenith. This lightweight unit has been designed with performance parameters suitable for deployment in high performance, executive class aircraft, and helicopters. The antenna is constructed of a foam filled fiberglass housing which contains all component parts including the required phasing coupler.

Intelligence, Surveillance, Reconnaissance: Scalable Open Architecture Reconnaissance (SOAR™), the ground-breaking new ISR solution from L3Harris and General Atomics Aeronautical Systems, Inc., integrates industry-leading, full-band signals intelligence (SIGINT) capability with a medium-altitude, long-endurance Predator B wing-mounted pod to offer unparalleled options for war-fighters in the ISR domain.

Electronic Warfare Systems: In partnership with Lockheed Martin and the U.S. Air Force, L3Harris is developing the new AN/ALQ-254(V)1 Viper Shield to provide U.S. allies with cutting-edge countermeasures against sophisticated, ever-changing threats. This advanced electronic warfare system will provide a virtual electronic shield around the aircraft, enabling war-fighters to complete missions safely in increasingly complex battlespace scenarios. Its modern, all-digital architecture using commercial-off-the-shelf (COTS) technology enables enhanced system performance, a smaller form factor, reduced weight and easier future upgrades.

Cockpit Voice and Data recorders: L3Harris has been providing voice and flight data recorder solutions for nearly 60 years. The L3Harris recorders support air transport, regional, military and business aviation platforms. Specialised recorders are available for helicopters and general aviation. With 100% data retrieval rate, L3Harris has a global footprint providing highly reliable and innovative products.

Data storage: Series 4 Data Transfer System (DTS) provides a compact, self-contained system to store and retrieve data from removable 2.5-inch flash disks over either a USB or SATA interface. It is designed to meet MIL-STD-810 and RTCA DO-160 environments and provides up to a maximum capacity of 8TB of storage.

Tactical Air Navigation: TACAN+, provides efficiency, reduces costs and offers flexibility to pilots on various helicopter and military aircraft platforms. It is the only TACAN able to run four TACAN/DME ground stations simultaneously, and two in bearing, with a tracking velocity at 1800 knots. It also provides optimised Air-to-Air ranging performance for multi-aircraft scenarios with a software-controlled dual antenna switching and configuration and enables interface flexibility with A429 input and output ports for communication.

Electronic Warfare: Harris offers advanced integrated defense electronic warfare systems ("AIDEWS") that provide integrated and podded self-protection and jamming. It also provides integrated defensive electronic countermeasures ("IDECM") system for the F/A-18;

Customers and contracts

L3Harris notes that its principal competitors include BAE Systems, Boeing, General Dynamics, Lockheed Martin, Northrop Grumman, Raytheon (Collins Aerospace), and Thales.

For the F-35 Lightning II Joint Strike Fighter and F/A-18E/F Super Hornet aircraft, Harris provide high-speed fibre optic networking and switching, image processing, digital map software and other electronic components, including a multi-function Advanced Data Link communication subsystem primarily intended for stealth platform air-to-air communications. Other specific products and programmes include:

- F/A-18: Integrated Defensive Electronic Countermeasures (IDEC)
- F-16: Advanced Integrated Defensive Electronic Warfare Suite (AIDEW).
- B-52: Self-protection, countermeasures system
- MH-47: Self-protection, countermeasures system
- CV-22: Self-protection, countermeasures system
- MH-60: Self-protection, countermeasures system
- B-1B: Countermeasures systems
- C130 variants: ALQ-172 self-protection integrated RF subsystem has successfully defended B-52 bombers and Special Operation C-130 Combat Talons and Gunships against RF threats in combat missions.
- Electronic Warfare: Harris supplies electronic warfare systems (IDECM) for F/A-18 and B-52 aircraft
- Mission Avionics and Electronic Warfare: long-term avionics platforms, including the F-35, F/A-18, F-16, CV-22 and B-52.

L3Harris derives an unknown percentage of its revenues from classified programmes.

Strategy

L3Harris provides insight via its annual report and investor presentations as to its strategy which is focused on increased penetration of DoD budget pools, seeking adjacencies to its existing capabilities and realising synergies from its merger between L3 and Harris. It's latest annual report outlines the following pillars:

- Perform Execute on time and on plan
  - "e3 excellence everywhere every day": Core to L3Harris culture; Enduring approach to delivering value for customers and partners; Empowering teams to be efficient, innovative and entrepreneurial; Bottom-up approach
  - LHX NEXT (cost saving plan) - Delivering operational efficiencies by leveraging scale and relationships across segments; Top-down approach
- Grow Focus on profitable growth
  - Deliver solutions across the value chain
  - Increase share of platform mission content
  - Partner early with customers
  - Integrate strategic acquisitions
- Expand in prioritized attractive markets
  - Innovate Leverage technology and agility as a competitive edge. Key areas:
  - Resilient Networking & Communications
  - Multi-Domain Autonomy & AI
  - Kinetic & NonKinetic Effects
  - Spectrum & Information Dominance

L3Harris has made a number of divestments of non-core business in recent years (see recent developments). This includes its commercial aviation solutions business and its antenna business.

Recent developments

June 2024: L3Harris Technologies received a $34 million contract from the U.S. Air Force to help modernize the B-52 Stratofortress bomber. The award is part of the Air Force's Global Strike Command B-52 Quad Crew Program to consolidate the functions of the electronic warfare officer and navigator into one position. The B-52H is currently operated by a five-person crew that includes two pilots, two navigators and an electronic warfare officer. The consolidation of the two crew positions will include moving the control and display unit panels to the navigator station. The joint effort with the customer-led Crew Station Working Group will include a series of analysis such as aircraft weight and balance, structural and electrical load analysis and thermal cooling to identify any impact on the B-52 airframe and inform the modification kit design. L3Harris has been providing critical B-52 technology for decades as the Original Equipment Manufacturer of the AN/ALQ-172 systems for this aircraft fleet. The company continues to help the Air Force evolve its capabilities from analog to digital solutions to defeat the continuously changing threat landscape.

June 2024: L3Harris completed the sales of the company's antenna and related businesses to an affiliate of Kanders & Company, Inc for $200 million. The businesses L3Harris divested were part of the company's Space & Airborne Systems segment which employed approximately 375 people.

February 2024: Thales' motion (launched January 2024) for a preliminary injunction in aid of arbitration against L3 for its intended sale of its stake in ACSS to a private equity group was granted. Arguments relating to both public interest and balance of equities were upheld. The granting of the preliminary injunction preserves the status quo pending the outcome of the ICC arbitration process.

February 2024: L3Harris Technologies, in collaboration with EDGE, the United Arab Emirates' (UAE) leading advanced technology group for defense, opened a new WESCAM Authorized Service Center (WASC). Managed and operated by expert, locally-trained UAE nationals, the enhanced 42,000 ft^2 service facility will be equipped with the tooling, resources and technology required to service WESCAM MX™ Series EO/IR systems operated by the UAE's Armed Forces and other regional customers. Combined with EDGE's in-country experience and mission execution, the facility will increase customer operational availability and minimize maintenance turn-around times.

January 2024: Thales took initial legal action against L3 through the International Chamber of Commerce to prevent L3 from selling its 70% stake in the Thales L3Harris joint venture Aviation Communication & Surveillance Systems, LLC (ACSS) to private equity buyer, Jordan Group. Thales contended that L3's sale of their stake violated the terms of the parties' LLC Agreement, would cause harm to Thales, and that the public interest favours a preliminary injunction stopping the sale in order to allow the arbitral tribunal to decide whether to award effective relief.

November 2023: L3Harris Technologies announced the signing of a definitive agreement under which an affiliate of TJC L.P. will acquire L3Harris' Commercial Aviation Solutions (CAS) business for $800 million. The acquisition includes a $700 million cash purchase price and $100 million earnout based on the achievement of certain 2023 and 2024 financial performance targets, which together represent an approximate 15x LTM 9/30 EBITDA purchase multiple. The transaction is expected to close in the first half of 2024 and is subject to customary closing conditions and regulatory approvals. The CAS transaction includes the sale of L3Harris' surveillance joint venture and is subject to a right of first refusal; if exercised, an affiliate of TJC L.P. will acquire the rest of CAS. L3Harris' CAS business employs approximately 1,450 people and offers pilot training, flight data analytics, avionics, and advanced air mobility products and services, among other capabilities.

November 2023: L3Harris Technologies won a contract from the U.S. Navy to continue developing advanced systems to modernize electronic warfare (EW) capabilities on F/A-18 aircraft, enhancing pilot protection against emerging and future threats. L3Harris will develop a next-generation EW system under the $80 million contract for the Navy's F/A-18 fleet. It is one of two companies down-selected for the initial prototype contract. The final decision for follow-on development and production contracts is expected in 2026. The advanced L3Harris system will feature an integrated electronic support measure and electronic attack system, providing prompt threat detection across all relevant radio frequency bands. With a modular open systems approach and open mission systems compliant design, this innovation allows crews to easily insert new and upgraded technology, saving time and reducing costs. L3Harris has been providing EW capabilities for F/A-18s for more than two decades. The company has also been providing these capabilities for more than 60 years to the U.S. Air Force and to other allied air services around the world.

October 2023: L3Harris Technologies, Leidos and MAG Aerospace have teamed for the U.S. Army's High Accuracy Detection and Exploitation System (HADES) program. The companies aim to deliver a fleet of aerial intelligence, surveillance and reconnaissance (ISR) aircraft to rapidly collect relevant and reliable operational intelligence against the nation's

most advanced adversaries. Integrated on Bombardier Global 6500 aircraft, the proposed HADES solution will offer greater survivability, capability and coverage in support of U.S. combatant commands.

September 2023: BAE Systems and L3Harris Technologies delivered the first of 10 EC-37B Compass Call aircraft to the U.S. Air Force for formal combined developmental and operational testing. The next-generation system evolves the Air Force's 40-year mission of employing electromagnetic attack (EA) capabilities in support of U.S. and coalition air, surface, and special operations forces. Mission system prime BAE Systems produces the Compass Call Airborne Electromagnetic Attack mission system at its Hudson, New Hampshire facility. The system disrupts enemy communications, radars and navigation systems, and suppresses enemy air defenses by preventing the transmission of essential information between adversaries, weapon systems and command-and-control networks. Platform integration prime L3Harris integrated the EC-130H Compass Call mission system into a modern Gulfstream G550 business jet at its Waco, Texas aircraft missionization center. The EC-37B has increased speed, endurance and high-altitude operation for improved survivability and range to deliver EA effects.

July 2023: L3Harris Technologies Inc., the aerospace and defense company, is exploring a sale of its avionics business, according to people with knowledge of the matter. The U.S. company is working with an adviser on the sale, which could fetch about $1 billion based on typical earnings multiples, the people said, asking not to be identified discussing private information. The asset could attract interest from private equity firms and strategic buyers, they said. No final decision has been made and L3Harris could opt to hold onto the business, according to the people.

January 2023: L3Harris Technologies announced closing its acquisition of Viasat Inc.'s Tactical Data Links product line commonly known as Link 16 for approximately $1.96 billion, subject to customary adjustments. The company announced the signing of a definitive agreement to acquire the TDL network in October 2022 and secured U.S. and allied partner regulatory approvals in December.

December 2022: L3Harris Technologies announced a $29 million contract to provide smart weapon release systems to the air defense forces of Bahrain, Jordan and Morocco, enabling their pilots to double the number of smart munitions their F-16s can carry. The Bomb Release Unit (BRU)-57/A allows F-16s to carry two smart weapons on each system instead of one, doubling munitions capacity. It is compatible with 500-pound and 1,000-pound guided weapons. Tailorable to mission requirements, the release systems provide ground crews the flexibility to add or remove smart weapons capabilities on F-16s.e on station with fewer returns to base for rearming. The indefinite-delivery, indefinite-quantity contract includes an initial lot of 105 release systems.

October 2022: L3Harris Technologies has delivered its 6,000th WESCAM MX-Series imaging system, which provides customers in more than 80 countries with advanced intelligence, surveillance and reconnaissance and targeting capabilities. The milestone delivery was a WESCAM MX-25D electro-optical/infrared (EO/IR) and laser designator sensor system delivered to U.S. Special Operations Command (USSOCOM) in support of the Air Force Special Operations Command's (AFSOC's) AC-130J gunship modernization strategy. L3Harris WESCAM MX systems are active in more than 80 countries. Operating across air, land and maritime domains, these intelligence, surveillance and reconnaissance and targeting systems support more than 200 different platforms.

October 2022: L3Harris Technologies and MAG Aerospace will provide enhanced intelligence, surveillance and reconnaissance (ISR) aircraft in support of the Army's Theater Level High-Altitude Expeditionary Next Airborne ISR Radar (ATHENA-R) program. The ATHENA-R aircraft, converted Bombardier Global Express 6500s with ISR mission capabilities, will support U.S. Army missions in the U.S. Indo-Pacific Command area of responsibility. Designed to close the gap between the Army's medium- and high-altitude ISR aircraft fleet, the ATHENA-R provides longer range, greater endurance, more capacity for bigger payloads and standoff ranges, and leading-edge sensor technology. The two companies will equip the aircraft with new radar and electronic and communications intelligence capabilities. MAG delivers world-class command, control, computers, communications, cyber and ISR service delivery expertise to bring turnkey disruptive technology to U.S. government and allied customers around the world. L3Harris currently operates a Bombardier Global Series jet as part of its Airborne Reconnaissance and Electronic Warfare System (ARES) supporting Army Pacific Command and expands its extensive Army ISR portfolio as part of L3Harris/MAG ATHENA effort.

September 2022: L3Harris Technologies won a $91.5 million contract from Boeing to supply mission-management processors for the T-7A Red Hawk, the first U.S. Air Force jet trainer in 60 years. The mission-management processors, developed specifically for the Red Hawk, collate multiple data streams, making the information a pilot has to process in-flight easier to decipher. The sensors and communication capabilities maximize battlespace awareness by connecting internal and external data networks and link video feeds to flight displays. The processors also host specific simulations for pilots undergoing training. The T-7A Red Hawk, slated to be operational by 2024, pays tribute to the

famed African American Tuskegee Airmen of World War II, known as the Red Tails.

August 2022: U.S. Special Operations Command (USSOCOM) has selected L3Harris Technologies and Air Tractor, Inc.'s AT-802U Sky Warden™ system for its Armed Overwatch program. Award of the Indefinite Quantity, Indefinite Delivery contract includes a cost ceiling of $3 billion. The program includes delivery of up to 75 manned, fixed wing aircraft, with an initial program contract award of $170 million. The fleet of modern multi-mission aircraft will address SOCOM's need for a deployable, sustainable single-engine fixed-wing, crewed and affordable aircraft system. It will provide close air support, precision strike, armed intelligence, surveillance and reconnaissance (ISR), strike coordination and forward air controller requirements for use in austere and permissive environments. The aircraft will be used in irregular warfare operations. L3Harris expects to rapidly modify last summer's Armed Overwatch prototype demonstrator into the production configuration and provide for customer weapon system testing in approximately six months. Production of new, fully-modified, Armed Overwatch mission-configured aircraft will begin in 2023 at L3Harris' Tulsa, Okla. modification center, following initial production at Air Tractor's Olney, Texas aircraft manufacturing facility. Six new aircraft will be delivered under the low-rate initial production Lot 1.

October 2021: L3Harris Technologies received a $500,000 state grant to help the company pay for a $2.6 million expansion at its Cascade Township factory that will create 34 jobs. The company is consolidating its aviation electronics manufacturing services at the Cascade Township plant, a move that will retain 21 jobs and is expected to create an additional 34 positions, according to the Michigan Economic Development Corporation.

Counterpoint comment

L3Harris maintains a significant presence in the US military sector and has established a notable foothold in Canada, Italy, and the UK, particularly in the domains of security and air traffic control infrastructure. Recent strategic realignments have seen L3Harris divest from non-core business segments, including its commercial aviation solutions and antenna businesses. Furthermore, the future of its joint venture with Thales, which focuses on providing surveillance products, remains uncertain due to ongoing disputes.

19.1.17 LOCKHEED MARTIN

Lockheed Martin is a Maryland, US based corporation formed in 1995 by combining the businesses of Lockheed Corporation and Martin Marietta Corporation.

It has four strategic business areas today including the following:

- Lockheed Martin Aeronautics platforms:
  - F-35 Lightning II Joint Strike Fighter
  - C-130 Hercules - international tactical airlifter
  - F-16 Fighting Falcon - low-cost, combat-proven, international multi-role fighter
  - F-22 Raptor - air dominance and multi-mission fifth generation stealth fighter.
- Missile and fire Control (MFC)
- Rotary and Mission Systems (RMS)
- Space

Lockheed Martin has the following capabilities within its MFC and RMS divisions:

- MFC has avionic related product capabilities including F-35 Electro-optical targeting system, Fire control, electro-optics, radar for warning/targeting, Lantirn sensor pod including NAV and IRST sensors.
- Within RMS has Electronic Warfare systems for Apache and Blackhawk, Radar warning.

Financials

MFC sales continued to decrease since 2021, with a year-on-year drop of $64m compared with 2022. In contrast, RMS experienced an increase - $91m from the previous year. In 2023, Lockheed Martin's total net sales amounted to $67.6bn across its four business divisions. MFC and RMS sales contributed to 16.8% and 24.0% respectively.

FYE 31/12/23	2023	2022	2021	2020	2019
MFC Sales $m	11,253	11,317	11,693	11,257	10,131
MFC Operating profit $m	1,541	1,637	1,650	1,545	1,441
MFC Operating margin %	13.7%	14.5%	14.1%	13.8%	14.2%
RMS Sales $m	16,239	16,148	16,789	15,995	15,128
RMS Operating profit $m	1,865	1,906	2,030	1,615	1,421
RMS Operating margin %	11.5%	11.8%	12.1%	10.1%	9.4%

We have estimated that Lockheed Martin generated $610m from avionics-related product sales in 2023.

Locations

Lockheed Martin's main manufacturing facilities for Missiles & Fire Control (MFC) and Rotary & Mission Systems (RMS) are as follows:

- Missiles and Fire Control - Camden, Arkansas; Ocala and Orlando, Florida; Lexington, Kentucky; and Grand Prairie, Texas
- Rotary and Mission Systems - Stratford, Connecticut; Orlando, Florida; Moorestown/Mt. Laurel, New Jersey; Owego and Syracuse, New York; Manassas, Virginia; and Mielec, Poland

MFC has its largest facility in Orlando which is also an R&D centre where it employs in excess of 8,000 people. Lexington Kentucky is a major MFC facility with 3,000+ employees. The Santa Barbara facility supports the design and manufacture of electro-optical products.

Rotary and Mission Systems - RMS employs approximately 34,000 people in the U.S., Canada, Mexico, Taiwan, Japan, United Kingdom, Germany, Poland, the Netherlands, New Zealand and Australia.

Capabilities

Missiles and Fire Control — Provides air and missile defense systems; tactical missiles and air-to-ground precision strike weapon systems; logistics; fire control systems; mission operations support.

- The Electro-Optical Targeting System (EOTS) for the F-35 Lightning II is an affordable, high-performance, lightweight, multi-function system that provides precision air-to-air and air-to-surface targeting capability in a compact package.
  - 1,149 produced to date.
- The Distributed Aperture System (DAS) Window Panel set for the F-35 Lightning II consists of six low-observable, infrared transparent windows for Electro-Optical (EO) DAS sensors that provide threat detection and 360-degree situational awareness to the pilot.
  - 7,104 produced to date.
- As a passive, long-range sensor system, IRST21 uses infrared search and track technology to detect and track airborne threats with weapon-quality accuracy, increasing pilot reaction time and improving survivability in radar-denied environments.
  - First operational flight on F-16 — July 2020
  - Competitively selected for F-15 program of record — August 2017
  - Block II contract awarded by U.S. Navy; the next generation of IRST21 technology — July 2017
  - First fielded on F-18 — March 2019
  - First flight on F-15 — July 2016
  - First flight on F-16 — June 2015

- A proven electro-optical targeting system, Sniper ATP is housed in a single, lightweight pod. Sniper ATP handles the most challenging precision targeting and intelligence, surveillance and reconnaissance (ISR) air-to-air and air-to-ground missions.
  - Operational across 15 aircraft platforms among 27+ domestic and international customers
  - Laser designator with aircrew selectable tactical and eye-safe wavelengths
  - Laser Lead Guidance (LLG) against moving targets

Rotary and Mission Systems: Lockheed Martin provides design, manufacture, service and support for a variety of military and commercial helicopters; ship and submarine mission and combat systems; mission systems and sensors for rotary and fixed-wing aircraft; sea and land-based missile defense systems; radar systems.

Electronic Warfare:

- Lockheed Martin has fielded more than 3,000 airborne electronic warfare systems over the last 45 years, including electronic support measure (ESM), electronic attack (EA), radar warning receiver (RWR), electronic intelligence, communications intelligence, and anti-jam GPS products.
- Lockheed Martin provides the AN/ALQ-210 for the U.S. Navy and international MH-60R and the AN/ALQ-217 on the U.S. Navy's E-2C/D aircraft. Lockheed Martin has recently upgraded the ALQ-217 with a digital receiver and enhanced capabilities. Lockheed Martin has modernised the targeting ESM system on the U.S. Army and international Apache AH-64D/E aircraft with the digital receiver based Modernised Radar Frequency Interferometer (MRFI). Lockheed Martin extends this digital receiver product line with its newest system, the APR-52 Digital RWR, on the USAF Combat Rescue Helicopter.

Anti-jamming systems: GSTAR is a fully digital system providing protection against adversarial jammers for all types of platforms. The beam-steering capability allows the platform to survive the harshest of contested environments. GSTAR can be configured as a nulling only solution for compatibility with existing GPS Receivers with the inherent growth to beam-steering without replacement of the GSTAR or the antenna.

Radar/Advanced Early Warning: Lockheed Martin's radar and electro-optical/infrared sensor systems provide advanced precision targeting, navigation, threat detection and next generation intelligence, surveillance and reconnaissance capabilities. From the Navy's Advanced Hawkeye system on the E-2D aircraft to the unmanned airborne Legion Pod's infrared search and track (IRST) system provides passive, high-fidelity detection and tracking of air-to-air targets in radar-denied environments.

Auto GCAS: Lockheed Martin Skunk Works - The Auto GCAS, developed jointly by Lockheed Martin Skunk Works® , the Air Force Research Laboratory and the National Aeronautics and Space Administration (NASA), is designed to reduce incidents of what is known as controlled flight into terrain, or CFIT. According to U.S. Air Force statistics, CFIT incidents account for 26 percent of aircraft losses and a staggering 75 percent of all F-16 pilot fatalities.

- The Auto GCAS capability is currently operating on more than 600 U.S. Air Force F-16 Block 40/50 aircraft worldwide
- Lockheed Martin and the F-35 Joint Program Office (JPO) completed F-35 Auto GCAS integration and flight testing in 2018 and began fielding this proven life-saving technology in 2019.

Displays: The TADS Electronic Display and Control (TEDAC) is the modernised replacement for the Optical Relay Tube (ORT) located in the co-pilot/gunner (CPG) crew station of the AH-64 Apache Helicopter. The TEDAC presents the CPG with high resolution sensor video from the Modernised Target Acquisition and Designation Sight (M-TADS). TEDAC replaces the ORT's small CRT display and direct view optics with a large 5" x 5" flat-panel cockpit display that utilises active matrix liquid crystal display (AMLCD) technology.

Customers and contracts

Specific avionics applications are listed below:

- F-35: Electro-optical targeting system and Distributed Aperture Radar system
- The AN/APR-48B Modernised Radar Frequency Interferometer (MRFI) is installed on the AH-64E Apache Guardian helicopter.

- The AN/ALQ-217 ESM system functions as the highly sophisticated ears of advanced tactical aircraft and is currently installed on the U.S. and international E-2C and E-2D Advanced Hawkeye and P-3C type aircraft.
- The multi-mission AN/ALQ-210 Electronic Support Measures (ESM) and concurrent RWR system is fitted to the MH-60R rotorcraft.
- AH-64: TADS AMLCD display system for target acquisition and designation.
- F-16: Auto — GCAS system
- E-2D Advanced Hawkeye early warning radar system.
- F-15/F-16/F/A-18: IRST 21 infrared search and track systems.
- Unmanned Air Systems: PODs for reconnaissance, search and tracking.
- Apache AH-64: Electronic Warfare suite
- Sikorsky Blackhawk: Electronic Warfare suite

Strategy

Lockheed Martin invests in advanced software and digital technologies required for next generation platforms. It clearly has an advantage as an OEM constructor of the F-35, C130J and Sikorsky platforms which arguably provides it with additional insight and access.

Its strategy is to continue to develop high end sensitive electronic capabilities for multinational platforms that are operating around the world.

Recent developments

July 2024: Lockheed Martin has been awarded a $4.6 million contract by the Defense Advanced Research Projects Agency (DARPA) to develop Artificial Intelligence (AI) tools for dynamic, airborne missions as part of its Artificial Intelligence Reinforcements (AIR) program. This project aims to provide advanced Modeling and Simulation (M&S) approaches and dominant AI agents for live, multi-ship, beyond visual range (BVR) missions. It is a critical step in prioritizing and investing in breakthrough technologies for national security and to meet the evolving needs of customers. DARPA's AIR program will improve the government-provided baseline models' speed and predictive performance to better match how the Department of Defense's systems perform in the real world. During the 18-month period of performance, Lockheed Martin will apply AI and Machine Learning (ML) techniques to create surrogate models of aircraft, sensors, electronic warfare and weapons within dynamic and operationally representative environments.

June 2024: Lockheed Martin Skunk Works has teamed up with the University of Iowa to demonstrate the use of AI in air-to-air interception scenarios. In successful trials, the AI piloted an L-29 Delfin jet using heading, speed and altitude commands, performing tactical exercises against a virtual adversary. The AI was able to transfer learned behaviours from simulation to reality, acting intentionally and decisively. These tests are part of a wider initiative to rapidly develop AI-driven autonomy for air-to-air missions.

May 2024: Lockheed Martin, U.S. Department of Defense, state and local officials celebrated the opening of the company's new $18 million engineering facility, labs and demonstration centre in Huntsville. The 122,000 ft^2 facility has space for 500 employees who will advance national security capabilities and drive innovation in North Alabama. Work performed at this site supports a more than 60-year legacy of Lockheed Martin customer partnerships in Huntsville supporting all domains air, space, land, sea and cyber. With the opening of this facility, Lockheed Martin's footprint in Alabama expands to 30 work sites in the state employing over 3,300 people.

May 2024: Lockheed Martin announced a $10 million USD investment in PV Labs, a Canadian firm renowned for its expertise in developing turnkey aerial imaging solutions. This investment represents one of the largest Lockheed Martin has made under Canada's Industrial and Technological Benefits (ITB) Policy, tied to the In-Service Support Contract for the CC-130J aircraft. The funds are directed towards advancing the commercialization of PV Labs' innovative airborne technology, specifically their Fifth-generation Advanced Stabilization Turret (FAST) technology. This modular and scalable gimbal technology, protected by intellectual property rights, promises unprecedented performance in smaller, lighter systems. Lockheed had previously invested in the company back in 2019.

March 2024: The U.S. Air Force Advanced Range Threat System Variant 3 (ARTS-V3) program office awarded Lockheed Martin an initial $276M contract, which includes production options, to develop and produce the Variable Aperture Digital Radar (VADR) system. VADR will leverage both X-band and C-band radars to train aircrew for engagements against advanced adversarial threats. The VADR system is a software-defined sensor that can be reprogrammed to emulate different adversary systems and training events. It will be built using Distributed Digital Active Electronically Scanned Array (AESA), leveraging commonality with other key radars in the Lockheed Martin portfolio.

December 2023: Lockheed Martin supported a successful government test of the Advanced Off-Board Electronic Warfare (AOEW) system's electronic attack capabilities while installed on a U.S. Navy MH-60R helicopter. This marked the first time in the program's development the system was able to perform engagement testing, demonstrate the ability to deter threats, and quantify system performance, while integrated and controlled by the target platform. In partnership with the U.S. Navy at Naval Air Station Patuxent River in Maryland, this integration event tested the capabilities of the system and operability on the MH-60R helicopter platform. While the system is designed for both the MH-60R and MR-60S host platforms, only the MH-60R was used for this test. AOEW is a pod-based electronic warfare missile defense system that will provide U.S. Navy with enhanced electronic surveillance and attack capabilities against anti-ship missile threats. To date, the system has successfully undergone a series of incremental developmental and operational tests at Lockheed Martin's facility in Syracuse, New York.

October 2023: The United States Army and Lockheed Martin have successfully tested the Multi-Function Electronic Warfare-Air Large (MFEW-AL) system, marking a step towards enhancing electronic warfare capabilities. This airborne electronic payload demonstrated its capabilities in detecting, identifying, locating and disrupting enemy communications and radars. The test showcased MFEW-AL's platform-agnostic nature. The recent flight test of the MFEW-AL system marks an achievement as it is the first time in decades that US Army electronic warfare soldiers have conducted a series of airborne electronic warfare operations against various threat emitters. This test has demonstrated the MFEW-AL system's extended range capabilities and versatility to sense and affect multiple signals of interest at varying distances.

September 2023: Lockheed Martin Skunk Works® in partnership with the U.S. Air Force, completed the first flight of the U-2 Dragon Lady's Avionics Tech Refresh (ATR) program. The successful first flight tested the new advanced capabilities aboard the U-2 as part of the ATR contract, including: an updated avionics suite (communications, navigation, display, etc.) that modernizes the U-2's onboard systems to readily accept and use new technology; a new mission computer designed to the U.S. Air Force's open mission systems (OMS) standard that enables the U-2 to integrate with systems across air, space, sea, land and cyber domains at disparate security levels; new modern cockpit displays to make pilot tasks easier, while enhancing presentation of the data the aircraft collects to enable faster, better-informed decisions.

Counterpoint comment

Lockheed Martin is both an aircraft OEM and a provider of avionic/electronic warfare systems. It sits within the top league of defense contractors within the US. We believe that it will remain at the forefront of US defense contractors.

19.1.18 LYNX SOFTWARE TECHNOLOGIES

Founded in 1988 under the name LynuxWorks, Inc. and changing its name to Lynx Software Technologies in 2014, Lynx is a software company that specialises in secure virtualisation and open and reliable real-time operating system. In May 2022, the company received a strategic investment from private equity firm Ocean Sound Partners in a leveraged buy-out for an undisclosed amount. In turn, in December 2023 Lynx acquired Timesys Corporation and 12 months later also acquired Thompson Software Solutions.

Lynx serves markets that are characterised by 'high-threat environments' such as fighter jets, UAVs, stealth ocean vehicles, military transport vehicles and helicopters.

Financials

We estimate that Lynx generated $42m of revenues in 2023 of which $16m were related to aerospace avionics.

Locations

Lynx has its headquarters and main office location at Lynx Software Technologies, San José, CA, United States. It has a UK Headquarters in Reading, England. Through its recent acquisitions, they now have a presence in Atlanta, GA and

Hurst TX (Thompson Software) and Pittsburgh, PA (Timesys).

LYNX MOSA.ic for Avionics is a set of Lynx software packages, 3rd party technologies, and associated tools which Lynx has proven to reliably work together for rapidly building robust avionics systems. Specifically, LYNX MOSA.ic for Avionics includes the following:

- LynxOS-178® (Safety RTOS)
- Buildroot (Linux)
- LynxSecure (Separation kernel)
- Lynx Simple Applications (bare-metal apps)
- Certification evidence
- Tools

LYNX MOSA.ic embodies the integrated business and technical DoD implementation strategy of the Modular Open Systems Approach (MOSA) defined in Title 10 U.S.Code ğ 2446a.Requirement for modular open system approach in major defense acquisition programs. It enables system developers to build systems compositionally using open standards, relying heavily on the reuse of well-tested and certified components.

LynxOS-178 (safety RTOS) is a native POSIX® , hard real-time partitioning operating system developed and certified to FAA DO-178B/C DAL A safety standards. It has been awarded a Reusable Software Component (RSC) certificate from the FAA for re-usability in DO-178B/C certification projects. LynxOS-178 is the primary host for real-time POSIX and FACE™ applications within the LYNX MOSA.ic™ development and integration framework. LynxOS-178 native POSIX implementation satisfies the PSE 53/54 profiles for both dedicated and multi-purpose real-time as well as FACE applications.

LynxSecure is a separation kernel which provides isolated environments in which multiple safety critical and general purpose operating systems can perform simultaneously without compromising safety, security, reliability or data integrity. LynxSecure offers both time-space partitioning and was designed from the ground up to be small, real-time, and safety and security certifiable.

The LynxSecure product would typically be utilised in IMA or common computing resources in order to allow for partitioning of utility/avionic functions with mixed levels of criticality.

Customers and contracts

Lynx customers include: Airbus, BAE Systems, Collins Aerospace, GE Aerospace, General Atomics, General Dynamics, L3Harris, Lockheed Martin, NASA, Northrop Grumman, Raytheon, and Thales. Lynx lists the following major positions:

- F-35 Joint Strike Fighter's (JSF) Mission System (TR3)
- F-35 Joint Strike Fighter's (JSF) Cockpit Display System
- General Atomics Gray Eagle Extended Range (GE-ER) UAV
- General Dynamics Integrated Computer System
- Boeing/Insitu ScanEagle
- NASA's SLR2000 Satellite Laser Ranging System
- All-Purpose Remote Transport System (ARTS)
- C3I Upgrade for Flyvefisken Class Ships (Royal Danish Navy)
- Bombardier Challenger 300 Flight Display
- Sikorsky UH-60 Blackhawk Helicopter
- NASA's AVIRIS (Airborne Visible/Infrared Imaging Spectrum)
- Lockheed Martin P-3 Orion Surveillance Aircraft
- Galileo Satellite Navigation System

- Collins CAAS "Glass Cockpit"
  - Little Bird (AH-6, MH-6)
  - Chinook (MH-47D, MH-47E)
  - Blackhawk (MH-60K, MH-60L, MH-60L-IDAP)
  - KC-135 Stratotanker
- Future Combat Systems (FCS)
- Medium Extended Air Defense System (MEADS)
- AFIRS Program (Automated Flight Information Reporting System)
- Software-Defined Radios (SDRs) from ITT Corporation

Strategy

Lynx states that its strategy revolves around helping customers build Mission Critical Edge platforms for avionics, unmanned aerial systems, satellites and for industrial applications.

Recent Developments

January 2024: Lynx announced the acquisition of Thompson Software Solutions, LLC. (TSS), a provider of software development, engineering, and integration solutions to mission-critical aerospace and defense (A&D) platforms, spanning military and commercial fixed- and rotary-wing aircraft, commercial space flight, hypersonic platforms, and command-and-control systems. Its customers include the U.S. Department of Defense (DoD), prime integrators, A&D original equipment manufacturers, and commercial space companies.

December 2023: Lynx announced the acquisition of Timesys Corporation, a provider of development tools, cybersecurity solutions, and differentiated software engineering services for open-source embedded and edge software applications. The combination of Lynx and Timesys creates a scaled software solution provider focused on Mission Critical Edge and embedded software applications for customers with the most demanding reliability, security, and interoperability needs. With the addition of products and services offered by Timesys, the LYNX MOSA.ic platform will be able to deliver incremental value, functionality, and security to mixed-criticality systems requiring the real-time software determinism of Lynx's core IP and the flexibility of the Linux open-source platform. All products currently offered by Lynx and Timesys will remain available and supported.

September 2022: Lynx was recognized among the best solutions by the 2022 Military + Aerospace Electronics Innovators Awards. An esteemed and experienced panel of judges from the aerospace and defense community recognized Lynx as a Platinum honoree. As a Platinum honoree, LYNX MOSA.ic for Avionics was recognized as a superb innovation characterized by a groundbreaking approach to meeting a need and/or a new level of performance, efficiency, ease of use or other beneficial quality.

May 2022: Lynx announced it has received a strategic investment from affiliates of OceanSound Partners, LP, a private equity firm that invests in technology and technology-enabled services companies serving government and enterprise end markets. Joe Benavides, Managing Partner of OceanSound commented "[CEO Gurjot Singh] and his team have done a phenomenal job growing Lynx over the last few years, most notably having the LYNX MOSA.ic™ software framework support the upgrade of the mission system avionics for the F-35 Joint Strike Fighter Program. The selection of Lynx's core platform in the Department of Defense's largest and most important program is a testament to the robustness of Lynx's core technology and validates their growth potential. The completion of this transaction marks the beginning of an exciting new chapter for Lynx, and we look forward implementing our engineering-like approach to value creation and pursuing strategic growth initiatives in partnership with the management team."

January 2021: Lynx Software Technologies announced that its LYNX MOSA.ic™ product has been selected as the winner of the "IoT Security Platform of the Year" award in the 5th annual IoT Breakthrough Awards program conducted by IoT Breakthrough, a leading market intelligence organisation that recognises the top companies, technologies and products in the global Internet-of-Things (IoT) market.

Counterpoint comment

Lynx has established itself as a technology "enabling" company that helps avionics suppliers with both bespoke and off the shelf software solutions. Its two acquisitions will reinforce its position in defence sector.

19.1.19 MANNARINO SYSTEMS & SOFTWARE INC.

Founded in 1999 by John Mannarino, Mannarino Systems & Software Inc.is a privately held corporation that was acquired by the Scalian Group in June 2024 through a leveraged buy out (LBO).

Mannarino provides safety-critical systems, software, and airborne electronic hardware engineering services to the aerospace, defense, space, simulation, power generation and rail industries. Mannarino is highly specialised in the design, verification and validation of critical systems and software, including Full Authority Digital Engine Controls (FADEC), avionics, Health and Usage Monitoring Systems (HUMS), Ground Support Equipment (GSE) software, aerial refuelling systems, Unmanned Aerial Vehicles (UAV) and industrial engine controls.

Financials

We estimate that Mannarino generated $6m of avionic related revenues in 2023.

Locations

Mannarino is located in Montreal (Quebec) Canada, the third largest aerospace hub in the world, as well as a gateway to European and US markets.

Capabilities

Mannarino is a Design Approval Organisation (DAO) for Airborne Software (RTCA/DO-178B/C) and Airborne Electronic Hardware (AEH) (RTCA/DO-254), authorised by the National Aircraft Certification Branch of Transport Canada Civil Aviation (TCCA).

M-RTOS is a modular, flexible and affordable operating system for a wide range of aerospace applications, from Commercial Off-The-Shelf (COTS) electronic hardware to federated LRU (Line-Replaceable Unit) aircraft systems, to IMA (Integrated Modular Avionics) platforms. M-RTOS was developed to minimise memory and timing usage and outperform the competition on key benchmarks. M-RTOS guarantees robust spatial and temporal partitioning and can run on microprocessors incorporating memory protection. The M-RTOS integrated development environment, Mannarino Workbench, is an Eclipse-based tool suite that employs a modern web-based help system and a role-based approach structured to easily accommodate concurrent collaborative development with large, distributed teams.

Mannarino lists its fields of expertise, in terms of successful software applications, to include Avionics, Aerial Refuelling, Health and Usage monitoring and Gas turbine Engine Control.

Customers and contracts

Mannarino has a long affiliation with Lockheed Martin Aerospace, where investment agreements were signed between the two companies as part of the Canadian Government Industrial Regional Benefits & Industrial Technological Benefits (IRB/ITB) requirements in exchange for the Canadian Government's acquisition of military equipment from foreign companies abroad.

Strategy

Mannarino states that its mission is to provide safety-critical systems, software, and airborne electronic hardware engineering services to the aerospace, defense, space, simulation, power generation and rail industries.

Recent developments

June 2024: Mannarino is acquired by business transformation specialists, Scalian Group (assisted by private investment firm Wendel). According to Wendel, the acquisition "is to be funded through a mix of drawdown on Scalian's ex-

isting committed credit facilities and shareholders' equity contribution, including a 43.7m equity injection from Wendel in Scalian." The acquisition is motivated by Scalian's strategy to expand internationally and focus on safety-critical systems and software engineering.

January 2021: Mannarino Systems announced that its recently launched real-time operating system, M-RTOS will achieve FAA approval on a Part 23 program within 18-24 months.

Counterpoint comment

Mannarino is a provider of RTOS software systems that enable avionics providers who are comfortable out-sourcing key elements of their computing platform software needs. The company is expanding internationally via acquisition and is focusing on safety-critical systems and software engineering.

19.1.20 MERCURY SYSTEMS

Mercury was founded in 1981 and is currently listed on the NASDAQ stock exchange.

Mercury is a market leader in secure mission-critical technologies for the aerospace and defense industries. Its innovative solutions power more than 300 critical aerospace and defense programs.

Since 2015, Mercury has added substantial capabilities to its technology portfolio including:

- embedded security, with the acquisitions of Lewis Innovative Technologies Inc., custom microelectronics, RF and microwave solutions, and embedded security, with the carve-out acquisition from Microsemi Corporation, The Athena Group, Inc., Delta Microwave, LLC, and Syntonic Microwave LLC;
- mission computing, safety-critical avionics and platform management, and large area display technology with the CES Creative Electronic Systems, S.A. , Richland Technologies, L.L.C., GECO Avionics, LLC, and American Panel Corporation acquisitions;
- rugged servers, computers and storage systems with the acquisitions of Themis Computer and Germane Systems, LC.
- ruggedized radio and data acquisition boards, recording systems and subsystems with the acquisition of Pentek Technologies, LLC and Pentek Systems, Inc.

Headquartered in Andover, MA, and with manufacturing and design facilities around the world, Mercury specialises in engineering, adapting and manufacturing new electronic and software solutions to meet the industry's current and emerging high-tech needs.

Mercury provides leading-edge sensor and processing technologies tailored for mission-critical applications. Their products include secure embedded processing modules and subsystems, mission computers, secure and rugged rack-mount servers, safety-critical avionics, RF components, multi-function assemblies, subsystems and trusted custom microelectronics.

Mercury offers a COTS-model approach to subsystem design and pre-integration that helps defense applications keep pace with the AI evolution by leveraging the best-in-class commercial technologies, engineering and commercial R&D investment.

Financials

FYE 30/06/23	2022/2023	2021/2022	2020/2021	2019/2020	2018/2019
Sales $m	973.9	988.2	924.0	796.6	654.7
Operating income $m	(21.7)	31.6	81.0	91.1	76.6
Return on sales %	(2.2%)	3.2%	8.8%	11.4%	11.7%

Mercury commented in its 2023 Annual Report: "Total revenues decreased $14.3 million, or 1.4%, to $973.9 million during fiscal 2023, as compared to $988.2 million during fiscal 2022 including "acquired revenue" which represents net revenue from acquired businesses that have been part of Mercury for completion of four full fiscal quarters or less

(and excludes any intercompany transactions). After the completion of four full fiscal quarters, acquired businesses will be treated as organic for current and comparable historical periods. The decrease in total revenue was primarily due to $33.3 million less organic revenues, partially offset by $19.0 million of additional acquired revenues. These decreases predominantly resulted from program execution delays, especially as related to approximately 20 challenged programs, primarily development in nature, for which completion is a precursor to follow-on production awards. In addition, incremental cost growth on these challenged programs delayed progress, and, therefore, revenue recognition in the fiscal year. Revenues from integrated subsystems decreased $77.2 million or 11.8%, partially offset by increases to modules and sub-assemblies and components which increased $33.0 million or 19.8% and $29.8 million or 17.8%, respectively, during fiscal 2023. The decrease in total revenue was primarily from the radar, EW, and other end applications which decreased $21.7 million, $13.1 million, and $2.4 million, respectively, and were partially offset by increases to the C4I and other sensor and effector end applications which increased $14.3 million and $8.5 million, respectively. The decrease was predominately in naval platforms which decreased $18.6 million and was partially offset by an increase of $5.9 million in other platforms during fiscal 2023. The largest program decreases were related to the MH-60, Filthy Buzzard, CPS, THAAD, and a classified C2 program. There were no individual programs comprising 10% or more of our revenues for fiscal 2023 and 2022. See the Non-GAAP Financial Measures section for a reconciliation to our most directly comparable GAAP financial measures."

We estimate that Mercury generated $426m of avionic related revenues in 2023.

Locations

Mercury's global headquarters are located in Andover, Massachusetts, USA, and has a presence across the US and in Europe.

USA

- Alabama: Huntsville
- Arizona: Phoenix
- California: Cypress, Fremont, Oxnard, Torrance
- Florida: Gainesville, Gulf Breeze
- Georgia: Alpharetta, Norcross
- Indiana: West Lafayette
- Maryland: Marriottsville, Lexington Park
- New Hampshire: Hudson
- New Jersey: Upper Saddle River, West Caldwell
- Virginia: Arlington, Chantilly

Europe

- Switzerland: Grand-Lancy (International HQ), Plan-les-Ouates
- Spain: Madrid
- United Kingdom: Silchester

Mercury has the following facilities operating as centres of excellence;

- Phoenix, Arizona AMC manufactures our custom microelectronics products in an AS9100 quality system-certified facility. The Phoenix, Arizona facility also contains our USMO, which is an IPC1791 and DMEA-certified trusted manufacturing facility and is primarily focused on advanced secure system-on-chip design, assembly, packaging, and test.
- Oxnard, California facility manufactures radio frequency and microwave products in an AS9100 quality system-certified facility.
- Cypress, California, West Lafayette, Indiana, Huntsville, Alabama and Mesa, Arizona facilities are AS9100 quality systems-certified facilities as well.

- Fremont, California and Alpharetta, Georgia facilities are ISO 9001:2015 quality systems-certified. Our Chantilly, Virginia facility is an AS9100 quality systems-certified facility.
- Andover, Massachusetts and Hudson, New Hampshire facilities design and assemble our processing products and are AS9100 quality systems-certified facilities. The Andover, Massachusetts facility is also a DMEA-certified trusted design facility and is primarily focused on advanced security features for the processing product line.
- Mercury's European operations, based in the UK and Switzerland, provides electronic design and manufacturing, maintenance and support services and is AS9001 and EASA Part 145 quality systems-certified. Its Silchester, England facility provides engineering, development and integration services and is AS9100 quality systems-certified.

As at June 30, 2023, Mercury had 2,596 employees. Of these, 2,456 (94.6 %) are based in the USA.

Capabilities

Mercury lists its offering under 3 generic headings which are:

- Electronic components
- Modules, subassemblies
- Integrated sub-systems

These categories apply themselves in end applications such as displays, EO-IR, avionic computing, mission computing, electronic warfare and sensor processing.

These end applications are utilised in aerospace and defense sectors including airborne platforms, missiles and naval ships.

Mercury are primarily used in both commercial aerospace applications, such as communications and ground radar air traffic control, as well as advanced defense and intelligence applications, including space-time adaptive processing, synthetic aperture radar, airborne early warning, command, control, communication and information systems, mission planning, image intelligence and signal intelligence systems. Their products transform the massive streams of digital data created in these applications into usable information in real time.

Historically, defense electronics providers have utilised closed architectures to meet the Department of Defense (DoD) emphasis on application-specific solutions with unique reliability, performance, space and security requirements. Mercury's open and modular design approach is particularly beneficial for Artificial Intelligence because it supports the rapid modernisation of mission-critical systems and accelerates AI electronics deployment through design flexibility and reduced complexity.

Mercury's open-architecture solutions span military and commercial aviation, navigation, unmanned aerial vehicles, missiles and helicopters. Their secure airborne capabilities include mission computing, safety-critical avionics, displays, processing, RF and radar. Mercury tailors the latest technology for rugged, secure, Size, Weight and Power (SWaP)-optimised airborne solutions.

Modules and Subassemblies. Modules and subassemblies include combinations of multiple functional technology elements and/or components that work together to perform multiple functions but are typically resident on or within a single board or housing. Modules and subassemblies may in turn be combined to form an integrated subsystem. Examples of modules and subassemblies include embedded processing modules, embedded processing boards, switch fabric boards, digital receiver boards, graphics and video processing and Ethernet and input/output boards, multi-chip modules, integrated radio frequency and microwave multi-function assemblies, tuners, and transceivers.

Integrated Subsystems. Integrated subsystems include multiple modules and/or subassemblies combined with a backplane or similar functional element and software to enable a solution. These are typically but not always integrated within a chassis and with cooling, power and are also often combined with additional technologies for interaction with other parts of a complete system or platform. Integrated subsystems also include spare and replacement modules and subassemblies sold as part of the same program for use in or with its integrated subsystems.

Customers and contracts

Given the product categories noted within the section above Mercury operates at a number of levels within the supply chain supplying components, embedded modules and integrated sub-systems.

Mercury lists its key customers as follows:

Mercury has successfully penetrated strategic programs including Aegis, Patriot, Surface Electronic Warfare Improvement Program ("SEWIP"), Gorgon Stare, Predator, F-35, Reaper, F-16 SABR, E2-D Hawkeye, Paveway, Filthy Buzzard, PGK, P-8, Advanced Integrated Defensive Electronic Warfare Suite ("AIDEWS"), Common Display System ("CDS") and WIN-T.

F-35: Mercury are providing the signal-processing systems for the Integrated Core Processing (ICP) system, F-35's central computer, which supports all of the embedded computing elements for several different aircraft subsystems, including digital signal processing (DSP) for the sensors and cockpit displays

Specific customers listed include the following:

- Airbus
- BAE Systems
- Boeing
- General Atomics
- L3Harris
- Leonardo
- Lockheed Martin
- Northrop Grumman
- Raytheon Technologies
- SAIC
- Sierra Nevada
- Thales

Mercury derives sales from avionic upgrade programmes including the F-15 and F-16.

Strategy

In their 2023 Annual Report, the company stated that "Our strategies are built around our key strengths as a leading commercial technology company serving the aerospace and defense industry. Our strategies include innovation and investment in scaling existing capabilities, as well as augmenting our capabilities through an acquisition strategy designed to focus on adjacent technologies. We believe our investment in R&D is more than double that of our competitors on a percentage of sales."

Mercury's overarching strategy is to provide all types of processing subsystems requiring trusted, secure mission related computing.

Mercury has a long history of driving modular open systems architectures and has remained committed to creating, advancing, and adopting open standards for all our products, from its smallest components and connectors to the largest, high-performance, integrated multi-computer systems.

Mercury has a strong merger and acquisition culture and track record with the following deals concluded in recent years:

- 2017: Delta Microwave EW, Space for $ 41m
- 2017: RTL Platform/Mission for $6m
- 2018: Themis C2I, Comm's $180m

- 2018: Germane Systems C2I, Acoustics for $45m
- 2019: GECO Platform/Mission for $37m
- 2019: Athena Security for $46m
- 2019: Syntonic Microwave Electronic Warfare (not disclosed)
- 2021: Atlanta Micro ($90m), Pentek Technologies/Pentek Systems ($64.92m)

Recent developments

July 2024: Mercury Systems announced an agreement with the U.S. Navy to advance sensor processing technologies that will allow radar and electronic warfare (EW) capabilities to be designed on much shorter timelines. The Office of Naval Research's Open Rapid Chipletized Approach (ORCA) program aims to reduce the time needed to design edge processing solutions by increasing the modularity of components at the chip level. Under a $13.2 million contract, Mercury will develop a next-generation RF System-in-Package (SiP) that integrates the latest commercial chips from major semiconductor providers within a smaller and lighter footprint. This work will build on Mercury's RFS1140 SiP, which integrates an AMD Versal FPGA, Jariet Electra-MA high-speed data converters, and Micron memory.

March 2024: Mercury announced that it will advance the manufacturing of defense technologies in Switzerland in collaboration with Lockheed Martin. This project is a direct result of the offset program between Lockheed Martin and the Swiss government as part of Switzerland's purchase of the F-35 Lightning II. Under two initial engineering development agreements, Mercury will begin manufacturing several embedded computing technologies at its production facility in Geneva. These projects will be enabled by the transfer of two of armasuisses's key security-relevant technologiessoftware-defined radio technologies and cryptologyto Swiss industry. Mercury expects to receive further expansion opportunities over time to bring the manufacture of additional capabilities to Switzerland.

March 2024: Mercury announced that it received a five-year, $243.8 million, indefinite delivery/indefinite quantity contract to deliver rapidly reprogrammable electronic attack training subsystems for the Naval Air Warfare Center Weapons Division. These subsystems build on more than 25 years of test and training technology from the Mercury Processing Platform to bring the most advanced, near-peer jamming and electronic warfare capabilities to U.S. pilot training organizations.

December 2023: Gainey McKenna & Egleston announces that a securities class action lawsuit has been filed in the United States District Court for the District of Massachusetts on behalf of all persons or entities who purchased or otherwise acquired Mercury Systems, Inc. securities between December 7, 2020 and June 23, 2023, inclusive (the "Class Period"). The Complaint alleges that Defendants repeatedly touted the success of the Company's growth, painting a false rosy financial picture for investors. Defendants repeatedly misled investors to believe that their growth was organic by misrepresenting several elements of Mercury's business, including by hiding that Mercury had switched from "point-in-time" to "long-term contracts" in order to improperly boost reported revenues and that several of Mercury's projects were in significant distress, including projects related to Mercury's acquisition of Physical Optics Corporation. Mercury also lied to investors about its strategic growth initiative, 1MPACT, which was designed to improve profit margins but unbeknownst to investors was used to disguise regular expenses as restructuring costs, enabling Mercury to claim that recurring expenses were one-time costs.

December 2023: Mercury Systems introduced the first commercially available flight testing simulator for air-to-ground synthetic aperture radar (SAR) systems. The ARES-SAR product builds on more than 25 years of test and train technology from the Mercury Processing Platform to enable government and commercial organizations to save time and costs by reducing the need for actual flight testing through the simulation of realistic SAR scenarios on the ground. SAR systems have become an integral tool for crewed and uncrewed airborne and space-based systems.

December 2023: Mercury Systems was awarded an $16.8 million order from the U.S. Navy for ruggedized data transfer units, high-definition video recorders, and other avionics accessories for the F/A-18C-F jet fighter-bombers and EA-18G Growler electronic warfare (EW) aircraft. Mercury Mission Systems (formerly Physical Optics Corp.) will provide 48 data transfer units and 121 high-definition video recorders for the F/A-18 aircraft. This equipment is part of a Small Business Innovation Research Phase III topic N102-0129 called Automatic Real-Time, Reconfigurable Interface Generalization Hardware Multiprotocol Data Recorder. Mercury won similar orders in September and December 2022. The company won a $35.7 million order for 104 1553 data-transfer units – 68 for retrofit on F/A-18C-F aircraft and 36 for EA-18G production aircraft; and 144 high-definition video recorders for retrofit on F/A-18C-F aircraft.

November 2023: Mercury Systems announced an agreement with the U.S. Navy to develop manufacturing capabilities that would allow commercial photonics chiplets to accelerate edge processing in defense applications. The Office of the Under Secretary of Defense for Research and Engineering (OUSD(R&E)) Trusted and Assured Microelectronics Program's Project KANAGAWA aims to mature the domestic supply chain and manufacturing processes for multi-chip packages, where co-packaged optics are integrated with electronic integrated circuits to enable long-reach and high-bandwidth data transfer. Compared to conventional copper connections, photonics uses optical fibers to enable orders of magnitude improvement in data bandwidth at a fraction of the power needed. The promise of this technology for defense systems has been well-known for decades, but demonstrations have relied on expensive and custom approaches that are not compatible with high volume production.

July 2023: Mercury Systems received a five-year contract worth as much as $83 million from the U.S. Naval Air Systems Command to deliver high-definition, digital Head-Up Display (HUD) systems for the T-45 Goshawk training aircraft. This firm-fixed-price delivery order was issued under a previously awarded basic ordering agreement. The Navy is the first customer to adopt Mercury's HUD1080 technology that enables aviators to see critical flight and weapons data in real-time without taking their eyes off the sky. Under this program, Mercury expects to deliver nearly 300 HUD systems, with the first $45 million production order awarded in conjunction with this contract.

October 2022: Mercury Systems, Inc. announced that its new mPOD, a rapidly reprogrammable electronic attack (EA) training system designed to train pilots using realistic, near-peer jamming capabilities, has successfully completed initial flight testing and is available for order. Tactical Air Support, a leader in commercial air services, tactical aviation training and technical advisory services for U.S. military and international partners, oversaw three days of flight testing that ran beyond visual range tactical intercept training engagements replicating adversary tactics. F-5 aircraft equipped with Mercury's mPOD EA training system successfully broke, delayed and denied opposing fighter radar locks, created multiple false targets on the opposing fighter radar, and performed other electronic attack techniques.

October 2022: Mercury Systems announced that the mission computer built for the Airbus A330 MRTT allowed the tanker to receive the world's first certification for automatic air-to-air refueling (A3R) boom operations. Mercury Mission Systems International, located in Switzerland and Spain, delivered a purpose-built computer for Airbus based on the commercial off-the-shelf (COTS) ROCK family of pre-integrated subsystem platforms that draw from a range of safety-certifiable modular COTS building blocks, addressing both the need for high-end video processing and the safety-criticality of the application. The system handles video streams with very low latency across multiple processors while meeting stringent DO-178 and DO-254 software reliability processes.

July 2022: Mercury Systems announced that its new mPOD, a rapidly reprogrammable electronic attack (EA) training system designed to train pilots using realistic, near-peer jamming capabilities, is currently undergoing final flight testing.

July 2022: Mercury announced it received a $56 million contract award from a leading defense prime contractor to facilitate the rapid data processing requirements for a defense radar application. The award was received in the Company's fiscal 2022 fourth quarter and is expected to be delivered over the next several quarters.

March 2022: The US Air Force (USAF) awarded Mercury a $165m firm-fixed-price indefinite-delivery/indefinite-quantity (IDIQ) contract. This contract involves the delivery of flight data recorders to support secure mission data systems (SMDS) on the F-16 fleet. These flight data recorders are expected to improve performance, security and reliability for the F-16 jets' current and future mission requirements. The contract includes an initial order worth $16.4m and carries a 72-month planned performance and shipment period.

November 2021: Mercury acquired Atlanta Micro, Inc. (Atlanta Micro). Based in Norcross, Ga., Atlanta Micro is a designer and manufacturer of high-performance RF modules and components, including advanced monolithic microwave integrated circuits (MMICs) which are critical for high-speed data acquisition applications including electronic warfare, radar and weapons.

May 2021: Mercury announced that it has acquired Pentek Technologies, LLC and Pentek Systems, Inc. (collectively, "Pentek"). Based in Upper Saddle River, N.J., Pentek is a leading designer and manufacturer of ruggedized, high-performance, commercial off-the-shelf ("COTS") software-defined radio and data acquisition boards, recording systems and subsystems for high-end commercial and defense applications.

Counterpoint comment

Mercury is one of the larger hardware computer peripheral providers that offers a wide range of components through to embedded systems. It's growth strategy is mainly focused on acquisitions.

19.1.21 MOOG

The company's operations are divided into three segments: Aircraft Controls, Space and Defense Controls and Industrial Systems. During FY2023, Aircraft Controls contributed to 42% of overall revenue. In the company's 2023 Annual Report, the CEO stated that the Aircraft Controls segment has been split into two businesses to focus on Military Aircraft and Commercial Aircraft customers respectively. This split is designed to improve operational and financial performance "with clearer line of sight, dedicated resources and accountability running deeper into our organization."

Moog Avionic Instruments designs and manufactures aircraft navigation, engine instrumentation, and custom military display systems. With over 35 years of experience in cockpit displays, avionics and instrumentation. Moog has in-house engineering capabilities for design, manufacture and test of a full range of products. Moog services the fixed wing and rotary wing communities in both the military marketplace and commercial aviation. Moog also has a separate business area, Advanced Avionics Systems, which provides designs specifically for spacecraft and payload applications. Further, Moog has another business area, Navigation and Surveillance Systems (NaSS), which provides navigation services for land and sea-based application. These two areas are not included in the scope of this report.

In December 2020 Moog acquired Genesys Aerosystems which is reported separately in this report.

Financials - Aircraft Controls

FYE 30/9/23 USD million	2022/2023	2021/2022	2020/2021
Net Sales - military	700	745	782
Net Sales - commercial	689	511	379
Net Sales - total	1,389	1,256	1,161
Operating income	145	124	97
Operating margin	10.4%	9.8%	8.3%

For the past two fiscal years, revenues from military sales have fallen. In the latest trading figures, a 6% decrease was recorded. Commercial revenue has however shown solid growth in the same two-year period, increasing by over one third (35%). When combined, revenue rose by 10.6%. Elaborating on this, the company commented:

"In 2023, sales increased $120 million across all of our commercial OEM programs. Sales increased $35 million across our widebody programs and increased $22 million across our other Boeing and Airbus commercial aircraft programs. Additionally, higher sales volumes for business jets increased sales $27 million. Also in 2023, sales increased $58 million across all of our commercial aftermarket programs. We benefited from higher amounts of spares and repair volume, primarily for the A350 program, as well as the sale of inventory on mature programs that we decided to exit as part of our simplification efforts. Partially offsetting the commercial increases were sales declines across both our military OEM and aftermarket programs. Sales decreased $30 million in our military OEM programs as lower funded development activities reduced sales $38 million. Partially offsetting the decline was a $13 million increase in sales for the F-35 program. Also, military aftermarket sales decreased $16 million across our programs due to lower repair volume."

Operating income continued on the upward trajectory seen in recent years, increasing by $21 million (17%) from 2022. Operating margin also rose slightly from the previous year. The company commented:

"Adjustments in 2023 included $5 million of impairment, inventory write-down and restructuring charges. Adjustments in 2022 included $15 million of impairment and $4 million of restructuring expenses, mostly offset by a $16 million gain associated with the divestiture of our NAVAIDS business. Excluding these charges, the adjusted operating margins in 2023 and 2022 were 10.8% and 10.1%, respectively. The resulting 70 basis-point increase in adjusted operating margin is largely due to the benefits of our pricing and simplification initiatives. Partially offsetting the margin increases were additional charges for military funded development programs."

We estimate that Moog's avionic-related business (including that of Genesys) generated $64m of revenues in 2023.

Location

As of September 2023, the company occupied 5,532,000 ft^2 of space. Of this, one third (1,875,000 ft^2) is occupied by Aircraft Controls. Of this, 79% is owned outright and the remainder leased.

Moog's corporate headquarters are in Elma / East Aurora, New York. Principal manufacturing locations for Aircraft Controls are the U.S., Philippines, United Kingdom and Ireland.

Aircraft divisional facilities are located in the following places:

- North America
  - Torrance, CA
  - Oklahoma City, OK
  - Fort Worth, TX
  - Everett, WA
  - Elma, NY
- South America
  - Sao Paulo, Brazil
- Asia Pacific
  - Bangalore, India
  - Baguio City, Philippines
  - Singapore
- Europe
  - Toulouse, France
  - Ballyboughal, Ireland
  - Luton, UK
  - Tewkesbury, UK
  - Wolverhampton, UK

Moog's main avionic instrument facility is located in Blacksburg, Virginia, USA.

Capabilities

Moog offers the following family of avionic products

- Navigational Instruments
- Engine Indicators
- Signal Data Converters
- Spares and Service

In terms of Navigation Indicators Moog offers Horizontal Situation Indicators, Digital Bearing Distance Indicators and Radio Magnetic Indicators

Customers and contracts

Moog lists its main customers within its Airframe Controls segment as follows:

Aircraft Controls: Boeing, Airbus, Lockheed Martin, Collins Aerospace, Northrup Grumman, Japan Aerospace, General Dynamics, Honeywell, Bombardier, BAE Systems Aerospace and the U.S. Government.

Specific avionics applications include:

- KAI T-50: Flight instruments
- Bell 407: Flight instruments

Moog is certified to repair and maintain instruments and accessories. These components have been manufactured under the names of:

- Moog Components Group
- Northrop Grumman
- Litton
- Aeronetics
- Edison

The company list the following commercial/business and military aircraft/rotorcraft as representative programs in each sector:

- Commercial Aircraft and Business Jets
  - Airbus A320, A330, A340, A350, A380
  - Boeing 737, 747, 757, 767, 777, 787
  - DC-8, DC-9, DC-10, MD-11, MD-80, MD-90
  - Bombardier Q400
  - Challenger 300, 350, 604, 605, 650, Global Express
  - Global 5500, 6500, 7500, 8000
  - Cessna Citation X
  - COMAC C919
  - Embraer E-Jets, including E-2
  - Gulfstream G280, G350, G400, G450, G500, G550, G600, G650, G700
  - Hawker 4000
  - Learjet
- Military Aircraft and Rotorcraft
  - Airbus A400M
  - C295 Transport
  - BAE Systems Hawk AJT, BAE-146
  - Bell-Boeing V-22 Osprey
  - B525 Relentless
  - V-280 Valor (FLRAA)
  - Boeing F/A-18 C/D, F/A-18 E/F, F/A-22, F-15 Eagle, KC-46A, MQ-25™ , CH-46, CH-47, AH-64, B-52, KC-135, B-1B
  - Eurofighter GmbH Typhoon

- HAL India Light Combat Aircraft
- KAI South Korea T-50
- KHI Japan C-2 Transport
- Leonardo Aircraft: M-346 Master, C-27J, AW159, T129 ATAK, AW609, AW101
- Lockheed Martin: F-35 (all variants), F-16 Fighting Falcon, C-5, C-130, P-3, U-2
- McDonnell Douglas: F-4, KC-10, T-45
- MHI Japan F-2
- Northrop Grumman: B-2 Spirit, E-2C, E-2D, EA-6B, Sikorsky UH-60 Black Hawk, Raider X (FARA-CP), S-76,
- S-92/VH-92, CH-53
- TAI Turkey Hürjet
- Taiwan AJT
- Fairchild Republic A-10
- Panavia Tornado

Strategy

Moog does not appear to have invested within its Avionics Product range which is largely a legacy portfolio of products. Clearly with the recent acquisition of Genesys it has acquired a business that includes defense electronic capability.

Recent developments

May 2023: Moog Inc. announced the opening of its new 209,000 ft state-of-the-art engineering and manufacturing facility in Tewkesbury, United Kingdom. People and equipment will transition over the next twelve months as operations condense from three smaller legacy buildings to under one roof. The building is expected to receive BREEAM excellent environmental accreditation while allowing Moog to house its growing engines and flight controls business in a cutting-edge, streamlined manufacturing environment. Moog has been operating in the UK for over fifty years, with nine locations and over 1,000 employees. They are one of the largest employers in Tewkesbury.

June 2022: Moog Inc. announced the formalization of its relationship with Robin Radar Systems, through the inclusion of Robin's MAX® and IRIS® radars into Moog's Digital Airfield Solutions portfolio. Moog customers will benefit through the seamless integration of Robin's bird and drone detection systems into Moog's existing Tarsier® FOD mitigation and pavement monitoring technologies. By bringing these normally siloed airfield systems together into one digital system, Moog can provide unique data insights to support the operators of the world's most complex airfield environments to optimize their FOD, pavement, wildlife, and drone management programs.

April 2021: Moog Inc. and Japan Airlines signed a long-term exclusive contract for comprehensive support of critical flight control and landing gear actuation components on Japan Airlines fleet of Boeing 787 aircraft. The program includes maintenance, reliability management and inventory support via Moog's global repair station network and strategically located stocking facilities, providing Japan Airlines 24/7 access to spares no matter where their aircraft are located.

Counterpoint comment

Moog has not been a strong player in avionics (other than space/satellites) and the investment in Genesys represents a key move. Genesys may have been acquired to strengthen Moog's existing space business although Moog has stated that it will help to build out beyond its existing flight control business.

19.1.21.1 GENESYS AEROSYSTEMS

Genesys designs and manufactures a full suite of electronic flight instrument systems and autopilot solutions specialising in fixed wing, rotorcraft, military and special mission aircraft fleet support with state-of-the-art avionics and product sustainment services.

During November 2020, Moog Inc announced that it has completed the acquisition of Genesys Aerosystems Group, for a purchase price of approximately $77.7 million. The purchase includes the operating subsidiaries S-Tec Corporation and Genesys Aerosystems, Inc. In its 2021 10-K filing, Moog confirmed that Genesys operations would be included in their Aircraft Controls segment.

Genesys Aerosystems brings together Chelton Flight Systems, Inc. and S-TEC Corporation, previously doing business as Cobham Avionics, and has 143 employees.

Financials

To avoid double counting, include Genesys's revenue within our estimate for Moog in Section 19.1.21.

Location

Genesys has its main facility at Mineral Wells, Texas, USA.

It also has a facility at Anchorage, Alaska.

Capabilities

We note the following key developments in Genesys Aerosystems' history.

- Chelton Flight Systems, founded in 1997, developed the world's first FAA-certified 3D synthetic vision EFIS and GPS/WAAS navigator. Key technologies include synthetic vision with three dimensional highway-in-the-sky navigation, integrated flight management and hazard alerting, and ultracompact, highly ruggedised sensors. The company's uniquely customisable open-architecture systems dramatically reduce integration costs and schedules for both OEM and retrofit applications. Chelton Flight Systems products have been certified on over 700 different aircraft types
- Genesys Aerosystems developed the world's first FAA-certified 3D Synthetic Vision flight display system and GPS-WAAS navigator. In addition, industry firsts like Highway-In-The-Sky navigation have helped it to grow to become a proven leader in integrated cockpit avionics systems for special-mission aircraft. Its display/EFIS products have been certified on over 700 different aircraft types in all four FAA regulatory classes: Part-23, Part-25, Part-27, and Part-29.
- S-TEC Corporation, founded in 1978, offers autopilots for aircraft and helicopters. From low cost analogue wing levellers to sophisticated, digital, three-axis systems with Flight Director and envelope protection, S-TEC has FAA certification for nearly 1,000 aircraft types and has delivered over 40,000 autopilot systems. The company's new HeliSAS brings digital, full-authority autopilot technology to the market in a package weighing an unprecedented 15 lbs. Available as a stability augmentation system only or with all autopilot modes, HeliSAS dramatically enhances safety for light single- and twin-engine helicopters.

Customers and contracts

- Airbus Military
- Air Medical Group Holdings
- Bell Helicopter
- Carson Helicopters
- Embraer
- Grob Aircraft
- Leonardo Helicopters

- Sikorsky
- Textron AirLand

Specific platforms worked on are as follows:

- Fixed-wing: Grob G 120TP; Pilatus PC-7; Lockheed C-130 Hercules; Aero L-39 Albatros; CASA CN-235
- Helicopters: Leonardo TH-73A Thrasher; Sikorsky UH-60 Black Hawk; Sikorsky S-61T Triton; Bell 412 Huey; Airbus EC-145e; Leonardo TH-119

Strategy

Since its acquisition by Moog, changes have been made to GA's visual corporate identity. While the Genesys Aerosystems name is retained, colours and styling are reflective of the parent company. "It's important as we grow to do more work with the U.S. government to have the backing of a big company like Moog," said Genesys director of sales and marketing Jamie Luster, in October 2023. "We want to keep the Genesys Aerosystems name; it does have traction in [the] marketplace. We value it but we value what Moog as our parent brings to the industry and especially to the customers that we're pursuing." When asked about the Genesys website, Luster commented that it "will be geared more for special-missions military type markets without losing that small-company feel we've always had." This was in no way to be viewed as a move away from their general aviation partners. "As we look onward and upward, we have to look at who our future customers will be."

Recent developments

February 2024: Genesys Aerosystems and Columbia Helicopters, Inc. announced a strategic collaboration to develop and certify a state-of-the-art digital cockpit for the Model 234 Chinook. The collaboration aims to introduce a modern, Instrument Flight Rules (IFR) capable cockpit that will significantly enhance the multi-mission capabilities of the Model 234 Chinook. The digital cockpit upgrade is designed to offer customers unparalleled safety, efficiency, and situational awareness. Key features of the digital cockpit upgrade include advanced avionics systems, intuitive interfaces, and cutting-edge navigation equipment, providing pilots with enhanced control and precision for safer flight operations. The upgrade will elevate the performance of the Model 234 Chinook and streamline cockpit workflows, optimizing mission effectiveness across a wide range of applications. The digital cockpit upgrade will be standard equipment on all new-build Model 234 Chinooks, offering customers immediate access to the latest in avionics technology. Additionally, existing Model 234 Chinook operators will have the option to retrofit their aircraft with the digital cockpit upgrade, ensuring compatibility with their current fleets. Certification of the digital cockpit upgrade is expected to be completed in the fourth quarter of 2025, with production and installation to follow shortly thereafter.

February 2024: Genesys Aerosystems announced that it is working with Enstrom Helicopter Corporation to install and certify the latest generation Genesys Helicopter Autopilot in the Enstrom 480B. The 3-axis VFR autopilot is scheduled for completion and availability for OEM factory fit and aftermarket retrofit by the end of 2024. Interested customers can have the autopilot installed by Enstrom or at select Genesys dealers.

February 2024: Genesys Aerosystems announced that it has completed an MOU agreement with AI-enabled avionics developer Daedalean to develop an integration roadmap of Daedalean technology into the Genesys Avionics Suite. This comes after successful flight testing of Daedalean's OmniX evaluation kit on the Genesys OH-58 Kiowa Helicopter. This represents a major milestone for both companies in advancing progress toward AI-enabled autonomous flight. Daedalean leverages the power of neural networks to build systems that process visual data in flight in real time for visual traffic detection, navigation, and landing guidance, offering what the company calls Situational Intelligence the ability to understand and make sense of the current environment and situation, and anticipate and react to potential threats.

November 2023: Genesys Aerosystems announced that its Genesys Control Panel (GCP) received FAA TSO approval on October 18, 2023. The Genesys Control Panel is two products in one which can control COMM radios, tactical radios, DME, ADF, transponder, HF, etc. The first being a stand-alone panel-mount radio controller connected directly to the Genesys Digital Radio (GDR®). The second being a Communications Display Unit (CDU) when paired with Genesys' IDU-680 based EFIS glass cockpit. Up to 5 GCPs can connect to the glass cockpit with EFIS radio controls replicated on each GCP. The GCP provides dedicated controls for frequently needed audio/radio controls, as well as additional controls for selecting and setting control parameters. The GCP is designed for both fixed-wing and helicopter aircraft applications and is NVG compatible for night operations.

June 2023: Genesys Aerosystems announced that its development of the Genesys IFR Helicopter Autopilot (GRC™ - 4000) has started company flight testing with the goal of completing STC by end of 2023. Genesys Aerosystems submitted an STC Application on April 4th, 2023, to the FAA for an S-TEC® ODA Project covering the installation of the 4-Axis autopilot on the Airbus Helicopters MBB-BK 117 C-2(e) (EC145e) rotorcraft. The STC amends the existing S-TEC STC (SR11339SC) to allow the option to install the Genesys 4-Axis IFR helicopter Autopilot in place of the existing 3-Axis IFR helicopter Autopilot. In response to FAA and NTSB recommendations to reduce fatigue related aviation incidents, Moog has been working on advanced autopilot systems. The Genesys Rotorcraft Controls (GRC-4000) product development is a result of the Moog innovation efforts.

June 2023: Genesys Aerosystems announced it has received an FAA STC for installation of its S-TEC 3100 digital autopilot on the Piper Twin Comanche aircraft. The S-TEC 3100 autopilot STC includes the following Piper Twin Comanche aircraft models: PA-30 and PA-39. The 3-axis S-TEC 3100 autopilot replaces the previously certified Genesys S-TEC 55X 2-axis autopilot on Twin Comanche aircraft. This update provides next generation digital performance upgrades and operational capability improvements.

March 2023: Genesys Aerosystems announced that it will work jointly with Airbus Helicopters for the development of Instrument Flight Rules (IFR) capabilities for the single engine H125. The Genesys Helicopter Suite™ to be certified will allow Airbus H125 operators to expand the helicopter's mission capabilities in all weather conditions. The avionics solution is composed of dual IDU-680 EFIS displays, Genesys VHF NAV/COM aircraft digital radio, Genesys IFR helicopter autopilot, dual redundant ADAHRS, dual GPS/FMS, and other equipment required to achieve IFR certification. The DO-178C Level A, IFR certified, IDU-680 displays offer high-resolution LCD glass depicting 3D Synthetic Vision, Highway-In-The-Sky (HITS), Enhanced HTAWS terrain awareness, Integrated FMS, Hover Vector, and many more features. The STC project is scheduled for completion by second half of 2024. Initially the certified solution will be offered for Airbus factory new H125 deliveries in North America with follow-on approvals expected in other countries, which allow single engine IFR operations.

September 2022: Genesys Aerosystems announced that it has received full civil certification and acceptance by the military end customer for the complete Genesys Avionics Suite installed in the Indonesian Aerospace (PTDI) CN-235 aircraft. The Genesys avionics consists of EFIS flight displays with embedded FMS and Class-A TAWS, dual ADAHRS (Air Data / Attitude/Heading Reference System), dual GPS/SBAS receivers, GDR integrated VHF/UHF software-defined digital radios, and an S-TEC digital autopilot. The CN-235 is a twin-engine transport aircraft jointly developed by CASA of Spain and PTDI. It is operated as both a regional airliner and military transport; its primary military roles include air transport and aerial surveillance.

September 2022: Genesys Aerosystems announced that it has received full EASA certification approval for the HeliSAS® Autopilot and Stability Augmentation System on the Bell 505 platform. The EASA approval covers both 2-axis and 3-axis configurations. The new certification approval is in addition to the existing FAA STC plus CAA and ANAC approvals for the HeliSAS® on the Bell 505.

August 2022: Genesys Aerosystems, announced its EFIS IDU-450 product line has received FAA STC approval for installation into smaller Part 23 aircraft including Alaska Capstone flyers. Genesys is now offering a trade-in program so operators will now be able to upgrade their aircraft with the Genesys IDU-450 EFIS displays at a cost-effective price to keep their aircraft operating and continue taking advantage of the FAA Capstone operations. The FAA STC SA02203AK authorizes replacement of current IDU-III installations with the IDU-450 displays.

May 2022: Genesys Aerosystems announced that it has completed flight testing of its S-TEC 5000R Autopilot on the Hindustan Aeronautics Ltd. (HAL) Avro HS-748 aircraft. This successful Part 25 aircraft autopilot integration represents another milestone for Genesys Aerosystems and its history of autopilot product leadership in the market. This was the first successful Part 25 autopilot integration in India in recent history. The Autopilot integration program is part of the avionics and engine upgrade and life-extension efforts for the HS-748 Avro aircraft fleet undertaken by HAL.

March 2022: Genesys Aerosystems announced today that it has started development of the 4th axis on the HeliSAS® Autopilot and Stability Augmentation System. The 4th axis brings Hover & Hold functionality as well as collective control to the highly-successful HeliSAS® product line. The new functionality provides operators with an easy single-button access to enter the helicopter into a stable fixed-position hover and hold orientation for a hands-free operation to focus on other priorities. It also includes collective control to ensure proper speed inputs for all phases of flight.

March 2022: Genesys Aerosystems announced its new Genesys Control Panel (GCP) for its current Genesys Digital Radio (GDR) product line. The GCP provides additional interface and control options for the GDR Nav/Comm integrated radio product when not installing with the Genesys Avionics Suite® . The GCP provides users with a single controller for VHF

Comm, VHF Nav, and UHF Comm frequencies. The GDR also continues to maintain third party compatibility to other approved Nav/Comm radio controllers.

Counterpoint comment

Moog appears to want to grow beyond its traditional areas of flight control and engine control and has targeted avionics/electronics which is arguably part of a more digital strategy. Genesys focuses on autopilot products for helicopters.

19.1.22 NORTHROP GRUMMAN

The Northrop Corporation was founded in 1939, and having acquired Grumman Corporation in 1994, was renamed Northrop Grumman Corporation. Following restructuring in 2019, this major US defence contractor has four operating divisions: Aeronautics Systems, Defence Systems, Mission Systems and Space Systems. According to their website, Northrop Grumman has approximately 100,000 employees with more than 550 facilities in all 50 U.S. states and in more than 25 countries around the world. Total sales in 2023 were $39.3 billion .

Insofar as this report is concerned the divisions most relevant are Aeronautics Systems, Defence Systems, and Mission Systems:

- Aeronautics Systems is tasked with the design, development, production, integration, sustainment and modernization of military aircraft systems for the U.S. Air Force, the U.S. Navy, other U.S. government agencies, and international customers. Major products include strategic long-range strike aircraft; tactical fighter and air dominance aircraft; airborne battle management and command and control systems; and unmanned autonomous aircraft systems, including high-altitude long-endurance (HALE) strategic intelligence, surveillance and reconnaissance (ISR) systems and vertical take-off and landing (VTOL) tactical ISR systems. Approximately 45 percent of this business is performed through restricted programs.
- Defense Systems is tasked with the design, development, integration and production of advanced tactical weapons and missile defence solutions, and a provider of sustainment, modernization and training services for manned and unmanned aircraft and electronics systems for the U.S. military and a broad range of international customers. Major products and services include integrated, all-domain command and control (C2) battle management systems, precision strike weapons; advanced propulsion, including high speed air-breathing and hypersonic systems; high performance gun systems, ammunition, precision munitions and advanced fuzes; aircraft and mission systems logistics support, sustainment, operations and modernization; and warfighter training. Less than 5 percent of this business is performed through restricted programs.
- Mission Systems is responsible for advanced mission solutions and multifunction systems, primarily for the U.S. defence and intelligence community, and international customers. Major products and services include command, control, communications and computers, intelligence, surveillance and reconnaissance (C4ISR) systems; radar, electrooptical/infrared (EO/IR) and acoustic sensors; electronic warfare systems; advanced communications and network systems; full spectrum cyber solutions; intelligence processing systems; advanced microelectronics; navigation and positioning sensors; and maritime power, propulsion and payload launch systems. Approximately 30 percent of this business is performed through restricted programs.

As of June 2024, Northrop Grumman stated that in these three divisions, workforce numbers are approximately 22,000, 14,000 and 27,000 employees respectively.

Financials

While overall revenue rose by 7%, more modest revenue increases were reported across Aeronautics (2%), Defence (5%) and Mission Systems (5%) from the previous year. The latest results show a significant 30% - decrease in overall operating income. Northrop Grumman cite a $1.56 billion charge on the B-21 program at Aeronautics Systems as being a significant factor.

The avionic, sensors and electronic warfare capabilities for airborne systems reside within both its Defense and Mission systems divisions.

We estimate that Northrop generated $1,190m in airborne avionics and sensors in 2023.

FYE $m 31/12/23	2023	2022	2021	2020	2019
Full Year Revenue	39,290	36,602	35,667	36,799	33,841
Aeronautics Systems revenue	10,786	10,531	11,259	12,169	11,116
Defense Systems revenue	5,862	5,579	5,776	7,543	7,495
Mission Systems revenue	10,895	10,396	10,134	10,080	9,410
Space Systems revenue	13,946	12,275	10,608	8,744	7,425
Operating Income	2,537	3,601	5,651	4,065	3,969
Operating Margin	6.5%	9.8%	15.8%	11.0%	11.7%

Locations

Northrop has its headquarters for its major divisions in US locations as follows:

- Aeronautics Systems: El Segundo, Mojave, Palmdale (Divisional Headquarters), Redondo Beach and San Diego, CA; Melbourne and St. Augustine, FL; Iuka and Moss Point, MS; Beavercreek, OH; Oklahoma City, OK; and Clearfield, UT.
- Defence Systems: Huntsville, AL; Mesa and Sierra Vista, AZ; Northridge, CA; Warner Robins, GA; Lake Charles, LA; Elkton, Linthicum (Divisional Headquarters), MD; Elk River and Plymouth, MN; Dulles, McLean and Radford, VA; and Keyser, WV. Locations outside the U.S. include Australia.
- Mission Systems: McClellan, San Diego, Sunnyvale and Woodland Hills, CA; Apopka, FL; Rolling Meadows, IL; Annapolis, Annapolis Junction, Elkridge, Halethorpe, Linthicum (Divisional Headquarters), and Sykesville, MD; Bethpage and Williamsville, NY; Cincinnati, OH; Salt Lake City, UT; and Chantilly, Charlottesville and Fairfax, VA. Locations outside the U.S. include France, Germany, Italy and the United Kingdom.

Capabilities

Northrop splits its capabilities into 4 distinct segments as follows;

- Airborne sensors and network (40%)
- Cyber and Intelligent systems (17%)
- Maritime land systems and sensors (22%)
- Navigation, targeting and survivability (21%)

In terms of the operating divisions, identified above, Northrop's Airborne Systems includes the following:

Manned Aircraft: Designs, develops, manufactures and integrates strategic long range strike aircraft systems, tactical fighter aircraft and airborne battle management systems. Key programs: Long range strike — B-21 Raider, B-2 Spirit Tactical fighters — F-35 Lightning II, F/A-18 Super Hornet Airborne battle management — E-2D Advanced Hawkeye, E-8C JSTARS

Autonomous Systems: Designs, develops, manufactures, integrates and sustains autonomous aircraft systems for strategic and tactical ISR missions. Key Programs: Strategic ISR platforms - RQ-4 Global Hawk, MQ-4C Triton, NATO Alliance Ground Surveillance Tactical ISR — MQ-8 Fire Scout, Firebird

Northrop's Mission and Defense Systems includes the following capabilities:

Radars: The SABR APG-83 is an Active Electronically Scanned Array (AESA) fire control radar. Building on Northrop Grumman's 40-year legacy producing radars for the F-16, it integrates within the F-16's current structural, power and cooling constraints without Group A aircraft modification. The capabilities of this advanced AESA are derived from Northrop Grumman's family of highly successful 5th generation fighter AESA radars, the F-22's APG-77 and F-35's APG-81.

Northrop is a world leader in airborne fire control radars and the sole supplier for both USAF 5th generation fighter platforms; the F-22 Raptor and the F-35 Lightning II. Northrop Grumman is unmatched as the largest producer of airborne fire control Electronically Scanned Arrays (ESAs).

Integrated Avionics: Northrop provides the Integrated Avionics Suite for the UH-60V, which modernises the U.S. Army's UH-60L Black Hawk helicopters with a digital, open architecture integrated glass cockpit, including an integrated computational system, visual display system and Control Display Units. This replaces the analogue gauges in UH-60L helicopters with an integrated system that provides one of the most advanced avionics systems in the U.S. Army.

Airborne Sensors & Networks: Fire control, surveillance and early warning and control radar systems; electronic attack and electronic support systems; software defined radios and network gateways, communications and countercommunications systems; and multi-sensor processing.

Key programs: Airborne Early Warning & Control and air-to-ground sensors Battlefield Airborne Communications Node (BACN) F-35 fire control radar, Distributed Aperture System (DAS), and Communications, Navigation and Identification (CNI) integrated avionics system Scalable Agile Beam Radar (SABR) for F-16 Restricted programs

Navigation, Targeting & Survivability: Competencies include EO/IR and RF self-protection; targeting and surveillance systems; digitised cockpits; and inertial navigation systems.

Key programs: LITENING Advanced Targeting Pod Large Aircraft and Common Infrared Countermeasures (LAIRCM, DoN LAIRCM, CIRCM) systems APR-39 DV(2) and EV(2) Radar Warning Receiver programs Embedded Global Positioning System (GPS)/Inertial Navigation Systems-Modernisation (EGI-M) program UH-60V Black Hawk integrated mission equipment package Restricted programs

Airborne Electronic Warfare: Northrop Grumman has provided Airborne Electronic Warfare solutions for more than 55 years.

Northrop provides the electronic warfare suite for its F-16 fighter aircraft fleet. The system provides full-spectrum radar warning, threat identification and advanced countermeasure capabilities. It also has proven pulse-to-pulse operability with the F-16's newly acquired AN/APG-83 Scalable Agile Beam Radar (SABR), also built by Northrop Grumman.

Northrop builds, maintains and upgrades electronic sensing systems for the Northrop Grumman Boeing EA-18G Growler electronic combat aircraft. They also provide radar warning receivers and electronic support measures for platforms such as the Boeing P-8A Poseidon.

Northrop Grumman has been selected to provide the B-kit for the AC/MC-130J RFCM Program. The AN/ALQ-131(V) Electronic Countermeasures (ECM) pod and the AN/APR-39D(V)2 Radar Warning Receiver/Electronic Warfare Management System maximise survivability by improving aircrew situational awareness via interactive management of all onboard sensors and countermeasures.

Customers and contracts

Northrop generates 85% of its revenues within the US and 15% from International/FMS sales. Within each of its operating divisions classified or restricted programs account for between 19% and 38% of its sector revenues.

Most of Northrop's key platforms and associated products are identified above under "technologies and capabilities".

Within its Aeronautics systems division Northrop produces a number of manned and unmanned platforms including B-2 Spirit strategic bomber, the E-8C Joint STARS surveillance aircraft, the RQ-4 Global Hawk, and the T-38 Talon supersonic trainer, the RQ-5 Hunter unmanned air vehicle, the BQM-74 Chukar, RQ-4 Global Hawk-based MQ-4C Triton, MQ-8 Fire Scout, Grumman C-2 Greyhound, and Grumman E-2 Hawkeye.

Northrop also provides major components and assemblies for different aircraft such as F/A-18E/F Super Hornet and the Lockheed Martin F-35 Lightning II.

Within Mission Systems Northrop provides tactical aircraft sensors include the AN/APG-68 radar, the AN/APG-80 AESA radar, and the AN/APG-83 AESA radar upgrade for the F-16 Fighting Falcon, the AN/APG-77 AESA radar for the F-22 Raptor, and the AN/APG-81 AESA radar for the F-35 Lightning II, and the AN/AAQ-37 electro-optical Distributed Aperture System (DAS) for the F-35, and the APQ-164 Passive Electronically Scanned Array (PESA) radar for the B-1 Lancer.

Northrop also maintains the AWACS aerial surveillance systems for the U.S., the United Kingdom, NATO, Japan, and others. Northrop Grumman is the prime contractor for the development and integration of the Air Force's $2-billion Multi-Platform Radar Technology Insertion Program.

A number of Northrop's key avionic supply contracts are identified as follows;

- Northrop provides Lockheed Martin with the AN/APG-81 fire control radar for the F-35 Lightning II. The Northrop AN/APG-81 active electronically scanned array is the cornerstone of the F-35's advanced sensor suite, providing unparalleled battlespace situational awareness that translates into platform lethality, effectiveness and survivability.
- Northrop provides the Integrated Avionics Suite for the UH-60V, which modernises the U.S. Army's UH-60L Black Hawk helicopters with a digital, open architecture integrated glass cockpit, including an integrated computational system, visual display system and Control Display Units.
- Northrop's approach for the design and implementation of the UH-60V integrated mission equipment package is based on experience with similar upgrades for the U.S. Marine Corps AH-1Z and UH-1Y helicopters, U.S. Navy E-2D Advanced Hawkeye, and the Royal Jordanian Air Force AH-1 programs.
- Northrop Grumman supplies the Navigation System for Embraer's New KC-390 Military Aircraft which includes the hybrid global positioning system (GPS) and inertial reference system for the KC-390 medium-lift military transport aircraft
- Northrop provides the AEA suite for the EA-18G Growler which allows the fighter to disrupt, deceive and deny a broad range of military electronic systems; it features wing tip pods and gun bay pallets, in addition to antennas and receivers.
- Northrop provides the B-kit for the AC/MC-130J RFCM Program. The B-kit includes the apertures, amplifiers and electronics including radio frequency countermeasures suite.
- Northrop's equipped Triton (based upon Global Hawk) has Multi-Function Active Sensor radar, Electro-Optic Infrared, Electronic Support Measures and Automatic Identification System have a 360-degree field of view radar.
- Global Hawk utilises Northrop's near-real-time, high-resolution imagery of large areas of land in all types of weather — day or night. The EQ-4B Global Hawk carries Northrop's Battlefield Airborne Communications Node (BACN) payload providing life-saving support to war fighters.
- The capabilities of the advanced AESA are derived from Northrop Grumman's family of highly successful 5th generation fighter AESA radars, the F-22's APG-77 and F-35's APG-81.

Northrop offers the market a range of retrofits upgrades including AESA radars, electronic warfare suites and electronic countermeasures.

Strategy

Northrop is both a provider of manned and unmanned autonomous airborne platforms and a provider of the high value electronics avionics, sensors and military systems embedded within these platforms.

As such it arguably has an advantage over the Tier1 suppliers in terms of access to customers, funding, R&D and the agencies that influence DoD budgets etc.

Recent developments

May 2024: Officials of the Naval Air Systems Command at Patuxent River Naval Air Station, Md., announced plans to contract with Northrop Grumman Corp. Aeronautics Systems segment in Melbourne, Fla., provide software and hardware upgrades to E-2D mission computers and displays to demonstrate manned and unmanned teaming (MUM-T) capability. The value of the contract has yet to be negotiated. MUM-T describes synchronized use of human warfighters, manned and unmanned aircraft, robotics, and sensors to achieve enhanced situational awareness, lethality, and survivability. The 18-month sole-source contract also will include technical support to update the E-2D mission computers and displays to process and display additional Joint Range Extension Applications Protocol (JREAP) messages.

May 2024: U.S. Navy avionics experts are asking engineers at Northrop Grumman Corp. to build eight electronic warfare (EW) avionics sets for the Navy MV-22B medium-lift tiltrotor aircraft under terms of a $9.1 million order announced in April. Officials of the Naval Air Systems Command at Patuxent River Naval Air Station, Md., are asking the Northrop Grumman Mission Systems segment in Rolling Meadows, Ill., for eight AN/APR-39 D(V)2 radar warning receiver/electronic warfare management systems, and eight D(V)2 battery handle assemblies for the MV-22B tiltrotor.

December 2023: Officials of the Army Contracting Command announced an $106.6 million order to Northrop Grumman Mission Systems in Rolling Meadows, Ill., for the AN/APR-39 radar signal detecting set program. It detects radar threats to aircraft, such as radar ground sites and particularly radar-guided missiles, and provides 360-degree coverage around the aircraft. When the system detects enemy radar, it alerts the aircraft crew to each threat with a graphic symbol on the cockpit display. The APR-39 also functions as an electronic warfare (EW) management system, and serves as the heart of Northrop Grumman's suite of integrated sensors and countermeasures that integrates and displays data from onboard sensors radio frequency and electro-optical sensors.

December 2023: The U.S. Defense Logistics Agency announced a $121.5 million contract to the Northrop Grumman Mission Systems segment in McLean, Va., for AN/APQ-164 offensive radar low observable antennas for the B-1 aircraft. Late-model B-1 aircraft have received upgrades to install the Northrop Grumman Scalable Agile Beam Radar-Global Strike (SABR-GS) - a multi-function active electronically scanned array (AESA) radar developed as an affordable low risk radar retrofit for the B-1. SABR-GS is replacing the APQ-164 radar antenna deployed on late-model B-1 bombers. Large synthetic aperture radar like the SABR-GS provides the B-1 with advanced image processing, and sensor integration for situational awareness and intelligence, surveillance, reconnaissance, and targeting.

December 2023: Northrop Grumman's AN/ALQ-257 Integrated Viper Electronic Warfare Suite (IVEWS jamming system that will provide F-16 fighter jets increased protection against modern electronic threats recently completed government lab integration, setting the stage for the first flight test next year. The testing took place in November and while the system has flown on Northrop-made systems, it has not taken its initial flight test on a military jet. It is anticipated that the maiden flight test will take place in the Q1 2024.

January 2023: Northrop Grumman is developing AN/APG-85, an advanced Active Electronically Scanned Array (AESA) radar for the F-35 Lightning II. Northrop Grumman currently manufactures the AN/APG-81 active electronically scanned array (AESA) fire control radar. The AN/APG-85 is an advanced multifunction sensor that will be compatible with all variants of the F-35 aircraft and will be capable of defeating current and projected adversarial air and surface threats. In addition to producing the AN/APG-85 and AN/APG-81 radars, the company also produces and maintains several sensor systems, avionics, mission systems and mission-planning software, pilot and maintainer training systems courseware, electronic warfare simulation test capability, and low-observable technologies.

November 2022: Northrop Grumman has been selected to provide engineering services for the KBR-led $156.7 million, five-year Department of Defense Information Analysis Center's (DoD IAC) multiple-award contract (MAC) vehicle. IAC MAC task orders are awarded by the U.S. Air Force's 774th Enterprise Sourcing Squadron to develop and create new knowledge for the enhancement of the Defense Technical Information Center (DTIC) repository and the research and development (R&D) and science and technology (S&T) community. The UH-60V is a comprehensive digital cockpit redesign that replaces the UH-60L's legacy analog instrumentation with a fully open and integrated avionics suite. The architecture flying in UH-60V is applicable to both Current Fleet and Future Vertical Lift aircraft, and is extensible to Apache, Black Hawk and Chinook aircraft.

March 2022: Northrop Grumman has been awarded a $65 million contract by the U.S. Navy to execute the full rate production of Link-16 for the U.S. Marine Corps AH-1Z and UH-1Y aircraft, which will involve the integration of data link hardware across the fleet. Link-16 is a secure data link that allows H-1 crews to share data and communications with other aircraft and users on military networks. This capability is a critical mission enabler as the Department of Defense moves to Joint All-Domain Command and Control. Northrop Grumman's mission systems solution for the H-1 fleet is trusted and combat-proven, with more than 450,000 total flight hours. The innovative processes, capabilities and open architecture developed for the H-1 fleet are directly applicable to other platforms and could be utilized in future aircraft development programs such as NAVAIR Vertical Take Off and Landing Family of Systems (VTOL FoS), MUX, and others.

February 2022: Northrop Grumman and Curtiss-Wright announced that they were collaborating to bring Real-time Virtualization And Modernized Protection (ReVAMP) technology to the embedded avionics market. The use of ReVAMP effectively "future-proofs" software systems by virtualizing obsolete hardware currently being used to run existing software. Northrop Grumman has enabled multiple programs to migrate their valuable application software from obsolete hardware to modern hardware using ReVAMP. Using ReVAMP, programs can move trusted and proven applications from legacy cPCI, VXS, or similar form factors, to a contemporary VME, OpenVPX™ , or XMC module from Curtiss-Wright, to both improve the performance of avionics systems and drastically reduce sustainment costs.

August 2021: The UH-60V Black Hawk helicopter, enabled by the Northrop Grumman Corporation (NYSE: NOC) integrated avionics suite, has entered service with the Pennsylvania National Guard's unit at Fort Indiantown Gap. This

First Unit Equipped milestone marks the entry into service of the Army's first helicopter with a modular, open architecture systems design, Northrop Grumman's OpenLift. The UH-60V enhances aircrew situational understanding and mission safety while reducing pilot workload. The pilot-vehicle interface is nearly identical to that of the UH-60M, enabling common training and operational employment. The system has been certified by the U.S. Army Combat Capabilities Development Command Aviation Missile Center for operation under Visual Flight Rules. OpenLift can be adapted to numerous aircraft and is approved for export.

Counterpoint comment

Northrop is a market leader within the US defense sector and has a global presence necessary to support both foreign military sales and to exploit non-US defense budgets.

It has a very strong presence in Unmanned Airborne Systems which we see as a significant growth sector.

19.1.23 PERFORMANCE SOFTWARE

Founded in 1998, and receiving its first ever "Preferred Supplier Status" from one of their clients in 2001, Performance is a software and engineering services firm that provides innovative, turnkey solutions for safety-critical projects serving clients in the avionics, aerospace/defense, healthcare, and energy markets. There are three divisions operating under the 'Performance' identity: Software (software, hardware, and manufacturing), Studio (full lifecycle product design studio), and Defense (embedded software and hardware solutions). By 2022, Performance employed a combined total of 500 staff in its various locations.

Performance specialises in developing real-time embedded avionics systems and full lifecycle software solutions certifiable to DO-178B and DO-178C levels A through D.

Financials

We estimate that Performance generated $63m of revenues in 2023 with avionics representing $15m.

Locations

Performance has its headquarters located in Phoenix, Arizona, USA, with around 250 employees based there. In 2007 it opened offices in Grand Rapids, Michigan and Clearwater, Florida. Since then it has opened other offices in Bothell, Washington (2009), Metairie/New Orleans, Louisiana (2014), Cedar Rapids, Iowa (2016). In 2016 it also opened premises overseas in the Philippines. According to the company website, there is a Cardiff, UK presence. This is most likely related to the tie-up between Performance Software and Auvation Software Ltd.

It also operates additional support offices in Seattle, Clearwater, Grand Rapids, Waukesha, and New Orleans.

Capabilities

Performance delivers software solutions for the following Aerospace & Defence related systems:

- Cabin systems
- Engine control systems (FADEC)
- Flight deck display systems
- Geospatial information systems (GIS)
- Onboard maintenance systems (OMS)
- Electrical power systems
- Flight Control systems
- Flight Management Systems
- Navigation and guidance systems

In terms of Avionics, Performance has the following product offerings:

- Precision Navigation & Mapping™ provides customisable, photo-realistic experiences with the highest precision. Increased pilot situational awareness; improve safety margins and enhance operational efficiency. With a world-wide database of airports accommodating general aviation through wide-body air transport.
- Performance JETS is a cloud-based systems and software development platform for the rapid deployment of avionics products. By using an FAA approved virtual platform it realise the benefit of unlimited access to hard-ware and accelerates time to market by finding bugs sooner, efficiently developing software, and running tests.
- Performance GPU is a customised OpenGL software—rendering library for embedded applications designed for commercial displays and military displays. It provides a means to render graphics through software rather than dedicated hardware, eliminating the need for hardware GPUs altogether by removing hardware from the graphics-processing equation.
- The Performance DataLoader™ suite of components are ARINC 615A and ARINC 665 compliant and were devel-oped with modularity, reliability, fast loading speed and customisation in mind. These onboard data loaders allow for fast implementation of new software developments.

Customers and contracts

Performance does not specifically identify its customers although it does have Boeing supplier approvals and within its case studies it does refer to large global OEM avionic providers (e.g. for FMS support).

In 2014 Performance signed a long-term contract with Rockwell Collins to provide its Airport database software as part of Collins Pro Line Fusion avionic suite. Performance also has FAA approval for airport database mapping products.

Performance was awarded two supplier accolades from Collins in 2010 so we believe that it has a long standing rela-tionship with Collins.

Strategy

Performance states that it is a software and engineering services firm that provides innovative, turnkey solutions for safety-critical projects. We serve clients in the avionics, aerospace/defense, healthcare, and energy markets whose missions require meticulous attention to detail.

Recent developments

None that we can see.

Counterpoint comment

Performance is focused on the aerospace and defense sector and has been supporting OEMs/Tier1s with its software and data services for many years. We have however not seen any contract won in the past 4 years.

19.1.24 RAYTHEON

Originally founded in 1922 as the American Appliance Company, Raytheon Technologies known as RTX Corporation since 2023 is one of the world's foremost aerospace and defence companies. RTX group comprises three businesses; Pratt & Whitney, Collins Aerospace, and Raytheon.

The Raytheon business combines Raytheon Intelligence & Space, and Raytheon Missiles & Defense. In 2023, its net sales amounted to $26.3 billion. It employs more than 53,000 people, of which around 28,000 are engineers. It operates in 58 countries around the world.

Within Raytheon, there are eight main focus areas: Air; Land; Sea; Space; Integrated Air & Missile Defense; Strategic Missile Defense; Advanced Technology; and Hypersonics.

Within the Air segment, a further five specialisations exist:

- Air-to-Air Missiles
- Air-to-Surface Effectors

- Surveillance & Reconnaissance
- Targeting
- Electronic Warfare

Raytheon is headquartered in Waltham, Massachusetts. In avionics, the business specialises in intelligence, surveillance and reconnaissance and space systems. This includes cybersecurity solutions, weather and environmental solutions and information-based solutions for homeland security. The company also provides training, logistics, engineering, product support, and operational support services and solutions for mission support, homeland security, space, civil aviation, counter-proliferation and counter-terrorism markets.

Financials

We estimate that its airborne avionic related products including sensors generated revenues of $1,830m in 2023.

Locations

Raytheon is headquartered in Waltham, Massachusetts

Raytheon's Avionics, and Mission Systems business are located in Cedar Rapids, IA.

The former Raytheon Intelligence and Space has a number of facilities located throughout the US as follows;

Fullerton, CA; Aurora, CO; Indialantic, FL; Orlando, FL; Palm Bay, FL; Indianapolis, IN; Louisville, KY; Billerica, MA; Burlington, MA; Marlboro, MA; Annapolis Junction, MD; Troy, MI; State College, PA; El Paso, TX; Richardson, TX; Dulles, VA; Herndon, VA; Newport News, VA; Springfield, VA; and Calgary, Canada.

It operates from a total of 5,258,700 ftš of facility space of which 92% is located in the US.

In terms of other overseas facilities these are located in UK, Germany, Poland and Saudi Arabia, however, these facilities typically support land, maritime and infrastructure projects and do not supply airborne equipment.

Capabilities

Raytheon's key technologies and capabilities include the following:

- AESA Radar
- Electronic Warfare
- Multi-Spectral Targeting Systems
- Joint Precision Approach and Landing
- Protected Satellite Communications
- GPS antennas and Receivers

AESA Radar

The APG-82(V) optimises the F-15Es multirole mission capability. In addition to its extended range and improved multi-target track and precision engagement capabilities, the APG-82(V) offers improvement in system reliability over the legacy F-15E APG-70 radar.

Raytheon's APG-79 AESA radar design, now extended to the APG-82(V) is combat-proven on fielded F/A-18s, and it's being adapted now to modernise the Strike Eagle.

The ALR-69A, the world's first all-digital radar warning receiver, alerts pilots to threats in dense signal environments. The system is being tested on the F-16 Fighting Falcon and is installed on the C-130H Hercules and KC-46A Pegasus.

Mission Computing

Raytheon provides a Modular Mission Computer (MMC) for the mid-life update for the F-16. The MMC delivers enhanced computing power to the aircraft's avionics and weapon systems. As a member of Lockheed Martin's F-16 team, Raytheon developed a single high-performance system to replace the fighter jet's three original computers. The MMC's advanced features and potential for expansion enable the F-16 to meet present and future mission challenges. For pilots, the MMC significantly improves situational awareness, air-to-air capabilities, targeting accuracy and information. Equipped with this powerful computer, the F-16 can take greater advantage of such growth technologies as helmet-mounted cueing systems, advanced weapons loads, reconnaissance pods and forward-looking infrared targeting and navigation systems.

Electronic Warfare

Raytheon's Next Generation Jammer Mid-Band is an advanced electronic attack system that denies, disrupts and degrades enemy technology, including communication tools and air-defense systems. Built with a combination of agile, active electronically scanned arrays and an all-digital back end, it gives E/A-18 Growler pilots an edge in the hotly contested electromagnetic spectrum.

In 2018 the U.S. Air Force awarded a contract for Raytheon's AN/ALR-69A(V, the world's first all-digital radar warning receiver. The contract calls for the rapid procurement of 779 units or more for the USAF fleet of tactical air and large body aircraft.

Multi Spectral Targeting System

Raytheon's Multi-Spectral Targeting System (MTS) combines electro-optical/ infrared (EO/IR), laser designation, and laser illumination capabilities in a single sensor package. To date, Raytheon has delivered more than 3,000 MTS sensors to U.S. and international armed forces and successfully integrated 44 variants of the system on more than 20 rotary-wing, Unmanned Aerial System, and fixed-wing platforms — including the MH-60 Blackhawk, the C-130 Hercules, the MQ-9C Reaper, the MQ-1 Predator, and the MQ-1C Gray Eagle.

Joint Precision Approach and Landing

Joint Precision Approach and Landing System, or JPALS, is a software-based, high-integrity differential GPS navigation and precision approach landing system that guides aircraft onto carriers and amphibious assault ships in all weather and surface conditions. It uses an anti-jam encrypted datalink to communicate between the aircraft and an array of GPS sensors, antennas and shipboard equipment.

In 2018, U.S. Marine Corps F-35Bs deployed aboard the USS Wasp using JPALS to guide them onto the deck. JPALS is also installed on the USAF land-based F-35A and USN/USMC carrier-based F-35C.

Protected Satellite Systems

Raytheon is a provider of protected Advanced Extra High Frequency terminals in production for the Army, Navy and Air Force. With more than 500 systems in the field, our terminals currently support the legacy Milstar satellites and are ready to operate with the newest AEHF satellites.

GPS antennas and receivers

The MAGR2K brings M-Code GPS capability to maritime and avionics platforms, including the F/A-18, MV-22, CV-22 and MH-53E. The MAGR2K enhances GPS acquisition and performance and provides all-in-view GPS satellite tracking and GPS integrity. The open architecture and modular design allows for easy upgrades. Raytheon has delivered over 3,000 units to 20 different platforms to the U.S. Air Force, Navy and international partners.

Customers and contracts

Raytheon provides avionic solutions for the following applications:

- F-15: APG-82 AESA radar systems, AN/APG-63 and AN/APG-70 are a family of all-weather multimode radar systems (earlier versions of APG-82).

- F-16: Radar Warning receiver, Modular Mission Computer
- F/A-18: APG-82C radar systems, MAGR2K GPS receivers, AN/ASQ-228 Advanced Targeting Forward-looking Infrared (ATFLIR) pod, AN/ALR-67(V)3 Radar Warning Receiver (RWR), Miniature Airborne Global Positioning System Receiver (MAGR-2000)
- F-22: design, develop and manufacture of the projector for BAE Systems' Digital Light Engine head-up display
- MV-22: MAGR2K GPS receivers
- CV-22: MAGGR2K GPS receivers
- MH-53: MAGGR2K GPS receivers
- F-35: JPALS precision landing system, Distributed Aperture System
- MH-60 Blackhawk: Multi-Spectral Targeting System
- C-130J: Multi-Spectral Targeting System, Radar warning receiver, MXF-626K VHF Communications Systems, APX-119 identification friend or foe (IFF) transponders
- MQ-9: Multi-Spectral Targeting System
- MQ-1: Multi Spectral Targeting System
- E/A-18 Growler: Next Gen Jammer System

Strategy

Raytheon is a US military defense contractor primarily with extensive capabilities in emergent technologies such as digital, cyber, AI and electronic warfare. It provides forward fit and retrofit solutions in addition to expanding its service support contract capabilities.

It's strategy, in part, is to exploit these capabilities with its acquisition of Collins Aerospace via synergies and cost savings.

Recent developments

April 2024: Raytheon will develop its 'Controlled, Advanced, Distributed Radio Frequency Effects' (CADRE) enough to integrate them with the US Navy's Next Generation Jammer (NGJ). The US Department of Defense allocated $40.59m to the supplier on 3 April 2024, to advance CADRE from technology readiness level (TRL) three to TRL six. The work will be divided into three phases: System Design and Risk Reduction; Detailed Design, Integration and Verification; and Ground Test and Flight Demonstration. These phases aim to achieve measurable progress toward the long-term Future Naval Capabilities objective of multi-aircraft flight demonstration. Work will be performed in McKinney, Texas, and the base effort is expected to be completed in November 2025. NGJ is the next step in Airborne Electronic Attack (AEA). It is needed to meet emerging electronic warfare (EW) threats. The system will augment, and ultimately replace, the legacy ALQ-99 Tactical Jamming System that is currently used on the Navy's EA-18G Growler Electronic Attack aircraft.

December 2023: The United States Navy awarded Raytheon an $80 million contract in a down select to prototype Advanced Electronic Warfare, or ADVEW, for the F/A-18 E/F Super Hornet. This prototype will be considered as a replacement for the existing AN/ALQ-214 integrated defensive electronic countermeasure and AN/ALR-67(V)3 radar warning receiver with a consolidated solution that will deliver superior electronic warfare capabilities to the backbone of the Navy's carrier air wing. Raytheon's Advanced Electronic Warfare offering will provide significant performance upgrades by modernizing existing electronic warfare systems into fewer components and incorporating government-defined open architecture. Development of this new solution will closely align and integrate with other combat-proven, radio frequency sensors and effectors employed by the Super Hornet. ADVEW will ensure F/A-18E/Fs maintain their operational electronic warfare advantage, while significantly improving survivability against advanced, complex threats. Development and testing of ADVEW will mainly take place in Goleta, California. During the prototype phase, the system will undergo preliminary design review, critical design review, and flight testing over a 36-month period.

September 2023: Raytheon delivered the first B-52 active electronically scanned array radar (AESA) to Boeing for the U.S. Air Force's B-52 Radar Modernization Program. This first radar will be used for system integration, verification, and testing. The B-52's new radar will enable improved mapping and detection range and increase the number of targets

the platform can engage simultaneously. Along with improved modes and capabilities, the AESA radar will help crews see further, more accurately and have increased situational awareness.

May 2023: Raytheon was approved to outfit Korea Aerospace Industries' FA-50 Light Combat Aircraft with the new PhantomStrike radar. PhantomStrike is a fully air-cooled fire-control radar designed to provide long-range threat detection, tracking and targeting. Working with the United States Government, PhantomStrike was approved to be exported as a Direct Commercial Sales product to KAI. PhantomStrike is a first-of-its-kind, compact AESA radar that is smaller, lighter and requires less power. It is designed for a wide range of platforms including light-attack aircraft, rotary-wing aircraft, uncrewed aerial vehicles, and ground-based towers.

April 2023: Raytheon Intelligence and Space, Northrop Grumman and Lockheed Martin's Skunk Works are teaming up to bid on the Navy's next command-and-control aircraft, to be used if a nuclear war breaks out. The "E-XX" would replace the Navy's fleet of 16 E-6B Mercury aircraft, which carry out a mission the Navy refers to as TACAMO, for "Take Charge and Move Out," that allows the president, the secretary of Defense and other national leaders to communicate with and control forces such as nuclear missile-armed submarines. The E-6B fleet is ageing and must be modernized, the Navy said in fiscal 2024 budget documents released last month. The Navy decided to use the Lockheed Martin C-130J-30 Super Hercules, a version of the C-130 with 15 feet added to the fuselage, as the platform for its TACAMO aircraft.

March 2023: Raytheon delivered their contracted Joint Precision Approach and Landing Systems low-rate production units to the U.S. Navy on time or ahead of schedule. JPALS is a software-based GPS navigation and precision approach landing system that guides aircraft onto carriers and amphibious assault ships regardless of sea state or weather conditions, bolstering safety and operational capability. It is integrated on the F-35 and was recently sold to the Japan Maritime Self-Defense Force.

September 2022: Raytheon Intelligence & Space has been awarded a competitive indefinite delivery indefinite quantity contract from the Federal Aviation Administration with a ceiling value of $375 million over the next 10 years. Task orders, valued at $215 million, were executed at contract award to provide technical refresh and Dual Frequency Operation (DFO) upgrades to the FAA's Wide-Area Augmentation System, or WAAS, a space-based precision navigation system, that will enhance safer air travel in support of the National Airspace System. Under the WAAS DFO-2 contract, RI&S will deliver more modern, and therefore sustainable, processing, system security, and network architecture, while also adding dual frequency service. WAAS is a Satellite-based Augmentation System (SBAS), which provides GPS corrections for critical navigation for the aviation community, first responders and other government agencies, ensuring pilots can land safely in austere environments, despite weather challenges.

December 2021: Raytheon UK has been awarded a £110m contract to upgrade the RAF's Shadow surveillance aircraft fleet. The current fleet of Shadow surveillance aircraft fleet will be upgraded with the latest UK Sovereign Defensive Aids Systems (DAS). The advanced DAS safeguards the aircraft from possible attack while allowing it to continue intelligence gathering in the future. The contract will also see the addition of two more aircraft, taking the RAF's existing fleet of six aircraft to eight. Around 150 jobs will be supported at Broughton, UK, as well as specialist aerospace skills and apprentices and other positions at the company's facilities at Harlow and RAF Waddington. Furthermore, the award is expected to sustain an additional 350 jobs across the UK supply chain.

Counterpoint comment

With Collins' focus primarily on the civil sector and Raytheon's focus on the defense sector the bringing together of these two entities appears to make a lot of sense. Recent contracts won are all defence programmes related.

The primes naturally are quite wary of entities this size with control over engine technology in the mix as well.

19.1.25 SIERRA NEVADA CORPORATION (SNC)

Founded in 1963 and acquired by its current private owners (husband-and-wife team Fatih and Eren Ozmen, originally from Turkey) in 1994 Sierra Nevada Corporation (SNC) has grown to be a $2.5bn revenue business in 2023 employing 4.4K personnel in facilities around the world. It is the only aerospace business that Deloitte ranked as one of the best managed private companies in the United States in both 2020 and 2021.

The company offers a range of capabilities in the areas of Aircraft Integration & Modification, Secure ISR Solutions, Electromagnetic (EM) Spectrum Capabilities, Tactical Solutions and JADC2, in Air, Land, Sea, Space, Cyber and All-Domain theatres.

SNC's business operations are split into two key areas:

- ISR, Aviation & Security (IAS)
- Mission Solutions & Technologies (MST)

They also currently have six subsidiaries:

- Sierra Space
- Deutsche Aircraft
- Kutta Technologies
- 3S Engineering & Certification
- StraightFlight
- SNC Mission Systems UK)

It has pursued growth via acquisitions with the following noted in recent years:

2003: Acquisition of San Francisco-based military computer designer Inter-4, 2004: Acquisition of California-based, WaveBand Corporation, 2004: Acquisition of Aviation Resources Delaware, Inc. 2008: Acquisition of MicroSat Systems, Inc. of Littleton, Colorado, 2008: Acquisition of SpaceDev, Inc. added tremendous space heritage with products that had flown on more than 300 spacecraft over 20 years, 2012: Acquisition of 3S Engineering LLC (a wholly-owned subsidiary of SNC), 2014: Acquisition of Orbital Technologies Corporation (ORBITEC) of Madison, Wisconsin, 2015: Acquisition of 328 Support Services GmbH allowed for global expansion of SNC's modern commercial aircraft technologies, 2015: Acquisition of Kutta Technologies Inc. and Kutta Radios Inc. expanded communications and visualisation capabilities in the areas of command-control-communications software applications and rugged, survivable communications systems.

SNC has developed the DreamChaser spaceplane which is a multi-mission space utility vehicle designed to transport crew and cargo to low-Earth orbit (LEO) destinations such as the International Space Station.

Within its portfolio of capabilities SNC provides avionic related offerings including C4ISR products and services and Enhanced Vision Systems for fixed and rotary wing platforms.

Financials

Sierra Nevada Corporation is a private corporation, but Counterpoint estimates revenues on the order of $2.5 billion.

Based upon its commercial avionics operations we estimate that Sierra Nevada Corporation generated $110m of revenues in 2023.

Locations

SNC's corporate headquarters are based in Sparks, Nevada, USA. The ISR, Aviation & Security (IAS) divisional headquarters is in Englewood, Colorado, while the Mission Solutions & Technologies (MST) headquarters are in Herndon, Virginia.

Within the USA, the company has facilities in the following states:

- Alabama: Huntsville
- Arizona: Phoenix
- California: Folsom, Fremont, Los Gatos
- Colorado: Englewood, Colorado Springs
- Florida: Duke Field, Hulburt Field, Jacksonville, Ft. Walton Beach
- Hawaii: Honolulu
- Kansas: Wichita
- Maryland: Hagerstown, Lexington Park

- North Carolina: Durham, Fayetteville
- Nebraska: Omaha
- Nevada: Sparks
- New Mexico: Clovis
- Ohio: Beavercreek, Dayton
- Oregon: Bend
- Texas: Greenville, Houston, Plano, San Antonio
- Utah: Salt Lake City
- Virginia: Arlington, Herndon

Outside of the US Sierra Nevada Corporation has offices in London UK, Ankara Turkey and Oberpffafenhoffen Germany.

328 Support Services GmbH, Germany, is a subsidiary of Sierra Nevada Corporation, USA. Employing over 170 aviation experts it supports more than 180 aircraft globally. Through its EASA Part 21J Design Organisation (Category 1A) as well as its Part 21G Production Organisation (C1, C2 and D1 rating) and Part 145 Maintenance Organisation, 328SSG provides the aero industry with design, certification, production and maintenance services. This includes base and line aircraft maintenance, avionics installation, exterior painting, Part-M services, refurbishment, training services (part 147), STC design activities and bespoke VIP interiors including avionic & IFE upgrades. 328SSG is based at Oberpfaffenhofen Airport, near Munich.

Capabilities

SNC offer the following capabilities:

- Aircraft Integration & Modification
- Secure ISR Solutions
- Electromagnetic (EM) Spectrum Capabilities
- Tactical Solutions
- JADC2

Sierra Nevada Corporation provides Command, Control, Computers, Communications and Intelligence, Surveillance and Reconnaissance (C4ISR). Sierra Nevada Corporation has more than five decades of experience with Signals Intelligence (SIGINT), wideband digital electronic intelligence (ELINT), electronic support measures (ESM) and systems wide-area motion imagery (WAMI) C4ISR technology enables customers to turn sensor outputs into tangible knowledge, bringing solutions to the table and allowing efficient, effective decision-making.

Sierra Nevada Corporation has installed end-to-end C4ISR capabilities on 200+ types of manned and unmanned aircraft for both commercial and government customers.

Sierra Nevada Corporation has developed Enhanced Visual Systems (EVS) for use in degraded environments. Sierra Nevada Corporation uses a multi-sensor suite fused in real-time with terrain, imagery and obstacle data that is then integrated with symbology and command guidance to restore the visual cues for all modes of flight, in both natural and degraded visibility. Sierra Nevada Corporation's primary sensor is a 94 GHz millimetre wave radar, which was specifically designed and optimised for improving vision in aircraft.

The Mission Solutions and Technologies (MST) business area provides affordable, turn-key command/control, communications, integrated ISR, force protection and security solutions worldwide. The MST team has a long legacy of supporting the Department of Defense, Department of Homeland Security, commercial and international customers with years of experience in platform operations, engineering and full lifecycle management across domains — air, land, sea, space and cyber.

Sierra Nevada Corporation also has a variety of STC's from Wi-Fi activation installations to avionics cockpit retrofit programmes.

Sierra Nevada Corporation has developed the Scorpion multi mission aircraft, based upon a turbo-prop airframe, which contains the following avionic mission related equipment:

- Retractable 15 inch, high-definition, electro-optical/infrared sensor in a nose extension modification that records, stores and transmits full-motion video
- Multi-mode surveillance radar with high-resolution
- Communications network with line-of-sight (LOS) and beyond-line-of-sight (BLOS) capability with secure voice and data features
- Two mission management workstations allows for simultaneous multi-sensor usage

Customers and contracts

Sierra Nevada Corporation has installed a range of C4ISR systems solutions on the following platforms:

PZL M-28, Boeing CV/MV-22, Embraer A-29 Super Tucano, Dornier D-328, Pilatus PC-12, King Air (SNC Scorpion® aircraft), Cessna Caravan, Cessna Sovereign, Cessna Citation, AH-64, De Havilland DHC-6 Twin Otter, De Havilland DHC-7, Merlin/C-26, Bombardier Dash 8, C-130, Gulfstream 3, UH-60, SH60.

Sierra Nevada Corporation has numerous STCs for Cessna aircraft and the Twin "Shrike" Commander 500-S.

Sierra Nevada Corporation has Type Certificate for the D328 jet & turboprop (EASA TC A.096; FAA TC No. A45NM; & FAA TC No. A55NM), as well as IP for the Dornier 428 & other assets.

200 Supplemental Type Certificates (STCs) & complete design & build-and-certify solutions for both helicopters and large aircraft types for an extensive customers list such as Airbus, Lufthansa & Turkish Technic

Sierra Nevada Corporation has FAA Parts Manufacturer Approval (PMA) and Four FAA Part 145 Certified Repair Stations.

Strategy

Sierra Nevada Corporation states that its mission is to Dream, Innovate, Inspire and Empower the next generation to transform humanity through technology and imagination.

Recent developments

June 2024: SNC has been awarded a $170-million contract to deliver two RAPCON-X jets to the Finnish Border Guard as part of the "MVX" program. Currently in production, the RAPCON-X family of systems is SNC's newest integrated aerial intelligence, surveillance and reconnaissance (A-ISR) solution. For this program, SNC is using a RAPCON-X-configured Bombardier Challenger 650 aircraft tailored to the Finnish Border Guard's MVX specifications that provides a modernized and dramatically increased capability to the fixed-wing fleet. The Finnish Border Guard's current fleet monitors borders and territorial waters, supports rescue efforts in maritime emergencies, identifies environmental emergencies at sea and supports clean-up efforts. The new, more efficient multi-purpose aircraft will significantly improve Finland's border security and the monitoring of territorial integrity, particularly along the eastern border.

June 2024: Eren and Fatih Ozmen, owners of SNC, recently announced a $1.13 million gift to the University of Nevada, Reno to launch an Aerospace and Defense Academy. The Academy will support the development of a skilled workforce and foster small business growth for the aerospace and defense (A&D) industry. The Academy will be housed under the Ozmen Center for Entrepreneurship in the College of Business. The Aerospace and Defense Academy will support both workforce and small business development. The Academy will develop resources and business platforms to aid small and woman-owned businesses looking that support the A&D industry. Additionally, the Academy will help build a strong workforce by inspiring new career paths in A&D through programming like high school outreach initiatives and a focused micro-credential program. The three-year pilot program is in development and will include a mix of in-person and virtual classes.

May 2024: SNC has been selected by the U.S. Air Force for its Survivable Airborne Operations Center (SAOC) contract. Under the multi-billion-dollar award, SNC will modernize and deliver a replacement for the USAF's current fleet of E-4B "Nightwatch" aircraft. This highly specialized aircraft serves as an airborne command center for the President (POTUS), Secretary of Defense (SECDEF) and Chairs of the Joint Chiefs of Staff (CJCS) to ensure continued critical command, control and communication (C3) during national emergencies. The USAF's selection of SNC marks one of the

largest aircraft modernization contracts awarded to a company other than the original aircraft manufacturer (OEM) and indicates a new acquisition approach that prioritizes open systems which fosters innovation, speed and cost competitiveness. SNC has championed this change as one of the only private mid-tier A&D prime contractors.

November 2023: SNC has been awarded a multi-year, $554-million contract to deliver aerial intelligence, surveillance and reconnaissance (A-ISR) jets in support of the Army's Theater Level High-Altitude Expeditionary Next AerialSignals Intelligence (ATHENA-S) project. Currently in production, the RAPCON-X family of systems is the newest addition to SNC's turnkey, A-ISR-as-a-service model for contractor-owned-contractor-operated (COCO) capabilities including aircraft, pilot, flight and maintenance operations, and logistics support that is deployable within just hours. The ATHENA-S project is a critical part of the Army's "campaign of learning" to familiarize its aviation and intelligence branches with high-altitude sensing operations.

July 2023: SNC signed a Memorandum of Understanding (MOU) with Leonardo UK Ltd. and its U.S.-based subsidiary, Leonardo Electronics US Inc., that brings the companies together to jointly address a range of international defence and security markets. The project is designed to capitalize on each company's technical expertise and draw on strengths in identified markets where they have relevant infrastructure and experience. With 40+ locations across 19 U.S. states, SNC will support the further development of Leonardo Electronics US Inc. as it expands its engineering, assembly and manufacturing capabilities. At the same time, Leonardo will leverage its success exporting airborne sensor products and close work with customers in the European, Middle East and Asia Pacific regions, and incorporate SNC's capabilities to add value to relevant projects. Leonardo and SNC have worked together previously on several projects for U.S. and international customers, with SNC selecting Leonardo as its radar supplier of choice for maritime patrol aircraft programmes. Most recently, SNC chose Leonardo to supply its Osprey 50 E-scan surveillance radar for the RAPCON-X intelligence, surveillance & reconnaissance (ISR) aircraft.

March 2023: SNC was awarded a five-year, $716.8 million contract to provide components and engineering support for the U.S. Navy's Multi-Intelligence Sensor Development (MISD) suite. The MISD suite is designed to support sensor tasking and data management functions for manned and unmanned aircraft platforms.

November 2022: The first of two commercial derivative aircraft (CDA) arrived at SNC for transformation into the company's new, rapidly configurable, aerial intelligence, surveillance and reconnaissance (AISR) platform, RAPCON-X. Work commenced immediately on the first aircraft, followed by receipt of the second jet in mid-December. Both aircraft are expected to enter service at the end of 2023 and will create an operational envelope that enhances survivability and the capacity to operate in peer- near-peer environments.

June 2022: SNC was recognized for having one of the nation's top security programs by the Defense Counterintelligence and Security Agency (DCSA). SNC's facilities in both Beavercreek, Ohio, and Hagerstown, Maryland received the James S. Cogswell Outstanding Industrial Security Achievement Award this year, marking the sixth time an SNC facility has achieved the rating. The Cogswell Award is the most prestigious honour the DCSA can bestow on cleared industry members, recognizing the importance of true partnership between industry and government to ensure the protection of classified information, materials and programs. It was awarded to only 26 contractor facilities this year, and of the more than 12,500 cleared contractors in the National Industrial Security Program (NISP), less than 1% are selected annually. SNC is one of only five companies to receive more than one award this year.

June 2022: SNC opened a location in Abuja, Nigeria, in partnership with Nigerian firm AVISTAR Consulting. This in-country location supports SNC's ongoing work with the Nigerian Air Force (NAF) as well as other business opportunities in the region. SNC is contracted to provide continuing technical and maintenance support for 12 SNC-modified A-29 Super Tucano light attack combat aircraft, delivered to the NAF in August 2021.

June 2021: SNC has been recognized for having one of the nation's top security programs by the Defense Counterintelligence and Security Agency (DCSA). SNC's facilities in both Sparks, Nevada and Folsom, California received the James S. Cogswell Outstanding Industrial Security Achievement Award this year, marking the fifth time an SNC facility has achieved the rating.

Counterpoint comment

Sierra Nevada Corporation is a successful privately owned business that can develop complete airframes in addition to providing avionics and electronic systems and as such it is somewhat unique. It is focused upon space and national security within the US with some overseas exposure. It has impressive contracts won in the past three years.

19.1.26 TELEDYNE TECHNOLOGIES

Becoming an independent public company in November 1999, Teledyne Technologies Inc "provides enabling technologies for industrial growth markets that require advanced technology and high reliability." These markets are numerous and wide-ranging, including medical imaging, air and water quality environmental monitoring, deepwater oil and gas exploration, and, aerospace and defence.

As of December 2023, the company had a workforce of approximately 14,900 people in 36 countries.

It has four divisions as follows:

- Instrumentation: Test and measurement, monitoring and control instrumentation, and power and communications connectivity devices for marine, environmental, electronics and other applications
- Digital Imaging: High performance sensors, cameras and systems within the visible, infrared, ultraviolet and X-ray spectra, used in industrial, government and medical applications
- Aerospace and Defense Electronics: Sophisticated electronic components, subsystems and communications products, including defense electronics, commercial avionics and harsh environment interconnects
- Engineered Systems: Innovative systems engineering, manufacturing and specialised products for government, space, energy and industrial customers

The third of these includes its avionics business.

Teledyne Technologies had net sales of $5.6 billion in 2023: of this, Aerospace and Defense contributed $726.5 million, equating to 12.9%. This contribution has decreased significantly over the past decades, having been responsible for 37% of overall revenue in 2000 and 34% in 2010 respectively.

Financials - Aerospace and Defense Electronics

FYE $m 31/12/23	2023	2022	2021	2020	2019
Sales	726.5	682.4	628.7	589.4	690.1
Operating income	199.6	184.1	133.2	80.8	143.4
Return on sales %	27.5%	27.0%	21.2%	13.7%	20.8%

Sales in 2023 increased by $44.1m, a 6.5% rise from the previous year. Similarly, operating income continued to rise (as it had done from 2021), experiencing an 8.4% growth from 2022. Commenting on the performance of the Aerospace and Defense Electronics division, Teledyne stated: "The 2023 net sales increase compared with 2022 reflected $25.2 million of higher sales for aerospace electronics and $18.9 of higher sales for defense electronics. The increase in operating income for 2023 primarily reflected the impact of higher net sales and favorable product mix, partially offset by higher research and development expense."

They added further: "Cost of sales for 2023 increased compared with 2022 and reflected the impact of higher net sales partially offset by favorable product mix. Cost of sales as a percentage of net sales for 2023 decreased compared with 2022 and primarily reflected product mix, including the increased sales of aerospace electronics which carry a higher margin than most defense electronics products. Selling, general and administrative expenses, including research and development expense, increased ion 2023 compared with 2022 and included $3.2 million of higher research and development expense in 2023. The higher research and development expense primarily reflected higher spending for aerospace electronics. The selling, general and administrative expense percentage in 2023 increased compared with 2022 and reflected the higher research and development expense."

We estimate that Teledyne Aerospace and Defense Electronics generated $166m of revenues for avionic equipment in 2023.

Locations

Teledyne Aerospace and Defense Electronics is headquartered in Southern California.

Additional locations include: United States of America

- Chatsworth, California: Teledyne Energetics (comprising Teledyne Electronic Safety Products (TESP) and Teledyne RISI Inc.) TESP specializes in developing solid state Electronic Safe & Arms for Military, Space, and Commercial (Oil Exploration/Production). RISI specializes in developing EBW and EFI detonators that integrate into Electronic Safe & Arms
- Hawthorne, California: Teledyne Relays & Coax Switches - providing switching solutions
- Milpitas, California: Teledyne HiRel Electronics - producing high performance, high-reliability semiconductors
- Mountain View, California: Teledyne RF & Microwave - designing, developing, and manufacturing of sophisticated components and integrated microwave assemblies
- Rancho Cordova, California: Teledyne MEC - 160,000 ft2 manufacturing space (including 8,500 ft2 of clean manufacturing space) for production of TWTs and TWTAs.
- Rancho Cordova, California: Teledyne Paradise Datacom - designing, manufacturing and selling satellite modems, solid state power amplifiers (SSPA), block up converters (BUC) and associated redundancy subsystems
- Torrance, California: Teledyne Reynolds US - high voltage interconnects
- Woodbridge, Illinois: Teledyne Storm Microwave - high quality interconnect products and cable assemblies

United Kingdom

- Bromborough, Wirral: Teledyne CML Composites - comprehensive manufacturing service for composite products in advanced engineering applications, including components and assemblies for aircraft structures and systems
- Chelmsford, Essex: Teledyne Energetics UK - safety, arming and initiation technology
- Lincoln, Lincolnshire: Teledyne Lincoln Microwave Amplifiers, Circulators, Custom Engineering, Receiver Protectors, RF Converters, Semiconductors
- Newbury, Berkshire: Teledyne Reynolds UK - High Voltage Connectors & Cable Assemblies, Wire and Cable, Spark Gaps and Mica Capacitors, RF and microwave cable assemblies, Initiation & Ordnance, and cable assemblies, connectors and wire for space payload and launcher applications.
- Presteigne, Powys: Teledyne Labtech - microwave solutions with specialist capabilities in design, manufacturing, assembly and testing
- Shipley, West Yorkshire: Teledyne Defence & Space - adaptive filter and microwave front end solutions, Radar ESM System, Radar Electronic Support Measurement and ELINT subsystems, Highly integrated receiver and jammer broadband sub-systems for Force & self-protection

As well as its California HQ and facility, Teledyne Paradise Datacom also has a UK sales office in Chelmsford, Essex which covers Europe, Middle East and Africa. An AsiaPac sales presence is located in Bangkok, Thailand, and a China office in Beijing.

In addition, Teledyne FLIR has a manufacturing facility in Waterloo, Ontario as well as numerous sales and support facilities around the world.

Capabilities

Teledyne's GroundLink® Comm+ system provides airlines with a data infrastructure backbone that supports numerous applications, seamlessly connecting aircraft equipment with back office systems. The newest solution enabled by the GroundLink system is Groundlink® Data Link. This application is designed to provide the ACARS system (CMU, CMF or ATSU) with cellular connectivity via the GroundLink Comm+ unit to send and receive AOC and AAC messages when the aircraft is on the ground. In-flight ACARS over IP is also available for aircraft equipped with broadband.

Electronic Flight Bags: Teledyne Controls provides for enhancing EFB systems functionality by adding off-board communication, access to aircraft parameters and data management capability via its new GroundLink® AID+ system. This solution extends all AID functions to Wi-Fi enabled EFB systems and other crew devices through a cockpit wireless network available in all flight phases. The AID+ system permits wireless tablet based EFBs (such as iPads) or traditional

Ethernet connected Class1/2 EFBs to be integrated with the aircraft regardless of EFB form factor, operating systems or whether they connect with the aircraft as a wired or wireless EFB system.

Software uploads: Teledyne Controls' GroundLink Dataloading allows airlines to efficiently transfer Software Parts (SPs) and navigation databases to their aircraft, instantaneously and reliably, with the press of a button. This integrated system enables airlines to transition from manual SP distribution based on floppy disks, CDs and paper-based methods, to a paperless and automatic distribution process.

Data acquisition: Teledyne Controls' enhanced Digital Flight Data Acquisition Unit (DFDAU) is an integrated system that combines the functions of Mandatory Data Acquisition and Recording with a sophisticated Aircraft Condition Monitoring System (ACMS). This comprehensive system provides aircraft operators with a standardised hardware and software solution for high-power data acquisition, management and recording in an internal PCMCIA recorder.

In 2011 Teledyne Controls and Thales signed a reseller agreement, whereby Thales will provide Teledyne's Wireless GroundLink Quick Access Recorder (WQAR) to existing EQAR (Extended storage Quick Access Recorder) customers.

Teledyne also offers low cost ACARS via mobile telephony (5G). The newest solution is enabled by the Groundlink® Data Link. This application is designed to provide the ACARS system (CMU, CMF or ATSU) with cellular connectivity via the GroundLink Comm+ unit to send and receive AOC and AAC messages when the aircraft is on the ground. In-flight ACARS over IP is also available for aircraft equipped with broadband.

Customers and contracts

Close to one quarter (24.5%) of total sales in 2023 were to the US Government. Of this, 23.9% ($330.3 mn) came from Aerospace and Defense Electronics. This represented a slight increase from the previous contribution of 19.6% in 2022.

Teledyne provides Digital Data Acquisition and Transfer Units to most civil platforms including Airbus, Boeing, Comac C919, Embraer 170/190 and Sukhoi SSJ 100 aircraft.

Teledyne Controls is a major provider of Electronic Flight Bags to all Airbus and Boeing modern platforms.

Selected by 90 operators worldwide, Teledyne's WQAR has been certificated on numerous aircraft types. It is available factory fit from Boeing on the 777 and 737NG aircraft; Airbus on the A320 family, A330, A340 and A380 aircraft types and Embraer on the E190/195 family.

The Royal Air Force (RAF) has selected AirFASE® - a leading flight data analysis (FDA) tool to monitor and measure the safety and operational performance of its current and future fleet of 22 Airbus A400M Atlas aircraft.

GroundLink® Aircraft Interface Device (AID) from Teledyne Controls has been certified and is fully operational for use across Austrian Airlines' entire fleet of Airbus, Boeing and Embraer aircraft.

Strategy

Teledyne built its name on intelligent solutions that collect, manage and deliver aircraft data more efficiently. Its innovative technology and collaborative customer relationships have revolutionised the way aircraft operators access, manage and utilise their data, helping them achieve higher goals in safety, performance and efficiency.

The FLIR acquisition is a major strategic move for Teledyne. The rationale for the acquisition of FLIR by Teledyne is stated as being entirely complementary in that they both serve different sectors with differing technologies. FLIR has significant exposure to Aerospace and Land systems whilst Teledyne is exposed to Space and Subsea sectors. Equally FLIR's technology is almost entirely based upon infra-red whilst Teledyne utilises microwave, radio, gamma rays, X-rays and ultra-violet light spectrums for its applications.

Recent developments

September 2022: Teledyne Controls, the aircraft data management business and subsidiary of Teledyne Technologies has obtained EASA Supplemental Type Certification (STC) approval for installation of its ACES® Cabin Air Monitoring System on the Airbus A320 aircraft series. Teledyne ACES is an autonomous solution that enables aircraft operators to monitor, measure and analyze air quality in the cabin and flight deck, to help them ensure a safe and comfortable flying experience for their passengers and crew. Teledyne ACES, which is also FAA and CAA certified for the Airbus A320 family and FAA certified for the Boeing 737 series, has been implemented at four carriers in the US, UK, and Australia.

Jan 2021: Teledyne Technologies announced that it will acquire thermal imaging camera supplier FLIR systems in a $8 billion cash-and-stock deal to increase its portfolio of imaging sensor technology. The deal is expected to close mid-2021. The combined entities will generate circa $3bn of digital imaging related revenues.

Counterpoint comment

Teledyne Controls provides onboard data loading, storage and transmission products which it then supports with data analytics, data uploads and general support services. Like many avionics providers its business model is delivering value thru the service and support associated with its installed hardware base.The FLIR acquisition complements Teledyne's exposed to Space and Subsea sectors with FLIR's offering to Aerospace and Land systems. FLIR's technology is almost entirely based upon infra-red whilst Teledyne utilises microwave, radio, gamma rays, X-rays and ultra-violet light spectrums for its applications.

19.1.26.1 TELEDYNE FLIR

FLIR Systems designs and manufactures thermal imaging, visible-light imaging, video analytics, measurement and diagnostic, and advanced threat detection systems.

Teledyne FLIR offers a diversified portfolio that serves a number of applications in government defense, industrial, and commercial markets.

In May 2021, Teledyne Technologies announced that it will acquire thermal imaging camera supplier FLIR systems in a $8 billion cash-and-stock deal to increase its portfolio of imaging sensor technology. FLIR is now included in Teledyne's Digital Imaging segment and operates under the name Teledyne FLIR.

Financials

FYE 31/12/23	2023	2022	2021
Sales $m	3,144.1	3,110.9	2,412.9
Operating income $m	517.4	519.3	325.6
Return on sales %	16.4%	16.7%	13.5%

Commenting on the results in the Teledyne Technologies 2023 Annual Report, the company stated: "Our Digital Imaging segment net sales for 2023 increased 1.1%, compared with 2022. Operating income for 2023 decreased 0.4%, compared with 2022. Total year 2023 net sales included $97.3 million in incremental net sales from current and prior year acquisitions as well as organic sales growth from X-ray products, infrared imaging detectors and surveillance systems, offset by lower sales of unmanned air and ground systems for defence applications, MEMS, and commercial maritime and commercial infrared products. The decrease in operating income in 2023 reflected the impact of higher employee severance and facility consolidation costs, which included $9.4 million of expense in 2023 compared with $1.9 million of income in 2022. The 2022 severance and facility consolidation costs amount included $4.0 million of income related to the favourable resolution of a facility consolidation charge in 2022."

Locations

FLIR Systems, Inc. Corporate Headquarters is in Wilsonville, Oregon, USA.

Teledyne FLIR's key global locations are as follows:

- Europe: West Malling, United Kingdom; Täby, Sweden
- Middle East: Abu Dhabi, U.A.E.; Riyadh, Saudi Arabia
- Asia: Tokyo, Japan

Capabilities

FLIR manufactures many of the critical components for its products, including but not limited to infrared detectors, pan-tilts, optics and coatings, laser sub-systems, and micro-coolers, and develop much of the software and middleware for its systems. This vertical integration minimises lead times, facilitates prompt delivery of its products, controls costs, and ensures that these components satisfy quality standards.

FLIR purchases other parts pre-assembled, including certain detectors, coolers and optics, circuit boards, cables, and wire harnesses.

These purchased and manufactured components are then assembled into finished systems and tested at one of its primary production facilities located in the United States, Sweden, Norway, Estonia, and Canada. Certain components and finished goods, including some of their visible-spectrum cameras, test and measurement products and maritime electronics, are produced by contract manufacturers.

FLIR's technology is almost entirely based upon infra-red. An infrared detector, which collects or absorbs infrared radiation and converts it into an electronic signal, is the primary component of thermal imaging systems. The two types of infrared detectors that FLIR manufacture are often referred to as "cooled" and "uncooled" detectors. Cooled detectors utilise a mechanical sterling cycle micro-cooler to reduce the operating temperature of the infrared sensor to approximately -200řC. These detectors offer very high sensitivity and spatial resolution for long-range applications or those applications requiring high measurement precision.

Cooled detectors, while more sensitive and thus able to see farther, result in a product that is more expensive, heavier, more complex, and uses more power than those using uncooled detectors. Uncooled detectors operate at room temperature and do not require a micro-cooler, resulting in products that are lighter, use less power and are less expensive to produce than those using cooled detectors.

Infrared imaging systems used for surveillance typically employ cooled infrared detector and numerous other imaging technologies to identify and track objects from long distances and at high resolution.

FLIR's Systems are often installed onto larger platforms and must be able to integrate with other systems such as aircraft avionics, radars, remote weapon systems, laser systems, command and control centres, and large, broad-based security networks.

FLIR offers several products that provide precise target location and designation capabilities in applications ranging from man-portable devices to high definition, multi-spectral, stabilised airborne laser designator systems.

FLIR are also active in the upgrade market. For example the 380X is a hardware, firmware, and software upgrade to support advanced image aiding features for our globally renowned Star SAFIRE 380 gimbal systems. Its impressive enhancements reduce operator workload and boost visibility for faster, smarter critical decision making.

Customers and contracts

A substantial portion of Government and Defense business unit consolidated revenue is derived from sales to United States and foreign government agencies, and FLIR's business will continue to be substantially dependent upon such sales.

Bell Helicopter has selected FLIR's BRITE Star II® airborne stabilised multi-sensor system as the Target Acquisition Sensor Suite (TASS) for the US Army's Armed Reconnaissance Helicopter (ARH-70A) Program.

Star Safire 380-HD has been selected by Bristow Helicopters for its fleet of AW189 and S-92 helicopters to be used in the UK's Search and Rescue (SAR) helicopter programme.

FLIR Systems selected by Sikorsky, with US Army concurrence, to supply the Talon for its HH-60M Black Hawk helicopters.

FLIR Systems Selected to Provide Thermal Imaging Systems for Air National Guard HC-130 Search and Rescue Aircraft.

FLIR generates revenues from the unmanned/autonomous defence sector with the following noted:

- $26m contract in Q3 for NBCRV Sensor Suite Upgrade program; augments $48m Army contract in 2019
- $32m Centaur UGVs award in Q4, resulting in $75m in orders year-to-date from Army, Air Force, Marine Corps and Navy

- ~$50m in awards year-to-date to deliver R80D SkyRaiders to U.S. federal government customers
- $14m award for lightweight vehicle surveillance from U.S. Customs and Border Protection

FLIR states that "These products and solutions are sold off-the-shelf or can be customised for specific applications and range in price from under $10,000 for certain hand-held and weapon mounted systems to over $1 million for our most advanced integrated sensing solutions platform."

Strategy

"At FLIR we provide superpower vision, helping people around the world save lives, protect the environment, and enhance productivity. We're building more than innovative technologies; we're striving to build a more sustainable, more efficient, safer future."

Recent developments

May 2024: Teledyne FLIR Defense introduced its new Rogue 1™ loitering munition system at the Special Operations Forces (SOF) Week convention in Tampa. Rogue 1 is a next-generation, rapidly deployed, and optionally-lethal vertical takeoff and landing (VTOL) small unmanned aerial system (sUAS) that enables warfighters to conduct precision-strikes against moving and stationary armored targets, soft-skinned vehicles, and dismounted threats. An advanced fuzing system on Rogue 1 features a first-of-its-kind mechanical interrupt that allows the aircraft to be safely recovered and reused when targets are disengaged or missions are aborted. It also features advanced electro-optical and FLIR Boson® 640+ thermal cameras to deliver day/night long-range reconnaissance and surveillance. Plus, a novel coupling between sensors and warhead in the gimballed payload enables extremely precise targeting. Operators can attach modular, mission-specific payloads with lethal effects designed for distinct target types. Users can choose from Explosively Formed Penetrator (EFP), Forward Fragmenting, or non-lethal Trainer payload options. It has a 30-minute flight time, burst speeds of more than 70 mph (113 kph), and range greater than six miles (10 km).

April 2024: Teledyne FLIR Defense announced that it had been awarded an Indefinite Delivery/Indefinite Quantity (IDIQ) contract worth up to $249 million by the U.S. Marine Corps Systems Command for its Organic Precision Fires-Light (OPF-L) program. The initial delivery order is valued at $12 million. Organic Precision Fires-Light is a new system designed to provide rifle squads and platoons with a man-packable "organic, loitering, precision strike capability to engage the enemy beyond the line of sight." Teledyne FLIR will deliver the first 127 loitering munition systems to the Marines for test and evaluation later this summer. The contract has a five-year performance period with a three-year option.

March 2024: Teledyne FLIR has been recognised by Northrop Grumman Corporation during the company's Supplier Excellence Awards. Recognized for Resilience Excellence, Teledyne FLIR was instrumental in aiding Northrop Grumman with manufacturing and distribution goals as the industry works to support Department of Defense customers and other commercial entities.

February 2024: Teledyne FLIR Defense announced that Canada's Department of National Defence is seeking over 800 SkyRanger R70 Unmanned Aerial Systems (UAS), valued at more than CAD$95 million (approximately US$70 million), that Canada will donate to the government of Ukraine. Built by Teledyne FLIR in Waterloo, Ontario, SkyRanger® R70 drones feature autonomous navigation capability, plus advanced thermal and daytime sensors enabling them to detect and identify targets at long range. The advanced multi-mission drone can handle a variety of payloads up to 3.5 kilograms, including munitions.

July 2023: Teledyne FLIR has won a five-year Indefinite Delivery, Indefinite Quantity (IDIQ) contract worth up to $93.9 million to provide its Black Hornet® 3 Personal Reconnaissance Systems (PRS) to the United States Army. The initial award under this IDIQ will cover delivery of the nano-unmanned aerial systems (UAS), as well as controllers, spare parts, and training. In 2018 the U.S. Army began acquiring Black Hornet 3's as part of its Soldier Borne Sensor (SBS) program. Since then, the Army has placed orders totalling more than $125 million for the multi-faceted drone. Soldiers are using the advanced nano-UAVs to augment squad and small unit surveillance and reconnaissance capabilities.

July 2023: The U.S. Department of Defense announced $400 million in additional security assistance for Ukraine, including U.S. furnished Black Hornet surveillance drones made by Teledyne FLIR Defense, part of Teledyne Technologies.

February 2022: Teledyne FLIR Defense announced that the U.S. Naval Surface Warfare Center has awarded the company an indefinite delivery, indefinite quantity (IDIQ) contract worth up to $43.9 million to service electro-optical sensor systems used for Intelligence, Surveillance and Reconnaissance (ISR). The contract will provide replacement parts and technical support for several land- and sea-based systems used by the United States Navy and Coast Guard, including the BRITE® Star II, the Sea Star SAFIRE® III, and the Star SAFIRE® 380-HD. In addition to the IDIQ award, the Defense Logistics Agency (DLA) also recently awarded Teledyne FLIR two contracts with a combined value of $16.2 million to procure BRITE Star II multi-sensory imaging systems. Those systems will support the U.S. Navy/Marine Corps H-1 program.

Jan 2021: Teledyne Technologies announced that it will acquire thermal imaging camera supplier FLIR systems in a $8 billion cash-and-stock deal to increase its portfolio of imaging sensor technology. The deal is expected to close mid-2021. The combined entities will generate circa $3bn of digital imaging related revenues.

Counterpoint comment

A focused innovative business that serves a number of sectors including defence. As surveillance and EVS demands increase globally we believe that FLIR will continue to prosper. The company showed impressive defence contract won in the past three years.

19.1.27 TRANSDIGM

TransDigm Group Inc. is a leading global producer, designer and supplier of highly engineered aerospace components, systems and subsystems for use on nearly all commercial and military aircraft in service today.

TransDigm operates via a Private Equity-like Capital Structure and Culture.

TransDigm Group is comprised of 50 independent companies. Each TransDigm company operates its local business autonomously and realises its own company-specific market strategy.

Heavily invested within the US, TransDigm has approximately 60 manufacturing locations in the U.S. and employs about 8,000 people.

In 2023 TransDigm reported revenues of $6,585m with associated EBITDA of $2,923m (44%).

Financials — Power & Control

FYE 30/09/23 - $ millions	2023	2022	2021	2020	2019
Sales	3,316	2,873	2,550	2,695	2,736
EBITDA	1,866	1,531	1,319	1,345	1,395
EBITDA Margin %	56.2%	53.2%	51.8%	49.9%	51.0%

TransDigm commented in its 2023 10K: “Net sales for the Power & Control segment increased $443 million, an increase of 15.4%, for the fiscal year ended September 30, 2023 compared to the fiscal year ended September 30, 2022. The sales increase resulted primarily from increases in organic sales in the commercial aftermarket ($236 million, an increase of 29.6%), defense ($145 million, an increase of 10.2%) and commercial OEM ($86 million, an increase of 16.3%). The increase in commercial aftermarket sales is primarily attributable to the continued recovery in commercial air travel demand and the resulting higher flight hours and utilization of aircraft in fiscal 2023 compared to fiscal 2022. The increase in defense sales is primarily attributable to slowly improving U.S. government defense spend outlays (though, in management’s estimation, the current lag between spend authorizations and outlays remains longer than historical average levels but has improved in the second half of fiscal 2023). The increase in commercial OEM sales is primarily attributable to the continued recovery in both narrow-body and wide-body aircraft production and deliveries.”

The Power & Control division has three businesses that operate within the Avionics sector and these are described as follows.

19.1.27.1 AEROSONIC

Founded in 1953, Aerosonic LLC located in Clearwater, Florida, designs and manufactures highly engineered air data sensors for military and commercial aerospace applications. They have experience with air data products and have been producing them for over 85 years. In 1993, Aerosonic acquired Avionics Specialties Inc. from Teledyne Corporation. Aerosonic itself was acquired by TransDigm in 2013.

Financials

Aerosonic employs 150 personnel within its Clearwater facility.

Counterpoint estimates that $25m were associated with Avionics products in 2023.

Locations

Aerosonic operates from a wholly owned facility located in Clearwater, Florida.

Capabilities

Aerosonic lists its product capabilities as including the following:

- Air Data Computers
- Angle Of Attack (AOA) Probes
- Digital Standby Instruments
- Oasis® , A New Electronic Standby Instrument System (ESIS)
- Integrated Multi-Function Probe (IMFP®)
- Commercial Pitot Probes and Pitot-Static Probes
- Mechanical Flight Instruments
- Pitot Probes Including Pitot, Pitot Static and Pitot/Angle-Of-Attack Probes
- Stall Warning Transmitter (SWT)
- Static Pressure Ports
- Outside Air Temperature Sensors (OATS)

Aerosonic's air data computers compute a variety of functions such as Static Pressure, Total Pressure, Calibrated Airspeed, Mach, SAT, TAS, Altitude Rate, Airspeed Rate, and Pressure Ratio — any air data function can be added. In some unique applications, equivalent airspeed is calculated instead of calibrated airspeed.

The Angle of Attack (AoA) Probe provides AoA or Sideslip (SS) by sensing the direction of local airflow. It is mounted on the fuselage with the sensing probe extending through the aircraft fuselage. The sensing probe is continually driven to null pressure differential between the upper and lower slots in its forward surface.

Pitot probes: Aerosonic has an extensive portfolio of pitot probes including pitot, pitot static and pitot/angle-of-attack probes designed and in service, meeting the requirements of virtually any type of aerospace application. Probes may be configured as standalone with pneumatic outputs to the Air Data Computer, or they may integrate the computing function and eliminate the pneumatic connection.

Digital Standby Instruments. Aerosonic, provides the next generation of stand-by indicators. Digital accuracy and reliability that will track with the primary flight display and reduce life-cycle costs.

Aerosonic is also a FAR 25 approved repair and overhaul facility.

Customers and contracts

Aerosonic lists 10 distributors that stock and supply its products located in the US, Far East and Europe.

At the time that TransDigm acquired the business Aerosonic's primary customers were recorded as the U.S. government and Boeing.

Aerosonic avionics equipment is listed in the Technical Orders and can be found on a majority of military aircraft including C-130, F-16, T-50, CN-235/C-295, UH-60 and many more.

In 2010 Aerosonic received an order from KAI to provide air data test equipment to provide in-country support of components used on Korean T-50s.

In 2011 Aerosonic said it received a contract from the U.S. Defense Logistics Agency to supply AAU/32A encoding altimeters used on Army OH-58 and UH-60 helicopters.

Strategy

To promote excellence in air data products and services within the aerospace and defense markets.

Recent developments

Jan 2020: Aerosonic entered an agreement with AllClear to support its products in the aftermarket. "We are very pleased to announce this partnership with AllClear. We believe this agreement will greatly increase Aerosonic's ability to support our F-16 and T-50 international customers."

Counterpoint comment

A focussed niche business with an established customer base largely in the US.

19.1.27.2 CMC ELECTRONICS

The company was founded in 1903 as Canadian Wireless Telegraph Company of Canada by Guglielmo Marconi. In 1925 the company was renamed Canadian Marconi Company. In 1948 English Electric purchased the UK based Marconi Company and in 1953 acquired 50.6% of Canadian Marconi Company.

It was also owned by BAE Systems before passing through ONCAP and was then acquired by Esterline in 2007.

Esterline/CMC was acquired by TransDigm group in 2018.

CMC Electronics has an international reputation for the design and manufacture of customised cockpit systems integration, avionics and display solutions for the military and commercial aviation markets.

Based in Montreal Canada since 1903, CMC Electronics also has facilities in Ottawa, Ontario and Chicago, Illinois, serving its customers worldwide.

The company serves customers in the following markets: Military Helicopters; Military Fighters/Trainers; Civil Helicopters; Air Transport; Unmanned Aerial Systems.

Financials

TransDigm do not report subsidiary sales, however, at the time of the acquisition of Esterline in 2018 CMC Electronics reported sales of $861m.

This includes simulator, medical and gaming revenues which we estimate accounts for at least 50% of sales.

CMC Electronics revenues are estimated as having been $331m in 2023.

Locations

CMC Electronics operates out of its headquarters located in Montreal where it owns a 272,000 ftš facility.

It also has facilities in St Laurent, Ottawa and Sugar Grove, Illinois (45,000 ft^2).

Capabilities

The company possesses capabilities in the following areas:

- Navigation
- Avionics Computers
- Cockpit Systems Integration
- Microelectronics
- Displays & Control Panels

Within these areas, the following products are offered:

- Navigation
  - Civil Flight Management Systems (FMS)
  - Military Flight Management Systems
  - Software Flight Management System (SW FMS)
  - GNSS Receivers
  - Doppler Velocity Sensors
- Avionics Computers
  - Multicore Avionics Computer
  - Aircraft Information Server (AIS)
- Cockpit Systems Integration
  - Fighter/Trainer Cockpits
  - Helicopter Cockpits
  - Air Transport Cockpits
  - Software Applications
- Microelectronics
  - Microcircuit Hybrids
  - Optoelectronics
- Displays & Control Panels
  - Multi-function Display
  - Custom Displays and Control Panels
  - Portable Mission Display TacView +
  - Head-Up Displays (HUD)

Avionics computers; The PU-3000 series of Avionics Computers is the fourth generation of Avionics Computers from CMC. These computers include a high-performance multi-core processing capability, an array of graphics performance options (from Quad Head Graphics Processing Units to software based rendering engines).

The FV-4000 is an open architecture avionics computer offering flexible power and advanced technology in a low-cost airborne processing and display generation system.

LCD Displays: The CMA-6800 LCD display is a form, fit and function replacement upgrade solution for the Honeywell ED-800 CRT units on selected regional, corporate and helicopter aircraft via STC. These include: ATR 42/72 series 200/300/500, Bombardier Aerospace (now De Havilland Canada) Dash8 Series 100/200/300, Fokker 50, Jetstream 41, Hawker 800/1000, Challenger 601, CL-415, Cessna 650, Falcon 900, Gulfstream III and Sikorsky S-76A/B/C.

The latest display development, the MFD 3068, is an ARINC 653-based display platform is based on Green Hills' Integrity 178 tuMP Real Time Operating System (RTOS) and MOSArt® (Modular Open System Architecture) middleware.

Integrated military cockpits: The Cockpit 4000 is a fully integrated avionics suite that provides a glass cockpit enabling air forces to download their training onto less expensive Basic and Advanced trainer aircraft. System capabilities include primary flight display, integrated communications/ navigation management, steer-point navigation, tactical situation display, engine indication and caution advisory, stores management, no-drop bombing scoring system, and a virtual Multi Mode Radar and Radar Warning Receiver (RWR) training system.

Integrated Avionics Computer: The CMA-5000 supports Multi-Function Displays (MFD), Head-Up Display (HUD) systems and mission functions on modern aircraft. A rugged platform with powerful processing capabilities, the system is designed to satisfy civil certification requirements for avionics systems.

FMS systems: The CMA-9000 is a compact flight management system designed for modern digital cockpits in fixed and rotary wing aircraft. It is intended for civil and military transport as well as helicopter FMS applications. It is the next generation FMS derived from the successful CMA-900 FMS/GPS and the CMA-3000 helicopter FMS. The CMA-9000 conforms to the ARINC-739 MCDU standard making suitable as display and control unit for other systems such as ACARS, ACMS, SATCOM. Moreover, it has the capability to act as Radio Management Unit.

Electronic Flight Bags: CMC's Crew Information System addresses requirements for information sharing associated with cockpit, cabin and aircraft maintenance systems. In conjunction with CMC's new PilotView® Aircraft Information Server, this product line delivers an integrated aircraft information management server that enables a wide range of cockpit and situational awareness applications.

CMC also provides both civil and military applications with a range of navigation and GPS sensors and receivers in support of the product lines noted above.

Customers and contracts

CMC lists its retrofit and upgrade displays/FMS sales on platforms including ATR 42/72 series 200/300/500, Bombardier Aerospace Dash8 Series 100/200/300, Fokker 50, Jetstream 41, Hawker 800/1000, Challenger 601, CL-415, Cessna 650, Falcon 900, Gulfstream III and Sikorky S-76A/B/C.

With more than 3,000 PilotView units delivered to Business Jet, Commercial Airline Operators and Aircraft OEMs, CMC's Electronic Flight Bag is designed with the cockpit in mind (certified for 777 amongst others).

CMC lists the following platforms that are OEM certified for its EFB products;

ATR 42 / 72, 737NG, Global XRS / 5000, Bombardier (now Mitsubishi) CRJ700 / 900 / 1000, Dassault F2000 / 900 / 7X, Legacy Embraer 600/650, Embraer E170/175/190

CMC also list a number of STC certified Pilotview EFB platforms including A330/340, 747-8, EMB 135J, 757, Falcon 2000/2000EX, 737-700 BBJ, Challenger 604/605, Global Express 5000/6000, Gulfstream 100/150/GIV/GV.

Strategy

CMC Electronics has achieved an international reputation for innovation and excellence in the design and manufacture of cutting-edge cockpit systems integration, avionics and display solutions for the military and commercial aviation markets.

Recent developments

March 2024: CMC Electronics and Hexagon's Autonomy & Positioning division develop a leading-edge multi-constellation, multi-frequency (MCMF) GNSS platform. With a focus on enhanced detection of spoofing and jamming, lighter weight and a smaller form factor, this innovative solution will shape the trajectory of GNSS technology for the future.

August 2023: CMC Electronics announced a multi-year contract with Swiss-based Pilatus Aircraft Ltd. for the purchase of its cutting-edge avionics solutions for the PC-21 Next Generation Trainer. This contract includes the supply of the Head-Up Display (HUD) sub-system, the Flight Management System, and the GNSS receiver. The award follows the acquisition of additional PC-21 turboprop-powered advanced trainers by Spain, an order that will bring Spain's PC-21 fleet to 40 aircraft.

March 2023: CMC Electronics announced a new multi-year contract with Sikorsky, a Lockheed Martin company, for the supply of its military Flight Management System (FMS) on several Sikorsky helicopter models including the UH-60M, HH-60M, HH-60W, S-70i and the S-70M. The helicopters with CMC's equipment will be delivered to the US Army, the US Air Force as well as numerous international Black Hawk customers for use in a wide range of missions including search and rescue, troop transport, medical evacuation, disaster relief, aerial firefighting and border patrol.

November 2022: CMC Electronics was selected by aviation technology leader Merlin to provide its civil-certified PU-3000 avionics computer to power their autonomous flight solutions. Merlin's autonomy systems aim to reduce crew in large cargo aircraft, and to eliminate crew entirely in small aircraft, solving a key aviation issue in an industry facing a severe global pilot shortage. As a strategic partner to Merlin, CMC will provide its latest multicore avionics computer certified by Transport Canada to host their advanced flight control software that enables autonomous flying. The PU-3000's open architecture platform offers high-performance multicore processing capability and an unrivaled set of interfaces, allowing Merlin to easily adapt the system for use on different aircraft types. The PU-3000 allows customers to retain their intellectual property by implementing their own applications using CMC's comprehensive Software Development Kit (SDK). The computer can host software applications developed to various Design Assurance Levels, up to DAL A.

July 2022: CMC Electronics (CMC) announced that Korea Aerospace Industries (KAI) has awarded a new contract to CMC for the modernization of the Republic of Korea Air Force (ROKAF) fleet of KA-1 trainer aircraft used for advanced mission training and light attack missions. CMC worked closely with KAI to meet their request and proposed its state-of-the-art mission computer-based cockpit built on the PU-3000, the world's first certified multicore mission computer. The PU-3000 and its partitioned, embedded, software applications offer a flexible solution to integrate several conventional multifunctional displays (MFDs) or a single large area display (LAD) configuration as used in the KA-1 solution. The PU-3000 software development kit also allows KAI to develop specific proprietary mission applications on their own.

March 2022: CMC Electronics was selected to supply its state-of-the-art mission-ready avionics and software applications for the all-new Calidus B-250, a next-generation light attack combat and training aircraft. CMC's solution includes the PU-3000, the latest generation certified avionics computer with video processing capabilities powering both a Large Area Display (LAD) and a heads-up display for critical missions. The PU-3000 is an open-architecture system that comes equipped with a Software Development Kit (SDK). The SDK will allow Calidus and third parties to develop and customize their own software applications such as PFD, EICAS and more. In addition to Calidus' custom applications, the PU-3000 will host CMC's Synthetic Vision System (SVS) and Flight Management System (FMS) software applications. The SVS enhances operational flexibility and safety by increasing the pilot's situational awareness, reducing workload and minimizing flight technical errors, particularly during the approach and landing phases of flight.

May 2021: CMC Electronics announced that its Smart Multi-Function Display (SMFD) MFD-3068 had received Canadian Technical Standing Order (CAN TSO) authorization by Transport Canada. The 6 x 8-in MFD-3068 is the latest display from CMC and part of the same family of products as the recently certified multicore PU-3000 avionics computer. The display's unique open architecture platform allows customers to retain their intellectual property by implementing their own applications using CMC's comprehensive Software Development Kit (SDK). A combination of customer developed and CMC developed software including primary flight display, navigation display, synthetic vision system, flight management applications can be hosted on the unit simultaneously. The display can host software applications developed to various Design Assurance Levels, up to DAL A.

April 2021: CMC Electronics announced that its latest PU-3000 multicore avionics computer was certified by Transport Canada to the highest Design Assurance Level. The PU-3000 avionics computer can host multiple avionics applications reducing equipment count and integration costs. The PU-3000 supports commercial serial interface standards as well as MIL-STD-1553B. Modular by design, the PU-3000 can be used as a common computing platform able to host a large variety of functions into a single unit including primary flight display (PFD), navigation display (ND), flight management systems (FMS), radio management systems (RMS), flight director systems (FDS), Terrain Avoidance and Warning System (TAWS) and mission-critical tactical applications. The PU-3000 series is capable of driving multiple screen sizes ranging from 10 to 21-in video displays with the redundancy needed for flight critical functions.

Counterpoint comment

CMC is a stand-alone business within the TransDigm portfolio and it has benefited from its focus upon the retrofit/upgrade market sector. It may struggle to continue to find success in the OEM market given the more integrated approach being adopted and the requirement for significant investment.

19.1.28 WIND RIVER

Wind River was founded in 1981 as a software company providing industrial customers with critical application software solutions.

It was subject to an IPO in 1993, acquired by Intel in 2009 and then acquired by its current private equity investor TPG in 2018. In December 2022, Wind River was acquired by Dublin-based Aptiv PLC (a global technology company "focused on making mobility safer, greener and more connected") for $1.2 billion.

For nearly 40 years, Wind River has helped the world's leading technology companies with generation of the safest, most secure devices in the world. And in a new era of autonomy and connectivity, Wind River continues to lead the way. Wind River's software runs the "can't fail" computing systems of modern infrastructure, including mission-critical aircraft, rail, automobiles, medical devices, manufacturing plants, and communications networks.

Wind River's technology is in more than 2 billion devices throughout the world and is backed by a global service support infrastructure.

Wind River supports a number of sectors including the following with key customers identified:

- Aerospace and defense: Airbus Group, BAE Systems, Boeing, Lockheed Martin, Northrop Grumman, GE Aerospace, Honeywell
- Automotive: BMW, Fiat, Ford, General Motors, Honda, Johnson Controls, Valeo Group
- Industrial and medical: ABB, KUKA, Mitsubishi, Rockwell Automation, Schneider Electric, Siemens, Toshiba
- Medical: GE Healthcare, Olympus, Stryker, Varian
- Networking: ARRIS, Avaya, Ciena, Ericsson, Tellabs

Financials

Intel recorded a reduction in revenues of circa $330m (annualised) when it disposed of Wind River in 2018.

We estimate that Wind River generated $35m of revenues for avionics related software sales in 2023.

Locations

Wind River has its corporate headquarters in CA, USA however it is supported by a global network of distributors and service centres throughout the Americas, EU and Asia.

Wind River also generates revenues from licensing of software and has specific facilities in the US, EU, Middle East and Asia that service this product offering.

Capabilities

Wind River is a market leader in offering a number of embedded software products as follows:

- Total IoT and embedded OS
- Commercial embedded Linux
- RTOS on a global basis

Wind River supports a range of workflows for a digital world, providing customers with open source offerings, an RTOS, or a combination. This flexibility allows companies to deliver products that leverage the latest community-driven innovations while meeting the safety, security and reliability requirements for mission-critical avionics applications.

VxWorks Real Time operating System (RTOS) has been utilised by many avionics manufacturers that need to operate multiple applications utilising shared resources in real time. These applications are hosted using VxWorks such that the criticality of each is recognised and managed in real time accordingly.

VxWorks is suited to IMA or shared computing resource platforms being adopted by military and civil avionics specifiers.

Wind River®Linux enables customers to build and deploy robust, reliable, and secure Linux-based edge devices and systems without the risk and development effort associated with in-house efforts.

In terms of avionics Linux provides an industry standard upgrade path at lower cost than many in-house bespoke solutions. The benefits of Linux include keeping code base up to date, track and fix defects, apply security patches, customise your runtime to adhere to strict market specifications and certifications, facilitate IP and export compliance, and significantly reduce costs.

Customers and contracts

Within Aerospace Wind River lists its customers as including the following:

Airbus Group, BAE Systems, Boeing, Lockheed Martin, Northrop Grumman, GE, Honeywell and Collins Aerospace.

We also note the following in recent years:

- March 2019. Teledyne e2v, Wind River and CoreAVI announced today that they will provide key technologies for BAE Systems' new mission computer. The solution includes Wind River VxWorks® real time operating system running on Teledyne e2v Qormino® Common Computer Platform, and CoreAVI supplying its temperature-screened AMD Embedded Radeon™ E8860 GPUs as well as its safety critical ArgusCore SC1™ OpenGL® 1.0.1 graphics drivers.
- Leonardo Helicopters turned to Wind River for its industry-leading VxWorks 653 product, a commercial off-the-shelf (COTS) platform for delivering safety-critical, integrated modular avionics (IMA) applications.
- Wind River's secure software has served as a key technology for the Mars Science Laboratory rover Curiosity, Northrop Grumman X-47B, unmanned aircraft, CIRA's FTB-1 reusable unmanned spacecraft, and the nEUROn Unmanned Combat Air Vehicle demonstrator, among others.

Strategy

Wind River is accelerating digital transformation of critical infrastructure by delivering the technology and expertise that enable the deployment of safe, secure, and reliable IoT systems. It is a global leader in delivering software for intelligent connected systems, and offers a comprehensive, edge-to-cloud software portfolio designed to address the challenges and opportunities critical infrastructure companies face when evolving and modernising their systems as they work to realise the full potential of IoT.

Recent developments

December 2023: Wind River® continues to lead the global embedded real-time operating system (RTOS) and commercial Linux categories, according to the latest VDC Research report. Research results reflect the worldwide market leadership of the company's edge OS platforms, which include VxWorks® , Wind River Helix™ Virtualization Platform, and Wind River Linux.

October 2023: Wind River® announced that the 2023 MAE Innovators Awards program has named VxWorks® container support as a Platinum winner in the Embedded Computing category. The voting engineering community recognized the innovative impact of VxWorks as the first and only RTOS (real-time operating system) to support application deployment and management through containers. The 2023 MAE Innovators Awards program celebrates outstanding innovation in defense and aerospace for the engineering industry. Every fall, it showcases and rewards companies, designers, and innovators who have contributed to the advancement of technology through their creative and impactful designs. The editorial staff at Military + Aerospace Electronics choose the qualified judging panel who selects the MAE Innovators Award winners.

September 2023: Wind River Linux, the industry-leading open-source operating system for embedded systems, has been validated against the Future Airborne Capability Environment (FACE) Version 3.1 standard. This development underscores Wind River's commitment to providing open solutions for the aerospace and defense industries.

May 2023: Wind River® announced it was named in Newsweek's Top 100 Global Most Loved Workplaces®list, ranking #13 overall. Backed by Best Practice Institute (BPI) research and analysis, Most Loved Workplaces® recognizes companies where people are happiest and most satisfied at work based on the level of respect, collaboration, support, and sense of belonging they feel inside the company. The results were determined after surveying more than two million

employees from businesses with workforces varying in size from 30 to more than 10,000. The list recognizes companies that put respect, caring, and appreciation for their employees at the center of their business model and, in doing so, have earned the loyalty and respect of the people who work for them.

January 2023: Wind River® announced it had worked with Airbus to support the A330 Multi-Role Tanker Transport (MRTT) aircraft for automatic air-to-air refueling (A3R). The MRTT aircraft is the world's first tanker to be certified for automatic air-to-air refueling boom operations in daylight. Airbus uses VxWorks 653 for the A330 MRTT air-to-air refueling boom system (ARBS). This system is comprised of multiple ARINC 653-compliant applications running at multiple levels of safety-criticality and achieved DO-178C DAL A certification. With this development, the Airbus A330 MRTT A3R capability has earned the distinction of being certified by the Spanish National Institute for Aerospace Technology (INTA), involving multiple ED-12C / DO-178C DAL A applications running simultaneously on multiple cores on a multicore processor.

May 2022: BAE Systems has selected Wind River to provide the software development and testing platform for the development of the Tempest sixth generation fighter jet's development. Last August the Ministry of Defence (MOD) awarded a contract worth approximately £250m (US$348m) to BAE Systems to progress the design and development of Tempest, the UK's Future Combat Air System (FCAS). An industrial consortium that also includes lead partners Rolls Royce, Leonardo and MBDA are working with the UK's RAF Rapid Capabilities Office and the MOD to develop the fighter jet by 2035. BAE Systems will be using Wind River's VxWorks 653 platform and associated DO-178C DAL B safety certification evidence packages, and AdaCore GNAT Pro Assurance as part of ongoing technology demonstration project work in support of the program.

January 2022: Aptiv PLC announced a definitive agreement to acquire Wind River® from TPG Capital, the private equity platform of global alternative asset management firm TPG, for $4.3 billion in cash. Wind River is a global leader in delivering software for the intelligent edge. Used on over two billion edge devices across more than 1,700 customers globally, Wind River's software enables the secure development, deployment, operations and servicing of mission-critical intelligent systems. This edge-to-cloud software portfolio spans the aerospace and defense, telecommunications, industrial and automotive markets and is anchored by Wind River Studio, a highly versatile, comprehensive cloud-native intelligent systems software platform that enables full product lifecycle management for edge-to-cloud use cases. Wind River generated approximately $400 million in revenues in 2021.

Counterpoint comment

Wind River has a long track record of providing software support to avionics designers and has worked directly with many blue chip customers within the Aerospace & Defence sector. We believe it to be one of the leading software houses in developing next gen open architectures for avionics computing solutions, especially in real-time operating system (RTOS) and commercial Linux categories.

19.2 AVIONICS SUPPLIER PROFILES --- EUROPE

19.2.1 BAE SYSTEMS

BAE Systems is a UK-based defence contractor that generated £25.2bn of sales revenues in 2023. It operates through several divisions: Electronic Systems (22% of revenue); Platforms & Services (15%); Air (32%); Maritime (22%); Cyber & Intelligence (9%) . including air (52%), land (15%), Maritime (26%), and Cyber (5%).

The US represents 42% of total group revenues and BAE has many facilities in the US where it designs and manufactures many of its defense related avionics and sensors products. The UK brings in 26% of revenue, followed by Kingdom of Saudi Arabia (11%), Australia (4%) and Other international markets (17%).

BAES is both a military OEM airframer, building platforms such as the Hawk trainer and the Eurofighter Typhoon, and a provider of electronic systems including Flight Controls, Engine FADECs and Electronic Warfare.

In 2000 BAE Systems acquired Lockheed Martin's Aerospace Electronic Systems which provided the basis for Electronic Systems today. Over the next few years, the company expanded into the US to win business in the large defence market. To this end and as a necessity to work on major US military programmes a new subsidiary, BAE Systems Inc., (headquartered in Delaware), was formed.

In 2013 BAES disposed of its UK based commercial Avionics operations businesses to Finmeccanica Group (now Leonardo).

In February 2024 BAES acquired Ball Aerospace , and in May 2024 acquired Callen-Lenz, a UK-based developer of Unmanned Aerial Systems (UAS), including avionics.

BAES's Electronics division is headquartered in Nashua New Hampshire, USA.

The Electronics Division operates via six 5 business units as follows:

- Electronic Combat Solutions (29% of division revenue)
- C4ISR Systems (22%)
- Controls & Avionics Solutions (16%)
- Precision Strike & Sensing Solutions (15%)
- Countermeasure & Electromagnetic Attack Solutions (14%)
- Power & Propulsion Solutions (4%)

As per the company's 2023 Annual Report, the Electronic Systems division employs around 17,500 employees, and "comprises the Group's US- and UK-based electronic solutions, including electronic warfare systems, navigation systems, electro-optical sensors, military and commercial digital engine and flight controls, precision guidance and seeker solutions, next generation military communications systems and data links, persistent surveillance capabilities, space electronics and electric drive propulsion systems."

This report covers ECS, PS&S, SST and C4ISR where BAE provide airborne EW, ECM and sensor systems.

Financials - Electronic Systems (defined by Group)

FYE 31/12/23 - £millions	2023	2022	2021	2020	2019
Sales	5,458	5,057	4,491	4,557	4,439
Underlying EBITA[1]	878	838	766	684	687
EBITA margin	16.1%	16.6%	17.1%	15.0%	15.5%

Sales in electronic systems rose by 8% from the previous year, continuing the upwards trajectory from 2021. Underlying EBITA also continued to rise by 5% - from 2022, although not to the same extent as 2021-2022 (9%).

BAE commented that the sales were led "by continued recovery in the commercial aviation business across both civil aviation and power and propulsion, along with gains in electronic combat systems. Underlying EBIT grew 5%, generating a return on sales of 16.1%, within the guided range. This reflected the absorption of lower pension recoveries partially offset by higher commercial activity. Operating business cash flow was £811m and reflects improved working capital management."

We estimate that BAE generated $800m of revenues associated with its airborne electronic warfare, countermeasures and sensors products in 2023.

Locations

BAE Inc. is a subsidiary of BAE Systems plc located in the US. Headquartered in Falls Church, Virginia, BAE Systems, Inc. employs approximately 35,100 across its major operations in the United States, United Kingdom, Sweden, and Israel,

BAE Inc has its Electronics Systems headquarters in Nashua, NH, USA where it develops much of its Electronic Warfare capabilities including DEWS electronic warfare and countermeasures as fitted to F15 and F35 platforms.

BAE Systems has design development and support for its Electronics Systems division in New Jersey, Texas, Virginia and Georgia.

BAE's Electronics Systems employs 16,600 personnel throughout the US, UK and Europe.

Capabilities

The most relevant sections within Electronic Systems and their capabilities are as follows:

- Electronic Combat Solutions: designing, building and supporting integrated electronic warfare systems for platform prime and government customers: trusted mission systems provider for all three electronic warfare missions: electronic attack; electronic protection; and electronic support.
- Precision Strike & Sensing Solutions: designing and manufacturing state-of-the-art systems and technology enabling precision strike missions.
- C4ISR Systems: providing actionable intelligence through innovative technical solutions for airborne persistent surveillance, secure communications, identification systems, and signals intelligence.
- Controls & Avionics Solutions: developing and production of electronics for military and commercial aircraft, including fly-by-wire flight controls, full authority digital engine controls, power management solutions, cabin management systems and mission computers.

BAE Systems' digital electronic warfare system geolocates potential threats by detecting adversary radars at significant ranges, allowing the aircraft to limit its own radar emissions, enabling it to better conceal its location when operating in hostile territory. Data collected by the system helps identify, monitor, analyse, and rapidly respond to threats by providing the pilot with maximum situational awareness. Advanced avionics and sensors provide a complete view of the battlespace, enabling pilot to take appropriate action and ensure mission success.

Key features of BAE's electronic warfare capabilities include:

- integrated radar warning, targeting support, and countermeasures in one system
- Reduced long-term lifecycle costs to keep the aircraft fielded now and in the future
- Enhanced situational awareness through all-aspect, broadband radar warning and geolocation capabilities
- Always-on multispectral, radio frequency (RF) and infrared (IR) countermeasures enable rapid response for complete pilot protection
- A 360ž view of the battlespace, promoting mission success even in signal dense environments.

Survivability, Targeting & Sensing Solutions exploits the electro-optical and infrared spectrum to provide leading threat warning and infrared countermeasures systems, precision guidance and seeker solutions, advanced targeting solutions, head-up displays and state-of-the-art tactical imaging systems.

C4ISR Systems: BAE addresses the market for actionable intelligence through innovative technical solutions for airborne persistent surveillance, identification systems, signals intelligence, underwater and surface warfare solutions, and space resiliency products.

Tactical networks — defending Mission Computers: BAE develops cyber defense systems that protect wireless tactical networks against zero—day attacks. Leveraging expertise in autonomic defense and wireless networking, BAE's cyber defense system combines monitoring, decision, and response technologies to automatically detect and contain any attack, known or unknown, and preserve critical mission capabilities.

Next Gen electronic warfare systems: With more than 60 years of experience BAE's electronic warfare systems have flown on over 120 platforms and operate on 80% of U.S. military fixed-wing aircraft, over 95% of U.S. Army rotary-wing aircraft, and those of U.S. allies. BAE Systems is the sole electronic warfare provider for 5th generation F35 aircraft.

Electronic Combat Solutions. Provides capabilities in advanced electronic warfare solutions for airborne applications, including electronic support, electronic attack, and electronic protection technologies.

- Electronic Protect (EP): BAE supplies the Directional Infrared Countermeasures (DIRCM) category, with a laser-based Advanced Threat Infrared Countermeasures (ATIRCM) system that protects fixed-wing and rotary aircraft from missile attacks under a more comprehensive range of mission situations.
- Electronic Support (ES) follows operational directives to rapidly detect, intercept, identify, and track electromagnetic energy sources to recognise threats, collect targeting and signals intelligence data, and inform future operational planning. ES threat detection is often considered Electronic Warfare's intelligence, surveillance, & reconnaissance (ISR) mission, which also includes geolocation and direction-finding capabilities.

- Electronic Attack (EA) is the use of electromagnetic or directed energy weapons to assault enemy forces' electronic infrastructure with the intent to degrade or eliminate their combat capabilities. This includes threat analysis and response, as well as countermeasures such as signal jamming, electromagnetic deception (spoofing), lasers, radio frequency (RF) weapons, or any combination of the above electronic warfare tools to achieve threat neutralisation.

Customer and contracts

BAE systems provides the electronic warfare suite for the F-35 lightning fighter platform and has delivered 500 systems to date. BAE supplies the following key avionic/sensor suites for the F-35:

- Management computer technology which is currently undergoing an upgrade development programme with Lockheed Martin.
- Active inceptor system
- Electronic warfare system (classified)

BAE supplies the F-22 Raptor programme with its AN/ALR-94 EW suite which provides advanced self-protection to detect and defeat surface and airborne threats with cutting-edge offensive and defensive technologies that combine robust situational awareness, precision targeting support, and robust threat countermeasures

BAE provides the AESA Radar system for the Eurofighter Typhoon — with the contract being upgraded and extended in 2020.

Via a contract with Boeing, BAE systems provides the USAF with its Eagle Passive Active Warning Survivability System for the F-15 fighter aircraft. The EPAWS provides advanced aircraft protection and has completed successful F-15 aircraft flight tests.

BAE also has a contract to digitally upgrade its ALR-56 Radar Warning Receiver system, enhancing the capability of technology on F-15 jets.

Recent contract wins include:

- June 2024: $95 million contract from the U.S. Navy for advanced countermeasure pods to protect the P-8A Poseidon Multi-Mission Maritime Aircraft from missiles and other threats.
- May 2024: US Navy has chosen BAE Systems to develop the Dual Band Decoy (DBD), a new radio frequency jammer based on the combat-proven AN/ALE-55 Fiber-Optic Towed Decoy to be used by fighter jets to counter enemy attacks. The DBD will consist of a towed unit connected to electronic warfare equipment onboard the US Navy's F/A-18E/F Super Hornets by fiber-optic cables. It will utilize its jamming capabilities to disrupt enemy radars and lure missiles away from the aircraft. The decoy can be launched manually and automatically and will have the ability to be updated in the future to counter emerging threats. Work on the DBD will be performed at BAE's Nashua, New Hampshire, facility.
- September 2023: five year contract to sustain the AN/ALR-94 EW suite in the F-22 Raptor, including repairs and upgrades.
- June 2023: BAE together with Leonardo was awarded a contract from the UK's MOD to modernise the radars of the Royal Air Force's Typhoon fleet. Under the 870-million pound ($1.1 billion) agreement, the companies will equip the fighter jets with the European Common Radar Systems (ECRS) Mk2.

Via a contract with Boeing and Warner Robins Air Logistics Complex, totalling more than $1bn (£0.8bn), BAE is responsible for the installation of the Digital Electronic Warfare System (DEWS) on new and existing F-15 aircraft. BAE are also executing a contract worth in excess of $300m (£227m) to provide DEWS to support the sale of new F-15 aircraft to another international customer.

BAE states that due to the sensitive nature of electronic combat systems and technology, approximately one quarter of its Electronic Systems' revenues are driven by its work on classified programmes.

Strategy

BAE systems is a market leader in EW and is already developing 6th generation EW technology for upgrades to the F-35 and next generation platforms. It also has extensive capabilities within Mission Computing, Radars, ECM and related sensor technologies.

It plans to continue to invest in Electronic Systems as a key part of its overall portfolio.

Recent developments

July 2024: BAE Systems has received $133 million in contracts to provide radar warning receivers (RWR) for the US Air Force's C-130J Super Hercules military transport aircraft. The announcement specified the delivery of the company's proprietary AN/ALR-56M Advanced RWR, which had already been ordered for the service's C-130J fleet and F-16 Fighting Falcon jets in previous agreements over the past 30 years. The AN/ALR-56M sustains a platform's situational awareness and enhances aircrew survivability by detecting hostile radars from the air and the ground. Its scanning capability applies to dense environments and covers modern search, tracking, and acquisition radars. The receiver can also be integrated with a plane's existing jamming systems, countermeasures, and avionics.

June 2024: BAE Systems received an $95 million contract from the U.S. Navy for advanced countermeasure pods to protect the P-8A Poseidon Multi-Mission Maritime Aircraft from missiles and other threats. The electronic warfare (EW) pod detects and counters inbound threats, protecting the Poseidon and its crews, and expanding the aircraft's operating range in contested environments. BAE Systems' survivability pod provides early threat detection and effective countermeasures to protect U.S. and international high-value airborne assets. The system's flexible, open architecture design allows rapid and affordable modernization, is compatible with future threat-detection and decoy countermeasure capabilities, and can host third-party EW techniques.

May 2024: BAE Systems acquired unmanned aircraft systems (UAS) developer Callen-Lenz, absorbing the business into its FalconWorks technology incubator.

May 2024: The US Navy has chosen BAE Systems to develop the Dual Band Decoy (DBD), a new radio frequency jammer based on the combat-proven AN/ALE-55 Fiber-Optic Towed Decoy to be used by fighter jets to counter enemy attacks. The DBD will consist of a towed unit connected to electronic warfare equipment onboard the US Navy's F/A-18E/F Super Hornets by fiber-optic cables. It will utilize its jamming capabilities to disrupt enemy radars and lure missiles away from the aircraft. The decoy can be launched manually and automatically and will have the ability to be updated in the future to counter emerging threats. Work on the DBD will be performed at BAE's Nashua, New Hampshire, facility.

April 2024: BAE Systems was awarded a 10-year, near-half-billion-dollar contract by Officials of the Army Contracting at Aberdeen Proving Ground, Md., for AN/ARC-231A multi-mode aviation radio suite hardware components, repair services, as well as technical, engineering, and logistic support. The value of the contract is $459.8 million over the next decade. The BAE Systems AN/ARC-231A avionics radio is part of the company's Fire series of aviation radios, which are software communications architecture (SCA) and software-defined radio (SDR) designs.

April 2024: The U.S. Air Force recently completed Initial Operational Test & Evaluation (IOT&E) of the Eagle Passive Active Warning Survivability System (EPAWSS), validating the game-changing capabilities BAE Systems' advanced system brings to the F-15. EPAWSS provides critical electronic warfare (EW) capabilities for the F-15E Strike Eagle and F-15EX Eagle II aircraft. EPAWSS provides instantaneous full-spectrum EW capabilitiesincluding radar warning, geolocation, situational awareness, and self-protection. The system enables freedom of maneuver and deeper penetration into battlespaces protected by modern integrated air defense systems.

February 2024: BAE Systems completed the acquisition of Ball Aerospace from Ball Corporation. The transaction closed at a purchase price of $5.5 billion (approximately £4.4 billion), which has been funded through existing cash and new external debt.

December 2023: BAE Systems will benefit from the $53 billion US Chips and Science Act. The US Commerce Department on Monday announced a preliminary memorandum awarding $35 million funding to modernize BAE's Electronic Systems division's Microelectronics Center. The facility, located in Nashua, New Hampshire, produces several mature-node chips used in US military applications, including the F-35 jet.

September 2023: BAE Systems received a five-year contract from Lockheed Martin to sustain the AN/ALR-94 advanced digital electronic warfare (EW) system for the F-22 Raptor. Under the contract, BAE Systems will continue to manage EW system repairs and upgrades, supplier logistics, test equipment maintenance, and provide depot-level spares and

engineering support to maintain F-22 EW readiness and relevancy for today's air dominance mission. As the original manufacturer of the complex AN/ALR-94 EW system, BAE Systems has provided life cycle management of the system since the program's inception.

July 2023: The UK Ministry of Defence has awarded BAE Systems and Leonardo a contract to modernize the radars of the Royal Air Force's Typhoon combat aircraft fleet. Under the 870-million pound ($1.1 billion) agreement, the companies will equip the fighter jets with the European Common Radar Systems (ECRS) Mk2, a programmable electronic warfare device that uses wideband attacks to detect and jam adversary radars. Work for the radar's development and integration will run for five years, with an initial flight test scheduled for 2024. The contract builds on the UK's 2.35-billion pound ($2.98 billion) plan announced last year seeking revamped Typhoon radars in response to emerging aerospace threats. Completing this effort will allow the Typhoon jets to deploy alongside F-35B Lightning IIs in various combat scenarios without the risk of detection. In addition, the radar's extended range and passive operability will allow pilots to identify threats far from enemy air defenses.

April 2023: BAE Systems received $491 million in contracts from Lockheed Martin to produce state-of-the-art Block 4 electronic warfare (EW) systems for future Lot 17 F-35 Lightning II fighter jets, adding to the 1,200 F-35 EW systems it has delivered to date. The powerful Block 4 systems will accelerate the delivery of advanced EW capabilities to warfighters by combining adaptable hardware and incremental software updates. The Block 4 EW systems will include significantly upgraded hardware and software that improves sensing and signal-processing capabilities. New, high-performance sensors will boost the system's ability to detect difficult-to-observe threats and more threats simultaneously.

September 2022: BAE Systems completed system components design and testing following the final delivery of key hardware for the US Air Force's inaugural EC-37B Compass Call electronic warfare (EW) aircraft. BAE said the last delivery would play a key role in the operational and developmental flight tests of Compass Call's Baseline 3 configuration. Baseline 3, which provides next-generation EW capabilities, is slated to begin configuration in January 2023. The EC-37B Compass Call is the US Defense Department's only long-range, full-spectrum EW jet equipped with enhanced stand-off jamming capabilities. The new platform is a redesigned EC-130H airframe model with enhanced flight performance.

May 2022: BAE Systems opened its new engineering and production facility in Manchester, N.H. as the latest step in a series of strategic facility investments across the country including in Austin, Texas; Cedar Rapids, Iowa; and Huntsville, Ala. The 200,000 ft2 Manchester facility includes engineering design space, modern laboratories, and office space, providing the company with additional capacity to support the design and development of electronic warfare (EW) systems for the United States and its allies. BAE Systems' advanced EW systems combine threat warning and self-protection capabilities to help pilots conduct their missions and return home safely.

May 2022: BAE Systems unveiled their new lightweight, compact Head-Up Display (HUD) for use in commercial and military aircraft. LiteWave is a laptop sized HUD mounted above the pilot's head which presents critical information, such as direction, altitude and speed, directly in their line of sight. Being 70% smaller and lighter than a traditional HUD, LiteWave can be fitted in aircraft with even the most limited cockpit space. It is also up to 80% faster to install and its simple design makes maintenance quicker and cheaper. Powered by BAE Systems' revolutionary, patented waveguide technology, LiteWave can be easily adjusted to suit any individual flying position and allows the pilot to maintain excellent situational awareness, even during poor weather or at night.

Counterpoint comment

BAE has been very successful at growing its revenue in the past three years. At the same time achieved significant contract win in 2023. The fact that the US DoD rely upon a UK company to provide some of the most sensitive systems on the F-35 is proof of its leadership position within military systems.

19.2.2 COBHAM

Cobham was founded in 1934 and became a public company in 1955. The company has made several acquisitions and divestments and, as a result, the Cobham name can be found in multiple contexts. This profile focuses on Cobham Limited which is currently controlled by private equity firm Advent International.

Advent International acquired Cobham in 2020. The company's business units were reorganised into distinct entities. Since then, a number of acquisitions and divestments have been made, including:

- Cobham Mission Systems (CMS), the company's air-to-air refuelling systems provider, was sold to Eaton in 2021 for USD 2.83 billion
- The Space Systems division of Cobham Advanced Electronic Solutions was sold to US private equity firm Veritas Capital and renamed as Frontgrade Technologies in 2021
- Ultra Electronics was acquired by Cobham in 2022. The deal required approval from the UK governement given national security concerns. Ultra Electronics is listed below in section 19.2.2.1
- The remaining Cobham Advanced Electronic Solutions (then renamed to simply CAES) purchased Herley Industries LLC from Ultra Electronics
- Cobham Aerospace Communications was acquired by Thales in 2023. This profile can be found in section 19.2.13.1
- CAES was sold to Honeywell in 2024. More information can be found in the Honeywell profile in

This profile of Cobham is retained only to provide redirection to the relevant profiles. We believe the remaining Cobham Communications and Connectivity business is largely a land and maritime satcom business.

19.2.2.1 ULTRA ELECTRONICS

Ultra primarily supports the defense and security sectors but does have some airborne mission related capabilities. The company was formed in the late 1980s out of a management buy-out from the former Dowty Group.

Following its establishment and flotation on the UK stock exchange it pursued M&A activity with many small acquisitions largely located in the US. In August 2022, the company was acquired by Cobham, via Blackstone and Advent International for £2.58bn through a public-to-private LBO. At the same time, the company was de-listed from the London Stock Exchange and renamed Ultra Electronics Holdings Limited.

The company is organised into several business units, namely: Maritime; Intelligence & Communications; Precision Control Systems; Ultra Energy; and Ultra Group support functions. Of the sections highlighted, Intelligence and Communications, Precision Control Systems, and Ultra Energy are involved to varying degrees with the aerospace sector.

In June 2024, it was announced that Ultra Energy was to be acquired by Curtiss Wright.

Within its Intelligence and Communications division Ultra offers avionics related products including communications for ADS-B and link 16 in military applications. It also provides a range of secure datalink options for communication and data transmittal.

Ultra employs around 4,400 people, with the largest number based in North America.

Financials

The results of Ultra Electronics Holdings Limited and its subsidiaries were consolidated into Cobham Ultra SeniorCo S.à r.l. from 1 August 2022, the date of acquisition.

FYE 31/12/23 USD million– continuing operations	2023	2022
Sales	1,183	510
Operating Profit	(135.2)	(100.5)
Return on sales %	-11.4%	-19.7%

* The results of Ultra Electronics Holdings Limited and its subsidiaries are consolidated into Cobham Ultra SeniorCo S.à r.l. from 1 August 2022, the date of acquisition, consequently these results reflect only five months of Ultra trading, not the full 12 months from 1 January 2022 to 31 December 2022.

As shown (August 2024) on the Ultra Group website, the percentage share of each group to overall revenue was as follows:

- Maritime 46%
- C4ISR/Electronic Warfare 28%

- Critical detection and control markets 26%

Counterpoint estimates that its avionics-related sales accounted for $40m in 2023.

Locations

Ultra's main Intelligence and Communications facilities are located in Greenford (London), Aberdeen, Farnborough, Gloucester, Tring and Southampton in the UK. In 2024, Ultra Intelligence & opened its new flagship facility in Maidenhead, U.K.

In the US Ultra has I&C facilities in Annapolis, MD; Austin, Texas; Germantown, MD; San Diego, CA; Lancaster, PA; Whippany, NJ; Woburn, MA; Tampa, FL.

Ultra's radar avionics products are produced in their Lancaster PA facility in the US.

Ultra I&C also has facilities in Canada and Australia but they do not supply airborne products.

Capabilities

The Intelligence and Communications offers solutions in the following areas:

- Artificial Intelligence & Machine Learning
- Command, Control & Intelligence
- Cyber Encryption, Key Management and Edge Network Security
- Data Analytics, Correlation and Fusion
- Integrated Tactical Communications
- Software Systems & Systems Development
- Tactical SATCOM

Advanced Tactical Airborne Systems: ATAS includes the maturity and adaptability of its certified tactical data link gateway software only distribution coupled with a flight-qualified COTS enclosure or coupled with existing platform equipment. The ATAS interfaces to the most common MIDS, JTIDS, JTRS, SATCOM, and small form factor airborne-capable Link 16 terminals for MIL-STD-3011A/C, Satellite TADIL J, MTC, CoT. The ATAS provides interfaces for Link 11, VMF, CMF, SADL connectivity with coalition forces.

IFF: With an emphasis on positive identification of airborne, sea-going and land-based vehicles, and the size reduction of these vehicles, its customers need small form factor IFF solutions. This is particularly true in military theatres, with an increasing requirement to identify an object prior to engagement to reduce fratricide. Compatibility with legacy IFF systems (Modes 1,2,3A/C,S) is required, but US and foreign militaries are moving toward Mode 5, which requires data encryption.

Radar Altimeter: Ultra provides advanced radar altimeter solutions capable of high accuracy altitude measurements in adverse conditions. Its radar altimeters are used in UAVs, space launch applications, autonomous targets and towed targets. The linear FM (Chirped) Radar Altimeter product line uses modular construction and advanced digital signal processing (DSP) techniques to provide a small volume, low power consumption, high performance RALT.

The Precision Strike Sensor Core (PSSC) provides the path to jam resistant, radar-based target detection, identification, designation and terminal guidance for conventional and precision munitions. PSSC was purpose built for use with the guided 105mm to enable first shot accuracy for AC-130 gunships.

Advanced Comms Pods: Designed for quick integration onto airborne payloads or wing stations via the REAP Pod, REAP provides full spectrum communication range extension, voice repeater and relay functions. Certified to TRL level 8 by the US Air Force, Ultra have provided advanced communication payloads for over 10 years.

Data Acquisition Units: The Ultra PCM890 System is the next generation of the highly successful PCM880 series of data acquisition systems. The PCM890 is used for instrumenting missiles, airborne vehicles, and other platforms requiring a small volume ruggedised PCM encoder.

Typical communications needs are delivered as follows:

- Enhanced communications to cooperate with state, local and federal agencies — Integrates MANET, Civilian P-25 and military radios for seamless relay and bridging.
- ADS-B — Transmits aircraft position without impact to the existing onboard IFF transceivers.
- Link 16 — Transmits ownership J2.2 direct PPLI on LOS Link 16 allowing all network participants real-time situational awareness of the Remotely Piloted Aircraft (RPA). Transmits J12.6 Target Sorting on the "Fighter to Fighter" NPG with decreased latency allowing time sensitive targeting.

Customers and contracts

79% of Ultra's I&C sales are to customer located in the US.

Ultra lists its major customers as General Dynamics, Raytheon, Thales, USAF, USN and US Army.

It provides a range of Radio Frequency products to Raytheon, Hensoldt, Boeing, Lockheed Martin and General Atomics.

A specific contract is:

- AC130: Precision Strike Sensor Core (PSSC)

Strategy

In its 2023 Annual Report, Ultra stated that following its acquisition by Cobham, and the renewed focus on the businesses within the Group, "Ultra's strategy continues to focus on how best to position each business unit to compete for greater market share whilst considering the views of key stakeholders including our employees, customers, suppliers, communities and investors across Ultra's core markets. The Group remains committed to research and development by investing in both new products and enhancements to the current product base, to allow the Group to build positions where it has technical differentiation."

Individual business units however have been "encouraged to make decisions closer to the customer in order to allow for greater focus and to be able to unlock their full potential. Each unit has full responsibility for its own strategy, and financial and operational performance."

Recent developments

June 2024: Ultra Intelligence and Communications has announced a $31.9 million agreement through an Other Transaction Agreement (OTA) with Consortium Management Group, Inc. (CMG) on behalf of Consortium for Command, Control and Communications in Cyberspace (C5) from the U.S. Air Force Cryptologic and Cyber Systems Division to deliver over-the-network rekey and remote management system upgrades for operationally deployed communications security (COMSEC) devices including identification friend or foe (IFF), Link-16 and in-line encryptors to reduce service costs and ensure reliable tactical networks.

March 2024: Ultra Intelligence & Communications, also known as Ultra I&C, celebrated the official opening of its flagship facility in Maidenhead, U.K., marking a major milestone in the company's ongoing expansion and development. Ultra I&C's Cyber Centre of Excellence represents a significant achievement in advancing expertise in cybersecurity and manufacturing, providing the company and its customers a new base for 250 engineers, made possible by a £30M investment in the new facility. The 56,000 ft2 engineering, integration and testing facility will serve as a hub for cyber technology development and the company's U.K. STEM program, supporting local schools and placements from the CyberFirst program. Ultra I&C leaders demonstrated their solutions to support the secure communications on the likes of the Typhoon aircraft, post-quantum security capabilities and satellite communications.

July 2023: A flight demonstration was successfully completed of the Rosetta Echo Advanced Payloads (REAP) pod onboard the MQ9-A Remotely Piloted Aircraft (RPA) in support of first responders in California. The REAP® pod was developed by Ultra Intelligence and Communications (Ultra I&C) and General Atomics - Aeronautical Systems Inc. (GA-ASI). The REAP pod provides potentially lifesaving communications infrastructure from an aircraft, ensuring lines of communication remain open between providers of emergency services and those desperately needing assistance.

July 2022: Following advice from the UK Ministry of Defence and after careful consideration of responses to a consultation, the UK Business Secretary cleared the acquisition of Ultra by Cobham to proceed. The announcement followed

the Business Secretary consulting on steps to address the national security concerns raised by the proposed acquisition of Ultra by Cobham (acquired by US private equity firm Advent International). The Business Secretary has accepted the undertakings from the parties to mitigate national security risks, with a small number of changes to reflect the responses to a consultation on them.

July 2021: Ultra Electronics is on the verge of accepting a takeover offer from rival Cobham, in a move that would further extend the private equity industry's grip on the British aerospace sector. Ultra said on Friday it had received a takeover bid of £35 per share from Cobham, which is owned by American private equity group Advent. The bid would value Ultra at £2.6bn, 60% higher than its valuation when Cobham first made a bid last month at the lower price of £28 per share.

Counterpoint comment

Ultra enjoys a strong presence within its maritime/naval and land defense business areas but less so in airborne defense. It does however have a significant presence in the US and supports a range of major US defense contractors.

19.2.3 DIEHL AEROSPACE

Diehl Aerospace, a joint venture between Diehl (51%) and Thales (49%), is primarily an avionics company. It is part of Diehl Aviation (known as Diehl AeroSystems until 2018), which is one of five corporate divisions in the Diehl Group, a German family-run enterprise with business fields in several industries and a workforce of more than 15,889 employees worldwide. All aviation activities within the Group are consolidated under Diehl Aviation.

Diehl Aerospace was founded in 2006 as result of the merger of Diehl Avionik Systeme GmbH and Diehl Luftfahrt Electronik.

Diehl's aviation activities lie within the fields of both avionics and cabin interiors, to which the latter is arguably the more well known and reported on area. Organisationally, several companies under the Diehl umbrella exist:

- Diehl Aviation Laupheim GmbH
- Diehl Aviation Operations Support Service Co.,Ltd
- Diehl Aerospace GmbH
- Diehl Aviation Gilching GmbH
- Diehl Aviation Hamburg GmbH
- Diehl Aviation Holding GmbH
- Diehl Aviation Hungary Kft
- Diehl Aerospace Pte. Ltd.
- Diehl Aviation Middle East FZCO
- Diehl Aerospace Inc.

Financials

Diehl Aviation had total sales of €1,053m in 2023, although the proportion accounted for by avionics is not published.

Diehl Aerospace had sales of €270m and 1,300 employees in 2015, the latest year for which separate financials are available publicly.

Counterpoint estimates that avionics sales were $225m in 2023.

Locations

There are twenty four locations around the world associated with Diehl's aerospace interests. These are as follows:

- China
  - Tianjin (Diehl Aviation Laupheim GmbH, On-Site Support)

  - Beijing (Diehl Aviation Operations Support Service Co.,Ltd, On-Site Support)
- France
  - Toulouse (Diehl Aerospace GmbH, Customer Service Center EMEA)
  - Colomiers (Diehl Aviation Laupheim GmbH, On-Site-Support Toulouse)
- Germany
  - Donauwörth (Diehl Aerospace GmbH, Airbus Helicopters FAL)
  - Frankfurt (Diehl Aerospace GmbH)
  - Hamburg (Diehl Aerospace GmbH, Customer Service Center)
  - Nuremberg (Diehl Aerospace GmbH)
  - Rostock (Diehl Aerospace GmbH)
  - Überlingen (Diehl Aerospace GmbH)
  - Gilching (Diehl Aviation Gilching GmbH)
  - Dresden (Diehl Aviation Gilching GmbH)
  - Hamburg (Diehl Aviation Hamburg GmbH)
  - Nuremburg (Diehl Aviation Holding GmbH)
  - Laupheim (Diehl Aviation Laupheim GmbH Headquarters)
  - Hamburg (Diehl Aviation Laupheim GmbH, On-Site-Support)
- Hungary
  - Debrecen (Diehl Aviation Hungary Kft)
  - Nyírbátor (Diehl Aviation Hungary Kft)
- Singapore
  - Singapore (Diehl Aerospace Pte. Ltd., Customer Support Center Asia Pacific)
- United Arab Emirates
  - Dubai (Diehl Aviation Middle East FZCO)
- United States
  - Everett (Diehl Aerospace Inc., Boeing FAL)
  - Seattle/Everett (Diehl Aviation Laupheim GmbH, Liaison Office)
  - Sterrett (Diehl Aerospace Inc., Customer Support Center Americas & The Caribbean)
  - Charleston (Diehl Aviation, On-Site-Support)

Capabilities

Diehl Aerospace designs and manufactures avionics systems in the following areas:

- Cabin and Utility Control Systems including:
  - Doors and Slides Management System (DSMS) to electronically control and centrally monitor the passenger and freight doors as well as the relevant emergency hatches and slides.
  - Cabin lighting control systems
  - Cabin security systems
- Cockpit and Display Systems including:

  - Multifunction Displays for all Airbus aircraft types. The latest A350 XWB Display System allows the presentation of flight and navigation parameters as well as the communication between the crew and the various software applications.
  - Symbol Generators: The Diehl Aerospace Centre of Excellence for symbol generation develops state-of-the-art technologies for graphic generation and processing.
- Flight control:
  - Flight Control Unit (FCU); an intelligent interface between the pilot, autopilot, and electronic display system in the cockpit. The FCU is an equipment that contains controls and displays required for: Auto-Flight System, Primary Flight Display configuration including baro setting. Navigation Display (ND-CP) configuration including: Range and Type of display, Weather information display, Terrain information display, Traffic information display. The FCU is installed in the glareshield of the Cockpit.
  - Actuator Control Electronic (ACE) for Honeywell Flight Control Electronic (FCE) of the Boeing 787. The ACE is connected to flight control actuators, associated sensors and acquires signals from the flight control internal and external sensors. The ACE is designed as self-checking pair and provides the highest data integrity to the flight control application hosted in the Flight Control Modules of the Honeywell FCE.
- High lift control systems
  - Slat Flap Control Computer (SFCC) controls and monitors the slats and flaps. This is realised by activation, control and monitoring of the actuators which move the slats and flaps. Each SFCC comprises of one slat and one flap channel.
- Integrated Modular Avionics
  - Core Processing Input/Output Module: The CPIOM is a high performance computer which provides processing capability to host multiple segregated applications on one computer. A standard ARINC 653 application programme interface enables clear independence of the application towards the computing device. The flexible core software is fully configurable by the seamless Tool Suite. The CPIOM is connected to the Avionic Full Duplex Switched Ethernet (AFDX) aircraft bus using Diehl Aerospace's AFDX End System.
  - The RDC consists of a high performance I/O computing intelligence including a core software. The interfaces (i.e. inputs, outputs and digital buses) are members of a standardised interface catalogue. Depending on the specific position in the aircraft the RDC selects different pre-defined configurations and adopts the functions accordingly.
  - AFDX End Systems: The AFDX communication data bus network is a worldwide standard defined in the ARINC 664 documentation. Most of the avionics computers today use this standard for intercommunication. An Avionics Full Duplex Switched Ethernet (AFDX) End System is available in PMC standard format that can easily be integrated to connect each computer to that network. The AFDX End System is available also to operate under harsh environmental conditions.
- APU control unit
  - Versatile Electronic Control Box: The abbreviation VECB denotes a universal engine control computer system for auxiliary power units. It controls and monitors the auxiliary power units in the aircraft. The VECB is a versatile system, meaning that the same unit can control different types of single engine families without substantial modifications.

The Diehl Aerospace Centre of Excellence for symbol generation develops state-of-the-art technologies for graphic generation and processing.

Customers and contracts

- A330; slat flap control computer and command sensor unit
- A380; display systems for the Cockpit and Display System (CDS) and the Onboard Airport Navigation System (OANS), Doors and Slides Management System (DSMS) (now aftermarket only)

- A320 family; Diehl Aerospace produces the Display Management Computer (DMC) of the A320 Cockpit Display System. The DMC is a data concentrator, that collects all data from sensors and external sources, consolidates it and sends it to the cockpit displays.
- A350; Diehl Aerospace in cooperation with Thales provides Multifunction Displays for all Airbus aircraft types and develops the Display System for the A350. The Display System allows the presentation of flight and navigation parameters as well as the communication between the crew and the various software applications. The work share of Diehl Aerospace consists of a metal housing with integrated ventilators for the cooling in the case of an emergency, of a Power Supply-I/O Board including an attached AFDX Module and a graphics processor board.
- Eurofighter Typhoon; Diehl Aerospace, delivers key components in the product areas Cockpit and Display systems, Aircraft control and Utility systems.
- Boeing 787; actuator control electronics. Since 2004 Diehl Aerospace, in cooperation with Honeywell, has developed components for the Flight Control Electronics (FCE) package for the Boeing 787. The FCE package consists of Flight Control Modules (FCMs), Actuator Control Electronics (ACEs), Power Conditioning Modules (PCMs), a Mode Control Panel (MCP), and Rate, Acceleration and Pressure Sensors. The FCE package integrates fly-by-wire primary flight control, high-lift control, autoflight, and processing of air data/inertial data for use by other airplane systems.
- NH90; display systems for the Helmet-Mounted Sight Display (HMSD) and Operator Control Panel (OCP)
- Airbus Helicopters Tiger; display systems for the Helmet-Mounted Sight Display (HMSD) and Operator Control Panel (OCP)

Strategy

Diehl Aviation will develop new products and get involved in new projects. Among other things, these include product innovations for touchless cabin functions in commercial aircraft, entering the Urban Air Mobility (UAM) market segment as well as taking part in the multi-national military Future Combat Air System (FCAS) project and also the development of sustainable lightweight materials as well as systems for flying with zero emissions".

Recent developments

June 2022: Diehl Aerospace and Volocopter, the pioneer of urban air mobility are further expanding their cooperation. The contract extension provides for the development and production of an optical splitter to complement the flight control system as well as other components for the battery management system for the first all-electric VoloCity air taxi. Diehl Aerospace has already developed the Flight Control Computer (FCC) for the VoloCity, including the primary and backup control computers. In addition, Diehl Aerospace is developing the Data Concentration Unit (DCU) for Volocopter, which is the counterpart to the optical splitter. The DCU collects optical signals from 18 rotors via an optical interface and converts them into digital data for the avionics. This provides the pilot with feedback on the status of engine speed and temperature. With the DCU box, Diehl Aerospace completes the Volocopter's Fly-By-Light system for the VoloCity.

July 2020; Diehl Aerospace announced that having been involved in the two-year concept phase (Joint Concept Study) for the development of the European FCAS (Future Combat Air System), it was now moving into the demonstration phase. The aim of the project initiated by Germany and France — which Spain has since joined as a further partner - is to develop a New Generation Weapon System (NGWS) by 2040.

May 2020; Diehl Aerospace has signed a contract with Volocopter for the development and production of Flight Control Computers (FCC). Volocopter is the manufacturer of the first fully electric air taxi in certification to transport passengers safely and quietly within cities. Under this agreement, Diehl Aerospace will supply the FCCs including the primary and backup control computers for Volocopter's "eVTOL" (electrical vertical take-off and landing) aircraft named VoloCity, currently under development.

Counterpoint comment

Diehl Aerospace is a niche avionics supplier but has a strong position on Airbus programmes and is also an important military supplier on German programmes.

19.2.4 HENSOLDT

Hensoldt is a publicly owned German military sensor manufacturer, albeit with a significant German Government shareholding.

The company originated from the electronics business unit of the defence division of the Airbus Group. At the end of February 2017, Airbus sold this business to KKR, a prominent US private equity company, for €1.1 billion, and at this point the business was renamed Hensoldt. Since then, Hensoldt has acquired the German company Euroavionics and British radar specialist Kelvin Hughes as well as the start-up PentaTec. Most recently, Hensoldt acquired the French-based company Nexeya and IE Asia-Pacific and Tellumat in South Africa.

In September 2022, there was an IPO, and the company was listed on the Frankfurt Stock Exchange. In 2023, the company was promoted to the MDAX, the mid-cap index of the Frankfurt Stock Exchange.

In December 2020, the German Federal Government announced its decision to acquire 25.1% of Hensoldt's shares from KKR, leaving KKR with approximately 43% of Hensoldt's shares upon closing of the transaction.

In its 2023 Annual Report (published March 2024), the company's shares were split as follows:

- Free Float, 52.1%
- Federal Republic of Germany, 25.1%
- Leonardo S.p.A., 22.8%

In March 2024, Hensoldt and Leonardo revealed that talks had occurred regarding a possible joint venture and cooperation on several projects.

Hensoldt's business is divided into two segments: Sensors, and Optronics. These are further split into the following sections:

- Sensors
  - Radar and Naval Solutions (including aerial IFF systems, e.g. Eurofighter)
  - Spectrum Dominance and Airborne Solutions (including Electronic Warfare and Avionics Systems)
  - Optronics and Land Solutions (including helicopter ECM)
  - Services and Aerospace Solutions
- Optronics
  - Optronics and Land Solutions (including sensor platforms for fixed/rotary-wing aircraft and drones)
  - Radar and Naval Solutions
  - Services and Aerospace Solutions

Within the Spectrum Dominance and Airborne Solutions division, Hensoldt's avionics portfolio includes latest generation avionics systems for sensing, computing, recording, and connecting, as well as mission support and management. While this is arguably the most important section pertaining to this report, other sections (even if to a lesser degree) within both overall segments contribute.

As of 31 December 2023, the company had a workforce of 6,907 employees (previous year: 6,463). Of these, 683 were trainees, interns, etc. (previous year: 611). Approximately 5,100 (previous year: approx. 4,700) were employed in Germany.

Financials

At the overall level, revenue maintained its upward trajectory over the past five years, increasing by two thirds over this period, and 8% from the previous year. Revenue from Sensors (home to Spectrum Dominance & Airborne Solutions section) has increased by 85% over the past five years, and by 10% from 2022. The company further notes: "Within the Sensors segment, 45.6 % of revenue was attributable to the Radar & Naval Solutions division, 28.7 % to the Spectrum Dominance & Airborne Solutions division, 21.1 % to the Services & Aerospace Solutions division and 4.7 % to the Optronics & Land Solutions division."

FYE 31/12/23 - €millions	2023	2022	2021	2020	2019
Sensors Sales	1,546	1,404	1,148	924	837
Optronics Sales	309	310	332	288	277
Total Sales (minus Elimination/ Transversal/Others)	1,847	1,707	1,474	1,207	1,114
Sensors Profit	306	233	194	156	162
Optronics Profit	24	59	68	66	54
Adjusted total EBITDA €ms	329	292	261	219	216
EBITDA margin %	17.8%	17.1%	17.8%	18.1%	19.4%

Sensors profits rose by 31% from 2022, again maintaining the segment's continued profitability over the past five years.

Of this we estimate that $165m was avionics in 2023.

Locations

Hensoldt is headquartered in Taufkirchen near Munich, Germany, and has a large presence in Europe, with a global footprint. It has sales offices in 19 defence markets globally. its major production facilities in Germany are in Ulm, Oberkochen, and Pforzheim (formerly EuroAvionics GmbH). It has a production site in Massy, France and Enfield, United Kingdom, as well as another two in Irene and Pretoria, South Africa.

Capabilities

Hensoldt's Airborne Solutions range from Avionics components and systems to complex Integrated Airborne Mission Systems, as well as Unmanned Solutions.

In avionics it offers the following:

- Airborne Computing
  - Single & Multi Core Processing computers
  - Various accessories for small, medium and large sized computers
  - Flexible control options (control unit, keyboard, touchscreen, line select keys joystick)
  - RTCA/DO qualified systems
  - Compact Certified Airborne Computer for civil and military applications
  - Flight Control Computer
  - Customisable Mission Computing
- Flight and Mission Data Recording & Management
  - Lightweight Crash Recorder (LCR) models
  - Fixed Crash Recorder (FCR) models
  - Deployable Crash Recorder (DCR) models
  - Solid State Data Carrier and Data Transfer Unit (SSDC + DTU) - a transfer solution for mission and maintenance data
- Connectivity
  - Cyber Security Solutions
  - Flying Firewall and Connectivity systems

  - Data exchange capabilities between ground and air
  - Individual and mission-optimised system configurations
- Mission Management/Pilot Assistance
  - Situational Awareness and Mission Management Systems
  - State of the Art maps
  - Fully certified computers
  - Vector Overlay Generator
- Video Management
  - Powerful mission systems for camera operations
  - Video Distribution Units
  - Video Configurations options
  - Video and Audio Recorder
  - State-of-the-art features for any airborne sensing platform
- Unmanned Systems
  - UAV/OPV systems
  - Manned-Unmanned Teaming solutions
  - Autonomous flight control
  - Systems for harshest environment conditions
  - Various payloads and sensors
- Mission Planning Support
  - Weight & Balance solutions for Windows PC, Laptop and iPad
  - Mission Planning Tools
  - Using/preparation of confidential maps and databases
  - Mission network through multiple communication methods
  - Simulation software for training purposes
  - Ground-based and modular mission management system
  - Fleet Management System
  - Sensor control software solution
- Data Analysis and Evaluation
  - Planning for optimum aircraft availability
  - State Data Carrier Adapter - Inferface device for read- out SSDC
  - Enhanced Handheld Computer - recorder models for large aircraft
  - Read-out Station for crash recorder products
- Cloud Solutions
  - OPTARION ® OptaCloud: Multi-Mission Planning in a safety and security cloud-based environment.
- Active Sensing
  - SferiSense500: Obstacle warning system based on very advanced laser detection and ranging technology.

- Displays
  - Compact displays and panel PCs for aircraft
  - Ruggedised multi-source displays in 4:3 and Full HD
  - Multifunction Displays (MFDs) for tactical operations
  - Tactical mission displays
  - Tactical mission tablet

Customers and contracts

Hensoldt's revenues are split geographically as follows:

- Germany 56%
- Rest of Europe 31%
- Rest of the World 13%

Over 30 years it has more than 6,500 delivered Airborne Computers operated on all major fixed-wing and helicopter civil and military platforms.

Significant projects currently of interest include:

- Eurofighter; Hensoldt (Germany) and Indra (Spain) are developing the Eurofighter Common Radar System (ECRS) MK 1 radar that will be delivered to Eurofighter partner Airbus Defence & Space for installation in German and Spanish Eurofighter combat aircraft.
- Kalaetron Attack jamming system: part of HENSOLDT's fully digital 'Kalaetron' product family, which is used in various versions in self-protection and signal reconnaissance systems by the Bundeswehr. This is part of HENSOLDT's fully digital 'Kalaetron' product family. In addition to cognitive elements of artificial intelligence, the core components are a fully digitalised, broadband sensor and an electronically controllable jammer.
- Future Combat Air System (FCAS): developing demonstrators in the core competence fields of radar, reconnaissance and self-protection electronics, optronics and also the overarching networking of sensor technology.

Strategy

The company's strategic objectives in the form of vectors remained unchanged during the fiscal year 2023:

- HENSOLDT wants to evolve from a pure sensor house to a holistic sensor solutions house
- HENSOLDT wants to further expand its innovative power and strengthen its role as innovation champion
- HENSOLDT wants to extend its international reach and presence, based on its success on its European home markets
- HENSOLDT wants to further expand its business beyond the defence industry by gaining market share in the security area

Coinciding with these are five strategic pillars:

- Drive digital and innovative portfolio
- Convince customers with our capabilities
- Become ESG1 sector benchmark
- Live strong company culture
- Improve operational efficiency

Recent developments

June 2024: HENSOLDT, Lufthansa Technik Defense and Bombardier Defense announced that the highly-specialized modification work on the Persistent German Airborne Surveillance System (PEGASUS) has achieved a significant milestone. Led by HENSOLDT for the German armed forces, the PEGASUS signal intelligence (SIGINT) system will be integrated on the Bombardier Global 6000 aircraft, the optimal platform to complete these critical missions. The first aircraft has now rolled out from the Bombardier Defense modification line in Wichita and is being prepared for the start of ground testing and for the subsequent flight. The remaining two aircraft are undergoing modifications in Bombardier's facility.

April 2024: HENSOLDT completed the acquisition of ESG Elektroniksystem- und Logistik-GmbH, which was agreed last year, having received all official approvals. ESG is a leading platform- and manufacturer-independent system integrator as well as an established technology and innovation partner for defence and security. The acquisition adds strong design and system integration capabilities to HENSOLDT's product and solutions business. Founded in 1967, ESG is a manufacturer-independent system integrator and technology and innovation partner for defence and public safety. The company develops, integrates, supports and operates highly complex, security-relevant electronic and IT systems in the fields of defence and security. The company has played a key role in important current and future programmes such as FCAS (Future Combat Air System) and the F-35. The company employs around 1,400 people in Germany, the Netherlands and the USA and generated sales of around 330 million euros in 2023.

March 2024: Leonardo and Germany's Hensoldt are discussing a possible joint venture. Leonardo is a shareholder in the German military sensor maker, alongside the German government which holds a 25% stake. However, it did not take part in a December capital raising which reduced its previous 25% stake in Hensoldt. Last year, outgoing Hensoldt CEO Thomas Mueller had raised the possibility of his company taking over Leonardo's defence electronics division, but Leonardo's then boss Alessandro Profumo dismissed the comments as "misleading". A Hensoldt spokesperson said on Friday that future Chief Executive Oliver Doerre had met with Cingolani in Rome and there is a list of possible cooperation projects between the two. "However, there are no concrete plans for a joint venture," said the spokesperson.

February 2024: HENSOLDT has announced that its EuroNav 7 mission system for critical airborne applications is now enhanced with the integration of Smith Myers' award-winning ARTEMIS Mobile Phone Detection, Location, and Communication System. EuroNav 7, integrated with ARTEMIS, stands out in its ability to identify, locate and interact with cell phones. This feature not only enables effective help for people in distress, but also provides support in disaster control and people smuggling and supporting other maritime patrol operations. The system also detects the cell phone's country of origin making it the perfect tool for detecting border intrusions.

February 2024: The results of the 13 weeks of work on the Future Combat Air System (FCAS) Accelerator led by HENSOLDT Ventures and Starburst was presented. The aim of the accelerator was to create an ecosystem for small and medium-sized enterprises (SMEs) and start-ups to develop dual-use and defence applications for FCAS. Almost 70 companies responded to the call to apply for the accelerator. HENSOLDT and the CPT selected nine of them for a boot camp with twelve mentors, focusing on the discovery and development of solution concepts for FCAS and examining long-term integration into the FCAS programme. This included an exchange with military leaders, but also a presentation of the NATO Innovation Fund, the European Defence Fund (EDF) and the EU Defence Innovation Scheme (EUDIS).

December 2023: HENSOLDT celebrated the topping-out ceremony for its new plant in Oberkochen. With the new building, the HENSOLDT Group is responding to the constantly growing demand for high-performance military equipment for the German Armed Forces and NATO members and to the ever-increasing demand from the semiconductor industry, which purchases high-precision optronic measuring devices from HENSOLDT Optronics. The company plans to move into the new site in 2025.

November 2023: HENSOLDT will work with BAE Systems in a contract awarded by the UK Ministry of Defence. This contract centres on the development of the Striker ® II helmet-mounted display for the Royal Air Force's Typhoon fleet. Building upon a history of successful collaboration and the development of Striker I, HENSOLDT South Africa will supply the advanced optic sensors for the helmet and will be responsible for the development of its intelligent tracking system. Developed at BAE Systems in Rochester, UK, the Striker II is one of the world's most advanced fighter pilot helmets, which uses the latest technologies to integrate its all-digital night vision system and daylight-readable colour display. At its core lies the optical helmet tracking system developed by HENSOLDT's Optronics business in South Africa.

September 2023: HENSOLDT joined forces with U.S. mission aircraft supplier Airdyne Aerospace Inc., Brooksville/FL,

to jointly offer an integrated and certified mission suite, in a first step specifically for C-130 mission aircraft. Both companies signed a MoU to set up the details of their relationship. The mission suite combines HENSOLDT's "MissionGrid" portfolio of different sensors and mission management systems and Airdyne's SABIR System which is a system of individual "bolt-on" modular components that can be configured in several ways to support various missions, aircraft configurations, and other customer-specific requirements.

February 2023: HENSOLDT is developing essential core elements of the novel sensor network in the German-French-Spanish armament project FCAS (= Future Combat Air System). As a member of the German FCMS GbR (FCMS = Future Combat Mission System) consortium, HENSOLDT has been awarded a contract worth approximately 100 million euros by the French procurement authority DGA for the development of demonstrators in the core competence fields of radar, reconnaissance and self-protection electronics, optronics and also the overarching networking of sensor technology. In the FCAS project, the participating nations want to develop, among other things, a successor system for the Eurofighter and Rafale fighter aircraft as well as a novel system of networked sensors. By 2024, several technology demonstrators will be developed to show the possibilities of a platform-independent networked solution. This sensor network with different platforms will then be further developed in the other FCAS demonstrator phases.

July 2023: HENSOLDT UK is announced that it had been awarded the prestigious Gold Award in the Defence Employer Recognition Scheme (ERS) by the British Ministry of Defence. This governmental recognition is a testament to HENSOLDT UK's commitment to supporting the armed forces community and its dedication to providing exceptional employment opportunities and support to military veterans, reservists, and their families. Currently employing 17 veterans, with a workforce of 160, the company makes specific provision within its employment policies to ensure that all the training and support is given to enable ex-forces personnel to make a successful transition and utilise their skills to meet the company's needs. Additionally, reservists and cadet instructors are given 10 extra paid days of leave to deploy and attend training camps.

June 2023: RAFAEL Advanced Defense Systems Ltd., Diehl Defence GmbH & Co. KG, and HENSOLDT Sensors GmbH have announced a teaming agreement focused on the modular SPICE™ 250 ER (Extended Range) system. Building upon previous successful collaborations, the partnership aims to provide cutting-edge solutions for the German Luftwaffe, featuring unique capabilities and enhancements in specific for the Eurofighter EK and overall LuWES program. The Eurofighter EK program, currently under development, is intended to replace the Tornado Eloka electronic warfare (EW) platforms currently operating with the German Luftwaffe.

October 2022: HENSOLDT and Rafael Advanced Defence Systems Ltd. are joining forces to offer a readily-available, state-of-the-art, and mature solution to the Luftwaffe's requirement of airborne electronic warfare capabilities with Initial Operating Capability (IOC) in 2028. HENSOLDT and RAFAEL agreed to embark on a joint endeavour to integrate and enhance RAFAEL's Sky Shield airborne electronic warfare pod as a mature off-the-shelf Escort Jammer (ESJ), with the latest airborne electronic attack national sensitive technology (KALÆTRON Attack) by HENSOLDT. This new capability supports the Luftwaffe's decision to adapt the Eurofighter Typhoon into an electronic attack (EA) platform. The new EA pod utilizes the existing interfaces of the Litening Pod, already combat-proven on the Typhoon, thus significantly simplifying the integration efforts and saving invaluable resources.

April 2022: HENSOLDT has been awarded a mid-three-digit million euro contract for the next phase of Eurofighter maintenance. The contract covers service tasks for HENSOLDT's share of various Eurofighter systems in the areas of radar, self-protection and avionics. HENSOLDT's service contributes to the desired increase in the number of Eurofighter flying hours. The full service flight hour contract is organised through consortial partnerships in the four Eurofighter core nations (UK, Italy, Spain and Germany) and mandated through several national contracts via the Eurofighter partner companies (Airbus GE, Airbus SP, BAE Systems UK, Leonardo Aircraft Division IT). HENSOLDT is the national leader of the Radar- and DASS- (Defensive Aids Subsystem) Consortium for the service of the German user until the end of 2026 and is also the service and consortium partner for the other nations. When the contract comes into force, the assemblies of the four Eurofighter core nations with their total of approximately 500 aircraft will be maintained by the HENSOLDT sites in Ulm, Friedrichshafen, Taufkirchen, Neuburg and Laage.

Counterpoint comment

A highly capable supplier. The core busines is sensors it is a significant avionics supplier particularly in military but also in commercial markets.

19.2.5 KONTRON

Kontron AG is a publicly traded (SDAX® of the German Stock Exchange) Austrian group, owning multiple subsidiaries around the world. It is a global leader in embedded computing technology (ECT). Previously known as S&T, Kontron offers a combined portfolio of secure hardware, middleware and services for Internet of Things (IoT) and Industry 4.0 applications. With its standard products and tailor-made solutions based on highly reliable state-of-the-art embedded technologies, Kontron provides secure and innovative applications for a variety of industries, particularly high speed trains, autonomous driving, In-flight communication systems, smart factories, and smart solar & 'GreenTec'.

As a supplier of integrated hardware systems for the commercial aerospace industry, products include critical system components to enable in-flight broadband services including: Internet, VPN access, email, multimedia capabilities, video-on-demand, games and additional entertainment choices in a fully-integrated wireless cabin over a broadband air-to-ground or air-to-satellite link.

Kontron is therefore more of a cabin services provider with a suite of "office in the sky" products and services including PAX entertainment.

Its avionic family of products is largely related to mission computing.

Kontron has a presence in 23 countries, and the business is separated into three primary divisions: Europe, Global (which includes Avionics), and Software+Solutions.

Financials - Global division

FYE 31/12/23 EUR million	2023	2022
Sales	207.7	199
EBITDA	19.1	4.1
EBIT	12.8	-13.6

Commenting on the results in the latest Annual Report, the company stated: "The 'Global' segment includes the Kontron Group's operations in North America and Asia and also improved in financial year 2023. Revenue in the segment amounted to EUR 207.7 million, representing an increase of just over 4% compared to the previous year (PY: EUR 199.0 million). Organic revenue growth amounted to around 3%. Gross profit also improved from EUR 46.9 million in the previous year to EUR 65.5 million in the past financial year. This corresponds to a gross margin of 31.6%, which also significantly exceeds the previous year's figure of 23.6% as a result. These improved results are primarily based on several price adjustments in the USA. After the "Global" segment and the other segments were affected by special impairment and write-off effects in the previous year, EBITDA before headquarter charges recovered significantly again in financial year 2023 and amounted to EUR 19.1 million (PY: EUR 4.1 million). The EBITDA margin was 9.2%, following a previous year's figure of 2.1%."

We estimate that Kontron generated $18m of aerospace related revenues in 2023 of which $6m is related to avionic products.

Location

Kontron's corporate headquarters are in Linz, Austria. Within the Global division, the following key locations are listed:

- Kontron Europe GmbH: Germany Ismaning (Headquarters), Augsburg
- Kontron America Inc. - San Diego, CA
- Kontron Canada Inc. Boisbriand, Quebec
- Kontron Asia Inc. Taipei, Taiwan

Capabilities

Kontron has 30+ years of experience building ultra-rugged computing platforms designed for commercial and defence applications and is uniquely positioned to address the needs of the In-flight Entertainment & Connectivity (IFEC) market.

Within avionics, Kontron offers a wide selection of military computing hardware solutions including application-ready COTS boards, integrated mission computers, and rugged enclosures. Kontron's high performance embedded computing (HPEC) systems provides advanced rugged architectures that balance processor power with I/O bandwidth to meet these needs. As the need for SOSA-aligned COTS platforms grows, Kontron's products, including the 3U StarVX and ApexVX based on Intel® Xeon-D and other next-generation processors, offer DSP performance and future proof APIs for sensor data processing applications.

Kontron's AF4783 MDOMAN has been designed in accordance with ARINC 791/792 and has the ability to support two different SATCOM modems without any compromise or feature limitations. The MODMAN also includes an Intel® Xeon® 6-Core processor, L2+ Managed Ethernet Switch, cellular modem, ARINC 429 and fixed/removable storage options. The dual integrated satellite modem approach eliminates the need for a second MODMAN to be installed onto the aircraft thus removing weight, cost and complexity while still allowing the aircraft the ability to utilise different satellite operators by selecting the appropriate modem during flight.

The Kontron ACE Flight™ 4600 is a complete, highly integrated application-ready platform that is specifically designed to meet advanced communication application requirements for Ethernet based network installations on both line fit and retrofit aircraft. Qualified to D0-160F and optimised for a full range of flight information systems, the enhanced Kontron ACE Flight 4600 line can build applications that include: crew and passenger web servers, flight maintenance or manifest servers, connectivity server, wireless content server and In-Flight Entertainment (IFE) servers.

The COBALT™ S1901 Mission Computing Platform features Intel high performance processor and is designed to meet the future needs of Defense computing platforms for AI, Deep Leaning and HPEC by providing multiple GPU or Accelerator card options. The compact S1901 is designed for various high speed I/O options such as 10GbE (copper, but fibre is an option), USB 2/3.0, ruggedised connectors for GPS and 1 PPS timing signals, and room for customisation options such as Camera Interfaces. Storage capacities are met using M.2 NVME slots, along with high capacity 2.5" SSD slots (fixed or removable). Standard options include Wi-Fi and/or LTE cellular modem, and MIL-STD-1553, CANBus, auxiliary cooling fan assembly, and a safety processor module for autonomous vehicle applications.

Customers and contracts

Kontron lists a number of key alliances/partnerships with the likes of Intel, Microsoft and Wind River. It also details the following applications/suppliers with its products:

- UAVs and the Rafale programme.
- It has worked with Qinetiq to host unmanned pilot control software on its computing platform for RAF trials.
- VX6090, a 6U VPX Dual 8-core Intel Xeon D processor has been certified by Thales for use in its radar systems.
- Sales direct to airlines for its range of Inflight entertainment/Wi-fi connectivity modules.
- Its Embedded Computing Technology (ECT) is used by Safran Electronics & Defense to supply COBALT mission computers for the Patroller Unmanned Aerial Vehicle (UAV).
- Supplies Collins Aerospace with the COBALT 904 media server that will host Collins new Stage™ content service, and it will also be integrated with its Venue™ cabin management and entertainment system. The system sells to bizjet and commercial airliners.

Strategy

In 2023 Kontron sold the majority of its IT services business and is firmly focused on the large and growing B2B IoT market. Kontron's vision is that of striving "to become the leading global IoT company and a pioneering force, developing secure, sustainable, and cutting-edge technologies." Their subsequent mission is that of "making the world a better place using smart technologies." In 2023, Kontron's tagline changed to "The Power of IoT." This represents the company's shared promise "and reminds us of the strength we use every day to develop smart and sustainable innovations."

Recent developments

October 2023: Kontron announced the securing of two design wins with a combined volume of approximately EUR 100m. These wins involve Kontron providing IFEC systems to be installed on aircraft operated by multiple airlines,

including one that utilizes satellite-based technology. For the first design win, Kontron will supply major components of a satellite-based IFEC (in-flight entertainment and communications) system which will be installed in aircraft from multiple airlines over five years starting in 2024. Kontron will deliver leading-edge technology, allowing connectivity through geostationary (GEO), medium earth orbit (MEO), and low earth orbit (LEO) satellite constellations. Potential revenues amount to roughly EUR 90m over a five-year span. In addition, Kontron announces a second design win with a volume of around EUR 10m over a two-year span. Starting in 2024, Kontron will supply a major satellite communications operator with IFEC equipment which will be installed in aircraft from multiple airlines. The agreement includes options to increase the volume and add further deployments.

August 2023: Kontron has acquired Hartmann and W-IE-NE-R, a group of rugged computing systems manufacturers based in Germany and the United States, from Phoenix Mecano AG. The companies generated revenues of around EUR 18 million and an EBITDA of approximately EUR 3 million in 2022. The purchase price is EUR 22.1 million subject to adjustment depending on the balance sheet upon closing. Hartmann designs and manufactures integrated modular VPX computing systems for ultra-high speed and harsh environments resilient to radiation and external influences. W-IE-NE-R complements the portfolio with redundant VPX power supplies. The biggest markets are United States, Germany, and Switzerland.

June 2023: Kontron announced the signing of an asset deal with Telit Cinterion, a US-based company headquartered in Irvine, California, United States. The agreement entails Kontron's acquisition of Telit Cinterion's Cellular Automotive Module Unit, marking a significant strategic move to enhance its Internet of Things (IoT) offerings with its proprietary software technology. The assets of the module unit achieved revenues of slightly above EUR 100 million in 2022 and will be integrated into Kontron Europe GmbH, a subsidiary of Kontron AG. The purchase price is EUR 24.5 million. Closing is expected by August. The acquisition of Telit Cinterion's Cellular Automotive Module Unit presents a compelling opportunity for Kontron to enhance its product portfolio and to bolster internal engineering capacities, while preparing for the increasing demand for advanced 4G/5G solutions. By integrating Telit Cinterion's solutions into its own IoT software technology portfolio, Kontron aims to leverage its expertise.

June 2022: Kontron announced its latest IFE&C product service center has officially been opened. The Part 145 certified European Repair Centre, located in Ismaning, Germany, at the Kontron Europe headquarters, will offer repair, modifications and updates for Kontron's In-Flight Entertainment range of avionics products within its dedicated 100 mš repair area. Initially, repair support will be offered on the range of Kontron Server products, Wireless Access Points (CWAPs) and Removable SSD; additional IFE&C products, including the MODMAN product family, will be supported over time.

June 2022: Kontron announced FAA PMA approval of the ACE Flight™ 2780 Auxiliary Modem Unit (AMU) and general availability of the ACE Flight™ 4783 Dual MODMAN. Both the ACE Flight™ 2780 AMU and ACE Flight™ 4783 Dual MODMAN are RTCA DO-160G qualified, compliant to industry standard ARINC 791 and 792 Ku/Ka Band Satellite Communication System, and are installed and flying on aircrafts around the world. The motivation behind these multi-modem architectures for Inflight Connectivity (IFC) is similar to a mobile phone user roaming between different cellular networks. Depending on which region of the world the aircraft is in, the satellite or carrier connection will be different. These standard platforms allow an airline to share a common satellite antenna connection on the aircraft and then switch seamlessly between multiple satellite networks as they navigate around the world, ensuring a completely seamless passenger experience across all regions. Both of these systems have been qualified with an iQ 800 ultra-high-performance multi-receiver modem board from ST Engineering iDirect.

June 2022: Kontron announced a technology refresh of the portable Cab-n-Connect™ wireless streaming IFE&C platforms for the commercial and business aviation industry. Providing a flexible and robust solution, this small form factor IFE&C system utilizes dual WiFi 6 radios that innovatively deliver high-quality streaming for up to 100 client devices enabling airlines to support an individual aircraft's in-flight entertainment needs. The product refresh, which results in new variants, introduces a display output, latest in connectivity with a 5G cellular modem, WiFi 6, larger batteries (up to 2x 100Wh) and more content storage: over 14 terabytes (TB).

June 2022: Kontron announced FAA PMA approval and general availability of the latest generation of Cab-n-Connect™ Wireless Access Points based on Wi-Fi 6. The Cab-n-Connect™ A200 provides a backwards compatible version to Kontron's previous generation Cab-n-Connect™ CWAPs and allows airlines to easily upgrade their existing CWAPs without changing any wiring on the aircraft. The Cab-n-Connect™ A201 provides a version that meets the ARINC 628 CWAP standard which utilizes a different connector interface and is preferred for linefit installations. The A200 product received FAA PMA approval earlier this year and the Cab-n-Connect™ A201 is expected to have PMA approval by Q3 2022.

November 2021: Kontron announced the availability of its latest generation of Cab-n-Connect™ Wireless Access Points based on Wi-Fi 6. The Cab-n-Connect™ A200 provides a backwards compatible version to Kontron's previous generation Cab-n-Connect™ CWAPs and allows airlines to easily upgrade their existing CWAPs without changning any wiring on the aircraft. The Cab-n-Connect™ A201 provides a version that meets the ARINC 628 CWAP standard which utilizes a different connector interface and is preferred for linefit installations.

November 2021: Kontron announced the first flight and qualification of the ACE Flight™ 4783 Dual Modem MODMAN. The Dual MODMAN accommodates two satellite modems in a single 4MCU LRU, while still maintaining compliance to the ARINC 791/792 standard for Modem Manager (MODMAN). The initial product configuration uses the two Ka-Band modem cards targeted for the new Inmarsat GX+ network the iDirect iQ800 and the Hughes Jupiter. Other modem sets for the Dual MODMAN are anticipated in the future by Kontron to support operation on different combinations of regional or global networks.

November 2021: Kontron announced the availability of its latest generation of Cab-n-Connect™ Wireless Access Points based on Wi-Fi 6. The Cab-n-Connect™ A200 provides a backwards compatible version to Kontron's previous generation Cab-n-Connect™ CWAPs and allows airlines to easily upgrade their existing CWAPs without changning any wiring on the aircraft. The Cab-n-Connect™ A201 provides a version that meets the ARINC 628 CWAP standard which utilizes a different connector interface and is preferred for linefit installations. Both products use the same Extreme WiNG Enterprise WAP engine which provides the highest level of efficiency and performance based on 802.11ax Wi-Fi 6 technology, optimized for video streaming in dense multi-client applications within the aircraft cabin and is optimally suited for high density application environments, providing intelligent edge capabilities with the highest level of client services without compromising security monitoring. This Cab-n-Connect™ is the only avionics certified CWAP that provides a dedicated, dual-band sensor that continuously scans and can detect security threats real-time, eliminating the risk of vulnerability or attacks, while also optimizing RF performance automatically. The CWAP delivers the highest level of security services, beginning with support for the Wi-Fi Alliance WPA3 security certifications and also provides a stateful L2-L7 DPI firewall for context based access security.

Counterpoint comment

Kontron is another embedded computing specialist that serves a number of sectors including aerospace and defence. It has carved itself a niche with IFE/Cabin related services in particular I/O modems for Wi-fi, data and content downloaded via satellite services. Equally it has provided a standard family of military mission computing platforms that are suitable for many applications (especially UAV market).

19.2.6 LEONARDO

Leonardo is the largest Italian aerospace and defence company, as well as being a significant player in electronics. The company Leonardo can trace its history back to the 1860's, however, its modern development commenced in 1948 when following the war, a number of industrial businesses including helicopters, structures, defense electronics came together. Agusta formed a JV with Westland in the 1960s and this eventually became the helicopter business of today. Various subsidiaries of Ferranti, Marconi and Racal formed the Selex ES electronics business which today is Leonardo Defense Electronics.

Leonardo also has a major subsidiary, Leonardo DRS, which has a number of facilities in the US (see below).

The headquarters and main manufacturing facilities are in Italy but there is a significant industrial base in the UK as well as important production facilities in the rest of Europe and in the USA. As of 2023 the company had 111 sites located around the world, and had a commercial presence in 150 countries. Leonardo had a workforce of 53,566 employees in December 2023, with 62% of these in Italy, 15% in the UK, 14% in the USA, 5% in Poland and 4% in the rest of the world.

The Italian Ministry for the Economy and Finance holds 30.2% of the share capital of Leonardo. The remainder is currently split between institutional investors (50.3%), individual investors (19%) and Treasure shares (0.5%) . By law, the shareholding may not fall below 30%. The state can:

- Oppose the acquisition of material shareholdings in the company (more than 3%).
- Oppose the signing of contracts in which 3% or more of the share capital is represented.
- Veto mergers, de-mergers or relocation.

Leonardo have a number of joint ventures, listed as follows: Leonardo UK (defence electronics and helicopters, 100%); ATR (regional turboprop aircraft, 50%); Kopter (helicopters, 100%); Thales Alenia Space (satellite production, 33%); Pzl-widnik (helicopters, 100%); Elettronica (defence electronics, 31.33%); Leonardo Drs (defence electronics, 72.3%); Avio (space propulsion, 29.63%); Telespazio (satellite services, 67%); MBDA (defence systems, 25%); Hensoldt (defence electronics, 22.8%); Larimart (defence electronics, 60%)

Overall, Leonardo reported sales of €15.3bn in 2023: a 3.9% increase from the previous year. 51,4392 in December 2022. €14.7bn in 2022. Revenue by geographical area was split as follows: Rest of Europe 24%; Rest of World 21%; Italy 18%; UK 11%; USA 2.6%. Regarding revenue by market during this period, it was split 75/25% between defence and civil markets.

As per the company website, there are eight business areas: five financial reporting activities:

- Helicopters (30% - €4.7 bn - of total revenue)
- Defence Electronics & Security (47% - €7.5 bn - of total revenue)
- Aircraft (19% - €2.9 bn - of total revenue)
- Aerostructures (4% - €636 mn - of total revenue)
- Space
- Cyber & Security
- Uncrewed Systems
- Automation

In so far as financial reporting is concerned however, five segments exist: Helicopters, Defence Electronics & Security, Aircraft, Aerostructures, Space, and Other activities.

Within the Defence Electronics segment, Avionics offerings include Mission and navigation systems, AAW/ASuW/ASW, ISTAR/ ISR systems. However, other avionics solutions exist, including: Radar and Sensors (Radar and IFF systems, IRST, Sighting systems); Airbourne Communications; Optronics; and Electronic countermeasures and self-protection systems.

The majority of Leonardo's avionic products today sits within its electronics business unit and its Leonardo DRS business in the US.

- The Defense and Electronics security business division breaks down further, including Leonardo's shareholding, into the following:
- Electronics Division
  - Leonardo SpA
  - Leonardo UK Ltd
- Leonardo DRS
- Cyber Security Division
  - Leonardo SpA
  - Leonardo UK Ltd
- MBDA (25%)
- Elettronica SpA (31.33%)
- HENSOLDT AG (22.8%)

The following part of this company profile refers to both the electronics division and Leonardo DRS.

FYE 31/12/23 - €million	2023	2022	2021	2020	2019
Sales	7,483	7,212	6,944	6,525	6,701
EBITDA	852	805	703	537	613
Return on sales %	11.4%	11.2%	10.1%	8.2%	9.1%

Financials - Defence Electronics & Security

Revenue has continued to increase since 2020, albeit by a modest 3.8% on the previous year. The company notes that a key factor in segment performance was the order "to complete the development and integration of the new ECRS Mk2 (European Common Radar System) radar for the Royal Air Force (RAF) Typhoon fleet in the United Kingdom. The new sensor will ensure that RAF aircraft can simultaneously detect, identify and track multiple targets on land and at sea, thus enabling increased capabilities in terms of air power" Earnings for the division have similarly maintained their upward trajectory, recording a 5.8% increase from 2022.

We estimate that Leonardo's airborne avionics and sensor sales in 2023 were $285m.

Locations

Headquarters of the Leonardo Group is in Rome. Within Italy, Leonardo has over 31,000 employees and 70 facilities, 38 of which are manufacturing plants, where it designs, develops, and make helicopters, aircraft, avionics systems, land and naval systems, cyber and security solutions, space systems.

Leonardo employs over 7,300 people across 9 sites in the UK, where it designs and builds new-generation helicopters, advanced avionics systems, land and naval optronics and communications.

Leonardo also has facilities in Poland with PZL-Swidnik S.A., a company with over 2,800 people that develops and manufactures helicopters.

Within the Leonardo DRS (US based subsidiary) business there are a number of facilities located in the US as follows:

- Leonardo DRS has its headquarters in 2345 Crystal Drive, Suite 1000, Arlington, Virginia, USA.
- Airborne and Intelligence systems located in Melbourne, FL. Leonardo DRS' Airborne & Intelligence Systems line of business provides ISR components, sensors and integrated systems spanning the EO/IR, SIGINT, MASINT, and Communications domains.
- Airborne and Intelligence systems located in Germantown, MD. This facility designs and manufactures high-performance RF tuners, receivers and exciter technologies, as well as SIGINT products emphasising small size, light weight and minimised power consumption.
- Airborne and Intelligence systems located in Fort Walton Beach, FL 32548. The line of business occupies a campus in Fort Walton Beach, Florida that is home to the Advanced Programs Support (APS), Air Combat (AC), and Mission Systems (MS) product lines.
- Electro-optical and infra-red systems has a facility located at in Cypress, CA. The Leonardo DRS Electro-Optical and Infrared Systems line of business in Cypress, CA conceptualises, develops, produces and sustains sensors and systems in the visible through long wave IR spectrum.
- Electro-optical and infra-red systems located at in Melbourne, FL. Leonardo DRS Electro-Optical Infrared Systems provides innovative, world-class military thermal imaging systems.

Capabilities

Leonardo's electronics division provides airborne, land and naval applications from advanced components to fully integrated ISR, C4I, ISTAR solutions; combat and mission management systems, tactical unmanned systems, radar, communications, electronic warfare, optronics, infrared search and track, artillery, underwater systems, air and maritime traffic management, automation systems and space payloads and equipment.

Key capabilities are described as follows:

Aircraft Monitoring Unit: In order to meet current and expected future avionics recording requirements, the AMU acquires and processes a diverse mix of signals and supports several digital I/O formats including MIL-STD-1553B, ARINC-429, ARINC-717 and high-speed RS-22. The AMU can also output data to multiple recording devices for dual-combined recorder installations.

Station Keeping Equipment: With the help of the AN/APN-243, aircraft can operate within a 10 nm radius of a selected participating master system on the same frequency, allowing for close contact between aircraft. The system is also designed for easy, accessible upgrade, with reduced weight, size and cost.

Aircraft Mission Recorder: The solid-state recorder (USSR) is a reliable, ruggedised, next generation net-centric data storage device, combining the functionality of a multi-channel video/audio/1553 recorder, mission data server and adjunct. It replaces legacy single-channel 8mm tape-based recorders as well as less capable, standalone solid-state recorders (SSRs) in fixed or rotary winged, manned or unmanned aircraft.

Altitude Hold and Hover Stabilisation: In brownout or whiteout conditions, over-water hovers and tight landing zones (LZ), the AHHS system provides hands-free cyclic and collective control for cruise, low-altitude hover operations, precision hover and drift control, automatic descend to the ground, and automatic go-around. Giving pilots confidence, safety and more precise control in otherwise blinding and debilitating conditions.

Modernised TADS/PNVS Receiver for the Apache: Leonardo DRS provides the integrated forward looking infrared (FLIR) receivers for both the Modernised Target Acquisition Designation Sight (M-TADS) and the Modernised Pilot Night Vision Sensor (M-PNVS) for Lockheed Martin's Arrowhead® Apache's advanced electro-optical fire control system, which is used for target acquisition/designation and safe flight in day, night and adverse weather conditions.

Ruggedised Laser System: Solaris™ is a lightweight, high-power military ruggedised laser system for aircraft survivability applications. Solaris™ has been adopted as the laser source for Northrop Grumman's Common Infrared Countermeasures (CIRCM) solution, their 5th generation infrared countermeasure (IRCM) technology for warfighter protection. Solaris provides fast, simultaneous breaklock jamming with high power in multiple colours to defeat current and future threats.

Radar systems: Leonardo is a leader in Airborne Radars for both surveillance and fire control applications. Its portfolio extends from value-driven mechanically scanned radars to the latest software-based AESA technology.

Electro-optical Infra-red: SkyWard has been designed and developed to satisfy the more demanding requirements of 5th generation fighter aircraft with an embedded solution. A pod configuration is also available to allow easy installation on existing platforms. It comprises two Line Replaceable Units (LRU) - a Sensor Head Unit (SHU) and a Processor Unit (PU).

Airborne Gateway Processor: The AGP is an Aircraft Survivability Equipment (ASE) controller contained within a single, flight qualified, Line Replaceable Unit. It integrates federated ASE sensors and countermeasures to provide a combined threat picture and prioritised tactical response per the user-programmed Pre-Flight Message (PFM). The AGP is installed by Boeing as aircraft 'A'-Kit on all new and remanufactured AH-64D/E Apache Longbow Helicopters.

Mission computing:

- SP2305 is an airborne Link 11 system providing modem and network control functions to operate in a tactical digital information link. It employs networked communication techniques and a standard message format for the exchange of information between airborne, land and shipboard tactical data systems using either HF or UHF equipment.
- The Cockpit Mission Display Processor (CMDP) is a high safety avionics computer platform with a powerful embedded graphics capability. It is configured using the base of the standard hardware and layered software modules, that make the CMDP certifiable according to DO178B and DO254 level B (optionally level A) and suitable as a main cockpit mission computer.

Customers and contracts

The Commercial element of Leonardo's business provides Electronic Controls, Display Solutions and Lighting Systems for commercial and military. aircraft, in support of many of the most advanced fixed and rotary wing programs, including the Lockheed Martin Joint Strike Fighter (JSF/F-35) and Airbus A320, A400M and A350XWB.

Specific contracts are listed below:

- Saab Gripen C/D: Skyward-G IRST (Infrared Search & Track) passive sensor and IFF (Identification Friend-or-Foe) system
- F-35: Targeting system laser
- Osprey radar has been selected for platforms ranging from the US Navy's MQ-8C Fire Scout unmanned helicopter to the Leonardo AW101 helicopter. It is the only radar of its type currently available to offer full spherical coverage with no moving parts.
- NH90: IFF Interrogator.
- AH-64: Airborne Gateway Processor for Aircraft Survivability Equipment.
- AH-64 UK fleet: Defensive Aids System (DAS)
- Typhoon: Praetorian Defensive Aids Sub-System (DASS), Captor-E Radar sub-system
- Schiebel UAS: AESA Radar system
- Royal Canadian Air Force's (RCAF's) CP-140 ISR/ASW aircraft: 'Miysis' Directed InfraRed CounterMeasure (DIRCM) system
- Saab Global Eye Swingrole Surveillance system: AESA Radar system
- General Atomics MQ-9B: electronic warfare suite.

The UK Dragonfire consortium — led by MBDA and comprising Leonardo, QinetiQ, Arke, BAE Systems, Marshall and GKN — has brought together the relevant UK industry expertise to develop a Laser Directed Energy Weapon (LDEW) Capability Demonstrator Programme (CDP) on behalf of the UK Ministry of Defence, under contract to the Defence Science and Technology Laboratory.

Strategy

At the company-wide level, Leonardo have stated that they aim to adopt a "two-fold strategic posture". This comprises:

- Strengthening the core business by sharpening strategic selectivity, via product portfolio optimization and a renewed approach to innovation driven by focused R&I and massive digitalization, meanwhile candidating as a catalyst for European Defence consolidation, steering international alliances.
- Paving the way to the future by investing in emerging markets, such as cyber and space domains and by focalizing its portfolio of solutions towards a more efficient capital allocation.

Furthermore, in its published Industrial Plan 2024-2028, the company states its intention to transform "a Company working in multiple Divisions and related domainsinto a Company working in a cross-divisional multi-domain environment powered by the Digital Continuum." Three key pillars are identified:

- Organic growth (Focused R&D and technological innovation; Massive digitalization of solutions and operations; Servitization and customer proximity)
- Efficiency boost (Group-wide efficiencies and Corporate cost reduction; Business and product focus/rationalization; Broad optimization of manufacturing)
- Inorganic growth (Steering of global alliances; M&A in emerging technologies and markets)

With specific regard to its Defence and Electronics division, the company currently views their position as being the second largest European player in Defence electronics with a qualified US presence. From this they wish to become " a global player with European leadership and catalyst for European cooperation, leveraging GCAP spillovers, alliances/JV (land and naval Defense systems), and a rationalized portfolio, with a distinctive US presence."

From this, they have five key targets, three of which are relevant to avionics/airbourne solutions:

- Rationalize 20% of the current portfolio in order to focus on the core offering and optimize the capital allocation (main area of rationalization being custom C2, communications, airborne, land & naval radars, and other legacy products)

- Increase competitiveness across all domains (airborne, land, naval), through: Update core platforms (EFA) enable disruptive new programs (GCAP, AICS1); Invest/update leading products: radars and other sensors, communications, C2.
- Wider access to the European market and unlock synergies in terms of product portfolio and R&D: (1) radars and EW2 for airborne, (2) combat systems for next gen frigates, (3) networked land sensor solutions, (4) advanced air defense systems and sensors, (5) optronics (in progressing cooperation with Hensoldt)

Recent developments

March 2024: Leonardo and Germany's Hensoldt are discussing a possible joint venture, according to Leonardo's CEO, Roberto Cingolani. Leonardo is a shareholder in the German military sensor maker, alongside the German government which holds a 25% stake. However, it did not take part in a December capital raising which reduced its previous 25% stake in Hensoldt. Last year, outgoing Hensoldt CEO Thomas Mueller had raised the possibility of his company taking over Leonardo's defence electronics division, but Leonardo's then boss Alessandro Profumo dismissed the comments as "misleading". Future (at time of writing; duly taking over April 2024) Chief Executive Oliver Doerre had met with Cingolani in Rome and there is a list of possible cooperation projects between the two, but as yet there are no concrete plans for a joint venture.

October 2023: Leonardo has opened its 8th site in the UK, a high-technology science and engineering facility in the Newcastle Helix innovation cluster. Located in the state-of-the-art 'Spark' development, Leonardo Newcastle will focus on the research, development and prototyping of Leonardo's next generation sensing, security and vertical lift products, many of which will incorporate emerging digital and data technologies. The site will connect to Leonardo's other scientific research and manufacturing sites around the country via the secure cloud, linking into the company's nationwide network of data-driven engineering projects. Engineering projects at the facility will include defence digital and AI research, as well as the development of advanced electronics and helicopter products

July 2023: Leonardo announced a contract from the UK Ministry of Defence worth around 134million euros (115 million pounds) that will launch the next stage of the Excalibur Flight Test Aircraft (FTA) project. The FTA will support the introduction into service of a new combat aircraft, which will be at the heart of the UK's Future Combat Air System (FCAS). This next generation fighter is being delivered for 2035 by the Global Combat Air Programme (GCAP), an international collaboration between the UK, Italy and Japan. The Excalibur project is a key part of FCAS, which will include the crewed fighter and a broader range of capabilities such as uncrewed aircraft, F-35, information systems and weapon systems. Central to the development of the crewed fighter is the FTA; a Boeing 757 aircraft that will be completely overhauled, turning it into a flying laboratory for combat air technology. Leonardo will primarily use the airliner to test new technologies being developed by the trilateral programme. The UK Tempest Partners, BAE Systems, Leonardo UK, Rolls Royce & MBDA, working together with the UK Ministry of Defence, are continuing to collaborate on a range of test and demonstration activities, including Excalibur, to enable the successful delivery of GCAP in the required programme timelines.

March 2023: Leonardo has been awarded a new contract for the modernisation of the Italian Air Force's C-27J Spartan aircraft fleet. The contract was signed between Leonardo and the Italian Ministry of Defence's (MoD) Directorate for Air Armaments and Airworthiness (Armaereo). According to the contract, the company will work on the development, integration, qualification and certification of the C-27J aircraft's new avionics configuration, along with the upgradation of several general systems, flight simulators and self-protection systems. Leonardo will deliver the first aircraft to the Italian Air Force in upgraded configuration while the remaining 11 aircraft are expected to undergo the same retrofitting process. Work includes integration of new features such as a flight management system, mission computer, head up/down displays and radio and satellite communication systems in the avionic suite of C-27J military tactical transport aircraft.

Counterpoint comment

Leonardo has good access to the EU market, the US market via Leonardo DRS and it also enjoys significant foreign military sales. Interestingly, its own internal market for electronics, i.e. its family of helicopters, is run at arms-length and avionics are competitively sourced.

The company views their position as being the second largest European player in Defence electronics with a qualified US presence. We believe that Leonardo is well positioned to continue to grow within the defence sector.

19.2.7 PARKER MEGGITT

With its origins dating back to 1852, Meggitt plc was a publicly listed UK company with sales of £1,684 million in 2020. The company focuses on aerospace, defence and energy. In August 2021, the company was acquired by Parker-Hannifin with the deal completed in September 2022 for a price of $7.2 billion . At the time, this was Parker-Hannifin's largest acquisition, and reportedly nearly doubles the size of its Aerospace division. Since acquisition, Meggitt is known as Parker Meggitt, and part of the Parker Aerospace Group. For the purposes of financial reporting to HMRC, the company is known as Meggitt (UK) Limited.

Aerospace has become increasingly important to Parker-Hannifin's revenue over the past decade. It has risen from an 18% contribution in 2015 to 27% currently. In its financial reporting, Parker-Hannifin has two divisions: Diversified Industrial, and Aerospace Systems, the latter of which was responsible for 23% of revenue in its 2023 financial results. Avionics sits within Aerospace Systems, alongside numerous other focus areas that include actuation systems, engine nozzles and components, fuel systems, hydraulics, and wheels, brakes and brake control systems.

According to its website, Parker Meggitt employs more than 9,000 people at over 37 manufacturing facilities and regional offices worldwide. The company serves both fixed- and rotary-wing civil and military markets, and its avionics offerings focus on air data and flight displays.

Meggitt Avionics today supplies Air Data, Attitude, and Heading Reference Systems (ADAHRS) , Displays, Air Data Computers, Oxygen systems and sensors.

Financials

Parker-Hannifin's financial reporting only considers Aerospace Systems at the overall level, and does not offer subsequent breakdowns of key areas within this. The 2023 Annual Report however does note that the acquisition of Meggitt added a significant ($1.6 bn) amount to FY23 overall revenue of the Aerospace division.

The 2023 Financial Report for Meggitt (UK) Limited for the year ending 30th June 2023 shows total revenue of £204.1m, and an Operating Loss of (£8.7m).

We estimate that Parker Meggitt generated $48m in avionics related revenues in 2023.

Locations

Parker Meggitt's EMEA Regional Hub is based in Coventry, United Kingdom. There is an Americas Regional Hub located in Miami, Florida, and an Asia Pacific Regional Hub in Singapore.

Capabilities

Key product offerings include the following:

- ADAHRU: An integrated air data and attitude/heading reference unit. Combines both measurement systems into a single line replaceable unit.
- Air Data Unit (ADU) is a stand-alone solid-state device that measures pitot and static pressures
- Secondary flight display instrument for commercial, military and rotary wing platforms. Provides attitude, altitude and airspeed with a single 3ATI display unit
- Electromechanical Indicators: Meggitt provides a range of 2,3 and 4 ATI instruments that show attitude, altitude, airspeed, engine parameters and other key performance indicators.

Meggitt Avionics also supplies Oxygen systems for pilots and crew, however, this product is not within the scope of this report.

Meggitt offers a repair and overhaul service for its range of products also from within its site in Fareham, UK.

Customers and contracts

Meggitt works with the major aircraft OEMs and its systems are used on many large commercial aircraft programmes including: A380, and Boeing 777X as well as business jets and trainers including the HondaJet, Cessna Citations, Dassault Falcons and Pilatus aircraft.

Meggitt also has a significant presence within the Rotorcraft sector working with all the major helicopter OEMs with systems on civil and military helicopter programmes, including: AH-64 Apache, AW109, AW139, AW189, AW101, AW129, CH-47 Chinook, H130 and Korea's Light Armed Helicopter.

Meggitt supplies its integrated secondary flight display unit to Leonardo Helicopters, HondaJet, Bombardier Learjet, Textron Aviation business jets, Boeing Apache.

Meggitt supplies the following customers with its Air Data Unit (ADU); BAE / Hawk variants, Pilatus, Textron Aviation business jets, Dassault.

Strategy

Parker-Hannifin's overall strategic approach is found in The Win Strategy 3.0. which Parker's business system that "defines the goals and initiatives that drive growth, transformation and success." There are four key tenets: Engaged People, Customer Experience, Profitable Growth and Financial Performance.

Recent developments

June 2022: Meggitt opened its new Ansty Park site bringing together a range of Meggitt's existing operations within a world-class aerospace engineering and technology facility in Coventry. Ansty Park is one of the biggest investments in UK manufacturing in a decade as well as being Meggitt's largest infrastructure investment to date, one of a number of the company's global infrastructure projects. The facility provides a base for nearly 1,000 employees and is also regarded as a blueprint for the future. Built to high building efficiency standards to meet the environmental needs of the future, it boasts grey water systems, a photovoltaic roof capable of generating power equivalent to 25% of the site's needs and an electrification ready car parking plan.

Counterpoint comment

Meggitt Avionics is a relatively small niche provider of stand-alone avionics products which are utilised in smaller airframes. However, there is some exposure to these stand-alone boxes becoming integrated within packaged avionic solutions.

19.2.8 ROHDE & SCHWARZ

The company was founded more than 85 years ago by university friends Dr. Lothar Rohde and Dr. Hermann Schwarz.

The Munich based technology group develops, produces and sells a wide range of electronic capital goods for industry and government customers with a focus on solutions that contribute to a safer and connected world.

Rohde & Schwarz has an extensive sales and service network and is present in more than 70 countries, primarily with its own subsidiaries. Exports account for approximately 85 percent of revenue. The company is headquartered in Munich, Germany, and has strong regional hubs in Asia and the USA.

The company has three major divisions: Test & Measurement, Technology Systems, and Networks & Cybersecurity.

The company has several areas of interest:

- Aerospace and defense
- Automotive testing
- Broadcast and media
- Critical infrastructure
- Electronics testing

- Networks and cybersecurity
- Research and education
- Satellite testing
- Security
- Wireless communications testing

Financials

The group generated net revenue of EUR 2.78 billion in the 2022/2023 fiscal year (July to June).

We estimate that $70m was related to avionics products in 2023.

Locations

Central R&D is based at company headquarters in Munich. Rohde & Schwartz's other R&D centres are located throughout Germany as well as in the USA, Singapore, China, Korea, Denmark, France, Great Britain, Romania and Switzerland.

On June 30, 2023, Rohde & Schwarz had about 13,800 employees worldwide. About 8,700 of them work in Germany.

Capabilities

Within the Aerospace & Defence sector, the company focuses on the following industry markets:

- Secure airborne communications
- Airborne reconnaissance payloads
- Avionics testing
- Radar / EW testing
- EMC testing

Rohde & Schwartz have a number of distinct technologies that are applied to airborne platforms as follows;

- Electronic protective measures: (EPM) protect radio links from electronic countermeasures (ECM) such as jamming. These methods ensure a jam-free radio link. To protect radio links from tapping and spoofing; the information being transmitted can be encrypted via embedded encryption or additional external encryption devices.
- Legacy radios: The Airborne Voice/Data Radio R&S® XK516 is designed for use in commercial aircraft. The system provides conventional voice and high-speed air-to ground, ground-to-air, and air-to-air data communication over long distances.
- Encrypted data: SOVERON® WAVE also offer a strong encryption concept for exchanging voice and data messages. The waveforms are adapted to environmental conditions at all times and help ensure continuously stable communications. The waveforms provide high data rate transmissions within self-administered ad hoc networks. The waveform suite provides the best options for transmitting secure high data rates without satellites in a jammed environment in various ground, air and combined ground-air-ground scenarios.
- Voice/data radio comms: The R&S® XK516 airborne voice/data radio is designed for use in commercial aircraft. The system provides conventional voice air-to-ground, ground-to-air, and air-to-air data communications over long distances. It is suitable for aircraft operational communications (AOC), airline administrative communications (AAC) as well as air traffic communications (ATC).
- Radio antennas: Rohde & Schwartz offer a range of HF/VHF radio antennas both for ground and airborne use by airframe constructors.
- Digital receivers: Rohde & Schwartz offer a wide range of digital receivers for both ground, handheld and airborne use by airframe constructors.

- Drone defense: Rohde & Schwartz ® ARDRONIS detects commercial drone activity, it automatically classifies the type of drone signal, determines the direction of the drone and its pilot, and disrupts the radio control link to prevent the drone from reaching its target. The majority of commercial remote controlled drones are controlled (uplink) via frequency hopping spread spectrum (FHSS), a modern frequency agile waveform. Another major family of drones is controlled (uplink) via WLAN. Signals transmitted from the drones (downlink) are typically FHSS, wideband or WLAN signals.
- Rohde & Schwartz ® M3AR multiband VHF/UHF software defined radios are designed for line-of-sight communications in avionics. The compact and lightweight transceivers make them suitable for operation in all types of aircraft, including unmanned aerial vehicles (UAV). More than 8,000 delivered units. Successfully integrated in many aircraft platforms

Longevity is a fundamental quality feature of Rohde & Schwarz products. However, the high pace of innovation in modern communications technology means that products have to be regularly adapted to new technological developments. Rohde & Schwarz supports customers by offering comprehensive services throughout all phases of the product lifecycle.

Customers and contracts

Rohde & Schwarz does not list its customers for Aerospace however it does refer to both Airbus and Boeing in respect to its legacy radio comms products. Some specific application provisions are listed below:

- Typhoon: Secure radio communications.
- Embraer E99 early warning aircraft: Secure communications suite

Strategy

Rohde & Schwarz invest heavily in R&D and are clearly developing a range of technologies including digitisation, cybersecurity, software-based communications and 5G infrastructure. It is not clear how focused they are on airborne Aerospace and Defense applications (see comment below).

Recent developments

December 2023: Rohde & Schwarz and Northrop Grumman signed a Memorandum of Understanding (MOU) at the Berlin Security Conference in Germany to collaborate on future resilient communications systems across Europe, including multifunction technologies and upgrades for 5th-to-4th generation aircraft interoperability. This MOU addresses current and future challenges to connect European and U.S. assets in the air, ground, sea and space domains and establishes a framework that enables the parties to: Strengthen technology development for more resilient, trusted secure multifunction capabilities to connect platforms across domains; Enable collaboration on strategic multi-domain connectivity for air-to-air and air-to-ground communications and to integrate with ground-based air defence systems; Develop new opportunities that complement each party's strengths, delivering best-of-breed solutions in support of Germany's National Security Strategy, NATO goals and European Union Defence objectives.

June 2022: Rohde & Schwarz has achieved a milestone with the delivery of its 1000th AN/ARC-238 software-defined radio (SDR) to Lockheed Martin. The AN/ARC-238 SDR includes two airborne radios from Rohde & Schwarz's SOVERON radio family, known as the R&S MR6000R/L radios. The radio will be integrated onto F-16 Fighting Falcon aircraft. The technology fulfils the requirement of secure communication while being compatible with the F-16 jets.

April 2022: Rohde and Schwarz is one of several companies working with General Atomics, which has been awarded a €15.5 million contract by NATO's Support and Procurement Agency (NSPA) for Risk Reduction and Feasibility Studies (RRFS) associated with the Alliance Future Surveillance and Control (AFSC) program. The aims of this effort are to examine ways in which the organization can conduct surveillance and control following the planned retirement of the current Boeing E-3A Airborne Warning and Control System (AWACS) fleet around 2035.

December 2021: Rohde & Schwarz and partners have carried out stationary tests of the company's data link communication system for rotary wing aircraft on the premises of the Bundeswehr Technical Center for Aircraft and Aeronautical Equipment (WTD 61) in Manching. According to the company, the influence of rotors on radio waves was tested on two types of helicopters, operational with the Bundeswehr, the CH53 and Tiger, as well as on the rotary wing UMAT R-350 unmanned aerial vehicle from ESG. Officials claim that the development and demonstration of the system comes from

the need for piloted and unpiloted rotary-wing aircraft of the Bundeswehr to be able to send data links through one or more rotor planes, where interference can be caused by rotor blade modulation. The tests demonstrated radio performance against level drops, phase shifts, and diffraction at rotor blades' edges; while digital voice and data transmission was possible at a high sensitivity. In addition, a comprehensive set of data was collected to develop waveforms for broadband data transmission in the SHF frequency band, according to officials.

March 2021: Officials of the Air Force Sustainment Center at Robins Air Force Base, Ga., announced a $38.4 million five-year contract to Rohde & Schwarz to provide kits to assemble the Versatile Diagnostic Automatic Test Station (VDATS). VDATS is the Air Force member of the U.S. military families-of-testers, and is the Air Force's directed and preferred automatic test solution. The station has a modular open-architecture design and is adaptable to most electronic test and measurement needs. It was designed originally for depot testing capabilities, but is suitable for intermediate-level testing under controlled conditions.

January 2021: Rohde & Schwarz was selected by the Brazilian Air Force (FAB) to equip its modernised Embraer E-99M aerial early warning and surveillance aircraft with modern and secure communications. FAB is modernising five aircraft, each E 99M equipped with highly secure software defined radios and waveforms of the SOVERON family, widely used in the country.

Counterpoint comment

Rohde & Schwarz appear to be strong within test and measurement, the role out of 5G infrastructure, broadcast and media and Air Traffic Control. Their presence is also well established in land, sea and handheld applications. It is therefore not clear how important the airborne equipment sector is to Rohde & Schwarz who continue to support their legacy installed base, although we have seen some recent contracts won. They do invest in digital/software technologies.

19.2.9 SAAB

When Saab was founded in 1937, its primary aim was to provide military aircraft for Sweden.

Saab today is headquartered in Stockholm, Sweden and serves the global market of governments, authorities and corporations with products, services and solutions ranging from military defence to civil security. As of 2023, the Group had 21,600 employees.

The company is divided into the following business areas: Aeronautics; Dynamics; Surveillance; Kockums; and Combitech (an independent Saab company), with Aeronautics and Surveillance the most relevant divisions pertaining to avionics.

As of 2023, The Aeronautics division had a workforce of 5,600 employees. Its core area is that of Fighter Systems. Similarly, the Surveillance division employed 6,300 people with its core area that of Sensors, Command and Control Systems.

Its main aircraft products include the Gripen fighter platform and the recently awarded Boeing/Saab T-X trainer for the USAF.

Saab's 2023 sales divide as follows (rounded):

- Aeronautics (fighter platforms) - 23.3%
- Dynamics (weapons, missiles) - 37.1%
- Surveillance (avionics, EW, Radar) - 30.7%
- Kockums (submarine systems) - 6.8%
- Combitech (technology solutions, independent company) 5.5%

Financials – Aeronautics and Surveillance

Saab's 2023 Annual Report shows overall Group revenue generation of MSEK 51,609, compared with MSEK 42,006 in the previous year: a 23% rise. Group operating income for FY23 was MSEK 4,272, increasing from MSEK 3,274 in FY22.

FYE 31/12/23 - MSEK million	2023	2022	2021	2020	2019
Aeronautics Sales	13,754	12,942	12,263	11,340	8,218
Surveillance Sales	18,559	14,616	13,175	12,324	7,699
Aeronautics Operating Income	710	694	746	(875)	677
Surveillance Operating Income	2,034	1,176	888	821	853
Aeronautics Return on sales %	5.2%	5.4%	6.1%	(7.7%)	8.2%
Surveillance Return on sales %	3.8%	8.0%	6.7%	6.7%	11.1%

Commenting on the performance of the divisions, Saab commented in its Annual Report: "In 2023, Aeronautics' order intake increased by 38 per cent and amounted to SEK 18.1 billion, mainly driven by a contract for additional functionality for Gripen E to Sweden as well as a production order for T-7A fuselage systems to Boeing. Sales increased by 6% for the full year and amounted to SEK 13.8 billion as a result of high activity level in the Gripen programmes and Aviation Services. The operating income was in line with last year while the margin declined somewhat compared to 2022 due to negative impact from production ramp-up and underutilisation in the T-7A project. Full year cash flow was negative as a result of timing of milestone payments."

Commenting on Surveillance performance, they added: "Surveillance had good order momentum in 2023, driven by orders from Poland for two Saab 340 AEW aircraft, orders for sight- and fire control for CV90 to BAE Systems, support for Arthur systems to South Korea as well as a share of the defence equipment order to a Western country. Sales growth was 27% for the full year, driven by high activity in several large projects. Operating income increased by 73% to SEK 2.0 billion (1.2), and corresponded to an operating margin of 11.0% (8.0). This was a result of the higher sales volumes and strong performance in several business units. The operational cash flow for the full year was at a similar level as last year and was driven by customer payments."

We estimate that Saab generated $320m of avionics related revenues in 2023.

Locations

Saab has its main design and manufacturing plants located in Gothenburg, Järfälla, Linköping, Lulea, and Arboga, Sweden.

A significant element of Saab's Avionic products are produced within its Huskvarna facility also located in Sweden.

Saab's Surveillance products are manufactured within a number of its plants including Gothenberg, Jarfalla, and Karlskrona.

Saab has a Surveillance facility located in Halden, Norway and a subsidiary business (Saab Grintek Defense) located in Cape Town, South Africa.

Capabilities

Within the area of Aircraft Systems, avionics solutions are offered in the following areas:

- Airborne Computer Systems
- Flight Control Systems
- AviCom (Secure Radio & Audio Management System)
- Fibre Optic Sensor System
- Global Image & Terrain Data Solutions

Electronic warfare: Saab's Arexis expands the concept of the platform protection, to provide not only survivability, but to enable offensive operations within hostile air defense systems. The Arexis pod enables protection and offensive capabilities to a full fleet. Arexis's deploys Artificial Intelligence (AI) therefore requiring a minimum of attention from the aircrew. The Arexis air-launched decoy can deceive a wide range of threats. The controls in the Arexis Air-Launched Decoy (ALD) together with its network connectivity will detect and suppress the threats, keeping other high-value assets safe.

Surveillance: Based on the Global 6000/6500 aircraft family from Bombardier, GlobalEye combines Saab's Erieye Extended Range radar with an advanced suit of sensors and a multi-domain Command and Control (C2) system. GlobalEye combines complex systems integration, radar, command, control and communication systems into one powerful solution. GlobalEye operating at 35,000ft can detect low-level threats (at 200ft) at distances exceeding 458 km (247 nautical miles). The numbers for ground based radars (2,800ft) are 152 km (82 nautical miles).

Communication systems: The TactiCall Voice Communication Solution provides Ground/Air & Ground/Ground communication capabilities for Air Control Centres such as Air Operational Centres (AOC), Combined Air Operational Centres (CAOC), Control & Reporting Centres (CRC), Ground Entry Points (GEP), Tactical Command Post (TCP) and Last minute briefing Systems. A conversation with a fighter aircraft can start as non-secure and during the conversation be switched to a national or NATO secret conversation "Go Secure — by a single touch". Air Operational modes on radio-based communication are supported in this way.

Command and Control: Saab's Airborne Command and Control (C2) offer is a non-flight-critical C2 and mission management solution for Airborne Early Warning (AEW), Maritime Patrol Aircraft (MPA), Maritime Surveillance Aircrafts (MSA) and Signal Intelligence Aircrafts (SIGINT) as well as rotary wing platforms. The solution supports, Core mission management functionality (route planning, sensor control, local situation picture), Air, sea and ground surveillance (target detection, identification and classification), Search and rescue coordination (SAR reporting, cooperation unit handling and search area management), Weapon management (threat evaluation and weapon allocation, vectoring, mission assign), ISR (capture EOS, image optimisation), ELINT/COMINT (identification and classification).

Customers and contracts

Specific applications are listed below:

- Gripen: Safety critical avionics core computers, enhanced PS-05/A radar with ECM defense modes using active Electronically Scanned Radar (AESA) system, Infrared Search and Track (IRST) system, the newly integrated Electronic Warfare (EW) system, missile approach warning systems.
- German Air Force's Tornado: EW Arexis sensor suite (total 15 aircraft)
- Pilatus PC-21: Mission and Graphics computers
- GlobalEye Bombardier 6000 MPA AEW: ERIEYE ER radar, IFF, ADS-B, Maritime Patrol Radar, Satcom, Self-Protection System, Datalinks.
- Saab 2000 AEW/MPA: Erieye AESA radar, IFF/SSR, comms voice and data, Self-Protection System (SPS)
- NH90: Mission Tactical Computer, Core Management Computer
- A400M: High-Lift Control and Monitoring System
- UAV (fixed- and rotary wing) — Mission and Communication Computer

Its Aviation Communication system is integrated on the GlobalEye AEW&C and the ATR72-600 MPA

Strategy

Saab's strategy revolves around key strategic markets and on strong core areas. The company highlights five key strategic pillars guiding the company forward:

- Growth in strategic markets: key focus on Sweden, U.S., U.K., Germany and Australia as the main platforms for future growth.
- Core areas and future capabilities: Fighter Systems, Advanced Weapon Systems, Sensors, Command and Control Systems, and Underwater Systems.
- Operational efficiency: improvements in capacity and efficiency, including investing in automated production lines and increased digitalisation and efficient digitalised development and supply, project excellence and cross-organisational consolidation.
- People and competence: robust recruiting, investing in learning and future leaders, building efficiency and simplicity in people processes, and creating the best people experience.

- Sustainable business: Resilient and safe societies; Green and social transition; and Innovation and partnerships.

Recent developments

September 2023: Saab presented Poland with the first Saab 340 Airborne Early Warning (AEW) aircraft, just two months after Poland placed an order for two AEW aircraft, equipped with the Erieye radar.

September 2023: Saab entered into a strategic partnership with Helsing, a defence company specialising in AI-based software technologies. The partnership is built on a cooperation agreement, combining Helsing's highly advanced AI capabilities with Saab's wide range of solutions, and an investment by Saab of EUR 75 million in cash for a 5 percent stake in Helsing GmbH. Helsing, founded in 2021, develops AI-based capabilities with a software-only approach, which has led to rapid market adoption across Europe. The company has offices in Germany, the United Kingdom and France and has a total of approximately 220 employees.

September 2023: Saab acquired CrowdAI, accelerating the development and implementation of Artificial Intelligence (AI) / Machine Learning (ML) capabilities into Saab's portfolio. Future operations will be carried out primarily in San Diego, California. CrowdAI is known for its practical, user-friendly no-code platform for mission-specific AI and its industry-leading work leveraging dual-use computer vision for military applications. The company's work with Fortune 500 corporations, the U.S. military, and the Intelligence Community has pushed the boundaries of AI derived computer vision models tailored to the unique needs of customers. CrowdAI has contributed significant advancements to the AI / ML field, earning a place among America's most promising AI companies as listed by Forbes in 2021.

August 2023: Saab acquired all shares in the U.K.-based company BlueBear, a world-leading provider of AI-enabled autonomous swarm systems for complex defence and security applications. The acquisition of all shares in BlueBear is part of Saab's continued international growth journey across key markets, which include the United Kingdom, Australia, the United States and Germany. BlueBear is a world-leading provider of AI-enabled autonomous swarm systems for complex defence and security applications. BlueBear employs 65 employees at their site outside Bedford, England with a turnover of £8 million in 2022.

June 2023: Saab announced its Arexis sensor suite has been selected by Germany's defence procurement office (BAAINBw) as the preferred solution for the German Eurofighter Electronic Warfare (EW) variant. The German defence procurement office. The order marked the start of the first phase of Saab's delivery of Arexis within this programme. Saab received the order from Airbus, which will equip 15 of the German Air Force's Eurofighters for EW missions with solutions including Saab's Arexis. These aircraft will replace the German Air Force's Tornado ECR, which are set to be decommissioned from 2030.

June 2023: Saab signed a collaboration and asset transfer agreement of the Head-Up Display (HUD) to Honeywell, a long-standing industry partner. The agreement sets out a three-year collaboration between Saab and Honeywell which upon completion transfers the Head-Up Display (HUD) assets to Honeywell for Honeywell's cockpit avionics systems, including the next-generation Honeywell Anthem integrated flight deck. Saab's HUD is an advanced, lightweight integrated head up display, which improves safety during all phases of flight.

September 2022: Saab and Heart Aerospace have also signed a collaboration agreement regarding the supply of subsystems and the exploration of further areas of collaboration, including certification and manufacturing. This is in line with Saab's ambition to support the transition to sustainable aviation. Heart Aerospace develops the ES-30, a regional electric airplane with a standard seating capacity of 30 passengers powered by batteries, allowing it to operate with low noise and with zero emissions. Other Heart Aerospace investors include Breakthrough Energy Ventures, EQT Ventures, European Investment Council, Lower Carbon Capital, Mesa Air Group, United Airlines Ventures and Air Canada.

May 2022: Saab AB and Lumibird SA have today completed a transaction whereby Lumibird, through a newly established Swedish subsidiary based in Gothenburg, is acquiring Saab's laser rangefinder business. The transaction, which was signed in March 2021, was subject to a number of conditions, all of which now have been fulfilled. As part of the transaction, 27 Saab employees in Gothenburg will be affected and join the newly established subsidiary Lumibird Photonics Sweden AB. The divested operations had revenues of around EUR 10 million in 2021.

May 2021: Saab received an order from Panavia Aircraft GmbH to upgrade the radar warning equipment on the Tornado aircraft operated by the German Air Force. The order value is approximately 400 million SEK. Saab will supply modern digital components, which will enhance the processing power and extend the lifetime of the Tornado's radar warning equipment. Deliveries will take place between 2021 and 2025. Saab will carry out the work at its sites in Nuremberg, Germany and Järfälla, Sweden.

Counterpoint comment

Saab is one of the smaller national defense contractors. In terms of defense avionics and electronics it has exposure to the Gripen and various maritime patrol and early warning platforms. It has enjoyed some success with foreign military sales of Gripen but less so with stand-alone avionics products.

19.2.10 SAFRAN

Whilst Safran is best known for its aero-engine business, and its associated CFM JV with GE Aviation, it has also enjoyed strong growth in recent years supported via a number of major acquisitions as follows:

- TI/Dowty Landing Gear
- Goodrich Electrical Power business
- Zodiac Aerospace
- Electro-Mechanical Systems (THSA business from Collins Aerospace)

In 2023, Safran acquired Thales' aeronautical electrical systems business, which includes Thales Avionics Electrical Systems and Thales Avionics Electrical Motors in France, with sites in Chatou, Meru, and Conflans-Sainte Honorine.

There are numerous companies operating under the Safran umbrella: the most relevant is Safran Electronics & Defense, Avionics.

Safran has leadership positions in optronics, avionics, electronics and critical software for both civil and military markets. Safran is the No. 1 company in Europe and No. 3 worldwide for inertial navigation systems (INS) used in air, land and naval applications. It is also the world leader in helicopter flight controls and the European leader in optronics and tactical UAV systems. Operating across the globe through the Safran international network, Safran Aircraft Equipment, Defense and Aerosystems and its subsidiaries employ 8,161 people in Europe, Africa, Asia-Pacific, North America and South America.

Safran has been operating within Avionics for 50 years offering a broad range of applications:

- Commercial aircraft: onboard information, maintenance aid, landing aid, engine control.
- Civil helicopters: inertial navigation, flight control suites, autopilots, observation systems.
- Commercial aircraft and civil helicopters: inertial navigation, data processing and transmission, flight control, autopilots, flight data recorders, aircraft situation tracking systems.
- UAVs: optical sensors for surveillance and targeting

Financials

Overall, Safran reported revenue of €23,199m in 2023, an increase of 22% over the previous year. In Equipment & Defense, revenue of €8,835m was generated, a 17% rise on 2022 results.

We estimate that the airborne avionics related revenues accounted for $205m in 2023.

Locations

Safran Electronics & Defense has much of its design and manufacturing facilities within France. It has major facilities located at Plaisir, Montreuil, Massy all located on the outskirts of Paris.

Safran Electronics & Defense Canada Inc. has full systems, hardware and software engineering capabilities, however, most of these capabilities are related to engine control electronics.

Safran Electronics & Defense has an Optronics and Navigation system facility in Bedford, New Hampshire, USA.

It has data systems business (part of Zodiac) located at Les Utils, south of Paris and Norcross, Atlanta, USA

Safran Electronics & Defense has a manufacturing facility for Avionics products located in Costa Mesa, USA.

Safran Electronics & Defense Brazil designs flight control systems such as the APIRS attitude and heading reference system and observation and fire control systems for helicopters, ships and armoured vehicles.

Safran Electronics & Defense has a low-cost manufacturing site located in Mexicali, Mexico.

Capabilities

Safran Electronics & Defense has developed a number of avionics and sensor related technologies and capabilities including the following:

Navigation: Safran Electronics & Defense offers a wide range of navigation systems based on proven sensors. SEDs new SkyNaute family covers requirements for all types of airborne platforms — long range, single aisle and regional airplanes, helicopters and drones. SkyNaute family adopts hybrid inertial/satnav systems like ADIRU (Air Data Inertial Reference Unit) or attitude and heading reference systems like APIRS (Aircraft Piloting Inertial Reference System).

Safran Electronics & Defense also offers navigation systems including:

- Hybrid navigation systems, combining inertial and satellite sensors, plus air data management:
  - ARINC 738 / D0 229C / ARINC 429 / ADIRU with optical (GLR) or vibrating (GRH) gyroscope.
- AHRS: Attitude and Heading Reference System:
  - APIRS (Aircraft Piloting Inertial Reference System) with fibre optical gyroscope (FOG).

Helicopter Navigation: Based on Safran Electronics & Defense HRG (hemispherical resonator gyroscopes) and accelerometers proven technologies (used in land and space navigation solutions), Safran Electronics & Defense's new integrated SkyNaute navigation brings:

- High performance Inertial & Piloting data
- Protection levels for RNP/RNP-AR operations
- 100% RNP 0.1, even in coasting > 10 min
- Fly-by-Wire, SVS (Synthetic Vision System) & HUD (Head-Up Display) architecture ready solution

Inertial reference units: Safran Electronics & Defense's FMU series of Inertial Measurement Units (IMU) are equipped with Fibre Optic Gyro (FOG) technology and servo-looped MEMS accelerometers.

FMUs, as well as their packaged versions, are proven solutions for civil and industrial applications such as hybrid GNSS-inertial navigation systems, which require high reliability, excellent signal stability and very low noise.

These devices are used in a range of civil/mil helicopter and airborne military applications.

Euroflir: Euroflir is a range of electro-optical gyro-stabilised observation systems for helicopters, aircraft and UAVs. The Euroflir EOS are equipped with latest-generation thermal cameras, HD day cameras and laser sensors, allowing them to carry out numerous military and security missions in optimal conditions. This includes theatre surveillance, SAR and CSAR, coastal patrols and homeland or maritime surveillance. The combat proven Euroflir™ 410 is already used on Patroller UAV.

Information/data systems: Safran Electronics & Defense, with expertise in flight data management systems and aeronautical maintenance support, offers a full, integrated range of equipment for the acquisition, management, recording and analysis of information.

- Safran Electronics & Defense's aircraft information systems (AIS) like that developed for the Airbus A380, provides access to multiple data: flight logs, onboard electronic documentation, navigation diagrams, performance calculations, etc.
- Safran Electronics & Defense's aircraft condition monitoring system (ACMS) records and analyses the flight data and information from aircraft equipment. The data can be used to monitor the condition of the systems, optimise preventive maintenance and aircraft lifetime
- Safran Electronics & Defense has developed a high-performance solution for operators and airlines: the analysis ground station (AGS). This system analyses flight data from each aircraft to optimise their fleet management and reduce maintenance costs.

Airborne optronics: As a specialist in gyro-stabilised optronics for helicopters, Safran Electronics & Defense offers high-performance equipment for search, location, identification and target designation including the following:

- Euroflir gyro-stabilised electro-optic pods, equipped with latest-generation thermal cameras, HD daytime cameras, multi-spectral spotting scope and laser sensors allow for all types of security operations: land or sea surveillance, patrols, rescue, weapons guidance, etc.
- The firing sights for helicopters developed by Safran Electronics & Defense are compatible with a wide variety of weapons used on the new generation of aircraft.
- The wide-angle sensors and enhanced vision systems (EVS) used in the Safran Electronics & Defense optronics solutions satisfy requirements to improve flight safety for aircraft: anti-collision, flying in poor-visibility conditions both day and night.

Safran Electronics & Defense also offers the industry flight services via its Cassiopee brand. CassiopÃľe is a twofold offer that combines flight data management software packages and analysis solutions for all types of airplanes and helicopters. Its services enable fuel consumption reduction, maintenance costs optimisation and flight safety enhancement.

Customers and contracts

- A320: Flight Data Management System
- A330: Data loading system
- A350: Aircraft Condition Monitoring System
- WEFA — Aircraft condition monitoring system: Together, the contracts awarded cover more than 1,000 airliners of various types: Airbus A320ceo, A320neo, Boeing 737, ATR 42 and ATR 72.
- GADIRS (GPS Air Data & Inertial Reference System) is a hybrid triplex navigation system selected by Airbus for the A400M
- Inertial Navigation System for the Rafale fighter.
- Data loading systems: Airbus to modernise all data loading systems for the avionics suites on its A320 family of commercial jets (A319, A320, A321) with SED data loading systems.
- The long-range electro-optical system Euroflir™ 350, GPS Inertial navigation system and Autopilot equip the Airbus H225M helicopter. The combat-proven Euroflir™ 350 is already used on many French Army and other nations' rotary-wings (H125M Fennec, AS350 Ecureuil, AS532 Cougar, H225M Caracal, etc.) EuroFlir 410 is used on the NATO Helicopter Management Agency's (NAHEMA) NH90 helicopters and the French navy's AS565 Panthers.
- The Sigma 95L Inertial Navigation System (INS) is used for NH Industries' NH90 helicopter program.
- SED has delivered its 10,000th APIRS™ inertial reference system, which will be fitted to an ATR 72-600 regional turboprop.
- Safran Electronics & Defense is very active in China in the optronics and navigation sectors through its two subsidiaries Reosc and Colibrys.
- Safran's Cassiopée Flight Data Monitoring solution. Starting in December 2020, this service will initially be available to all ARes II-equipped Cessna Citation CJ4 jets.
- HAL and SED have announced the signing of three new contracts, at the Aero India 2019 Airshow, for Safran-designed autopilots for various helicopters manufactured by HAL.

Strategy

Safran Electronics & Defense states that its "primary areas of focus are multispectral optronics, image processing, new-generation tactical drones, vibrating gyros and MEMS (micro-electromechanical systems), applied to next-generation navigation systems for both military and civil applications".

It is also focused upon generating IP and has 2,100 patents filed round the world.

Recent developments

October 2023: Safran Electrical & Power today completed the acquisition of Thales' aeronautical electrical systems business, which covers electric conversion, power generation, and motors for civil and military aircraft. Thales's aeronautical electrical systems business employs nearly 600 people and generated revenues of €145 million in 2022. This acquisition includes Thales Avionics Electrical Systems and Thales Avionics Electrical Motors in France, with sites in Chatou, Meru, and Conflans-Sainte Honorine. It also includes the support, maintenance and production activities for aeronautical electrical equipment in Orlando (USA) and Singapore. Business activities in France are integrated into Safran Electrical & Power with immediate effect. Business activities in the USA and Singapore will be absorbed at the end of a transition period, during which the necessary certification approvals will be obtained.

June 2023: Safran Electronics & Defense and Archer Aviation Inc.in San Jose, Calif. provided further details of their avionics technology collaboration, which kicked off back in 2021. This collaboration is focused on delivering solutions to Archer that utilizes Safran's components. The two companies have initially focused their development and testing on Safran Electronics & Defense's ultra-compact avionics platform (UCAP) flight control computer (FCC) and SkyNaute navigation system, which are both used in Archer's Midnight eVTOL aircraft. Equipped with a multi-core processor, Safran's UCAP provides high-performance computing capabilities, as well as high-integrity and safety features. SkyNaute adheres to the safety and reliability requirements necessary for certification by relying on mature technologies such as HRG Crystal (Hemispherical Resonator Gyroscopes). This innovative navigation system achieves high performance and integrity while providing a 35% reduction in size and weight when compared to alternatives. With a range of up to 100 miles and an expected payload of approximately 1,000lbs, Archer's Midnight is a piloted, four passenger aircraft designed to perform rapid back-to-back flights with minimal charge time in between flights. Archer's goal is to transform urban travel, replacing 60-90 minute commutes by car, with estimated 10-20 minute electric air taxi flights.

July 2022: Safran Electronics & Defense acquired Orolia, a company offering positioning, navigation and timing (PNT) and related activities, technologies and equipment. Orolia employs more than 435 people in Europe and North America and has revenues of around €100 million. Its solutions include atomic clocks, time servers, simulation and resilience equipment for GNSS* signals, as well as emergency locator beacons for commercial aviation and military applications.

January 2021: Safran Electronics & Defense has been chosen by Textron Aviation to incorporate its range of Cassiopée flight data monitoring (FDM) services on Cessna Citation jets. Cassiopée is initially available to all ARes II-equipped Cessna Citation CJ4 light business jets. Safran's Cassiopée FDM services were designed for irlines, business aviation and helicopter operators. Its user interface provides a complete overview of all operations by data visualization, including automatic events notification, flight path, crew feedback and reports, and operational statistics.

Counterpoint comment

Safran Electronics & Defense is an amalgamation of a large number of businesses spread throughout many sites and facilities and appears to be largely as a result of mergers and acquisitions. It has two main capabilities in inertial navigation and electro-optics. Recent moves into data and services (via its Cassiopee brand).

We do not see Safran Electronics & Defense as being a strong contender within next generation integrated avionics but it is a very capable provider of a range of discrete products and services like auto-pilot and navigation.

19.2.11 SCIOTEQ

Originally founded as Barco in the 1980's from their television and display business, Barco Avionics displays (Belgium) was acquired by Esterline in 2015 for $200m and at the time it generated $200m of revenues and employed 600 personnel.

It was subsequently renamed as ScioTeq and then in 2018 TransDigm acquired the business as part of its acquisition of Esterline. In 2021 TransDigm divested the company, and ScioTeq was acquired by OpenGate Capital. In 2023, ScioTeq acquired Toulon-based IRTS.

Today ScioTeq offers products which include video displays, smart displays, mission computers, software platforms, and radar displays, are used in the air, on the ground, and at sea, providing mission critical information.

It operates via three business sectors as follows:

- Avionics

- Air Traffic Control,
- Defense & Security

Financials

In 2019 it was reported that ScioTeq employed 322 personnel and generated $105m of revenues.

We estimate that ScioTeq's revenues generated from sales of Avionics was $40m in 2023.

Locations

ScioTeq's facilities are as follows:

- Kortrijk, Belgium: Manufacturing, Engineering, Sales & Support, Service functions with 130,000 ft2 of manufacturing space
- Dulruth, GA, USA: Manufacturing, Engineering, Sales & Support, Service
- Bangalore, India: Sales & Support, Service
- Singapore: Sales & Support, Service
- Paris, France (IRTS): Manufacturing, Engineering, Sales & Support, Service
- Toulon, France (IRTS): Manufacturing, Engineering, Sales & Support, Service

Capabilities

ScioTeq has been serving the Avionics market for 35 years, and is present on more than 150 aircraft types, both civil and military platforms, both fixed wing and rotor wing. ScioTeq's visualisation technology allows it to provide aircraft manufacturers and system integrators the best image quality in a scalable manner, supported by an open system solution (MOSArt®).

Key product areas are as follows:

- Video displays
  - Rugged Display Units (RDU)
  - Flight Display Units (FDU)
  - Mission Display Units (MDU)
  - Custom Display Units
- Smart Displays
  - Multi-Function Displays
  - Control Display & Management System
  - Touchscreen Control Units
  - CRT To LCD Upgrade
- Display Head Assemblies
- Certified Avionics Display Computers
- Software Platform
- Airborne Mission Displays

Smart displays: Smart display products combine optical quality with a high-performance multi-core processing capability graphics performance and a set of interfacing options. Equipped with the ARINC 653 compliant MOSArt™ platform services, these displays are capable of hosting multiple, high-demanding software applications developed to varying Design Assurance Levels, up to and including DAL A.

Multi-function displays: Modular design allows customers to simultaneously host combinations of software applications that can be customer proprietary, ScioTeq proprietary, such as Primary Flight Display (PFD), Navigation Display (ND), Synthetic Vision System, etc., and from 3rd parties.

Control and Display Management: These are offered as a complete product family, including the civil CDMS-3739 (ARINC 739), the military-oriented CDMS-3753 (combo ARINC-429 and MIL-STD-1553), and the versatile CDMS-370x, which hosts ScioTeq's unique MOSArt® platform. This MOSArt® -equipped version allows customers to develop or integrate their own application (e.g. FMS or mission solution) on the flexible CDMS-3000 platform.

Mission Computers: Mission computers include a high-performance multi-core processing capability. Modular by design, these provide an array of graphics performance options (from Quad Head Graphics Processing Units to software based rendering engines), and a vast set of interfacing options.

Customers and contracts

ScioTeq lists the following platforms as having its commercial avionics installed on the following platforms;

PC-12, PC-24, L600, L650, G-IV, G-V, Citation X, GEX, L45, Tu-204, Tu-214, Be-200, An-124, Il96, Il114, A380, ATR42, ATR72, DHC-6, C-919.

Scio-Teq lists its military platforms supported as follows:

F-16, C-130, C-5, A400M, A330MRTT, C-27J, F-35, Mirage 3, Mirage 5, PC-21, KT-1C, E-2D, P-3, P-8, C-160, C295.

Supporting air forces from multiple countries, including US Airforce, Royal Air Force, French Airforce, German Airforce, Spanish Airforce.

ScioTeq has been active in the upgrade market for many years with display upgrades including EC105, Super Puma, RC-135 Rivet trainer, P-3C, Beriev Be-200.

ScioTeq were also selected by Honeywell to provide a dedicated interface display as part of Primus Epic which was used to upgrade PC12, Y12 and Twin Otter aircraft amongst others.

Strategy

ScioTeq enables its customers to make real-time decisions by providing advanced visualisation solutions with the features and capabilities needed to ensure success. Its products are used in the air, on the ground, and at sea, providing mission critical information to customers on some of the most advanced platforms on earth.

Recent developments

February 2024: ScioTeq announced the establishment in Bangalore, India of ScioTeq Pvt Ltd, a wholly owned subsidiary of ScioTeq bv. This move will further extend ScioTeq's global presence by providing Sales, Procurement and Services at its Bangalore location. Additionally, by joining with local partners it will position ScioTeq to support local trade sales and manufacturing of its products and solutions for the Defense market.

June 2023: ScioTeq launched its open and modular PU-5200 Certifiable Display Computer at the Paris Air Show on 19 June 2023. The Open Architecture Display Computer utilizes ScioTeq's DAL-A Certifiable MOSArt® software framework which can drive all the Avionics visualization displays in any aircraft, whether it's ScioTeq's, a 3rd party's or a combination of both.

September 2023: ScioTeq has been selected by Airbus Defence and Space for its display computer PU-5200, avionics video touchscreen displays RDU-3068 and the MOSArt® Platform software, for the new generation Airbus A330 Multi-Role Tanker Transport (MRTT) aircraft. The new Open Architecture Display Computer and Displays will be replacing ScioTeq's previous generation computers and displays on the aircraft.

March 2023: ScioTeq had acquired IRTS, a manufacturer of ruggedized displays and embedded computers for defense, aerospace and industrial applications. Headquartered in Toulon, France, IRTS was founded in 1995 and has earned a reputation as a premier manufacturer of industrial electronics that prioritizes research and development and maintains a team of highly experienced engineers. IRTS's specialty, state-of-the-art products are mission-critical in ground army vehicles and other military applications.

Counterpoint comment

ScioTeq has a strong focus on upgrade and retrofits, however, we question how sustainable this is if OEM sales are not forthcoming. The business has shrunk significantly since the 2015 acquisition. We look forward to see how the company evolve under the new ownership of the private equity firm.

19.2.12 TECNOBIT

In 1976, Tecnobit was created in Madrid and was moved to Valdepenas in 1981.

In 1983 Tecnobit obtained the first contract with the Ministry of Defense for the development of an encrypted communications system and, since then, it has been considered a national strategic company.

In 2008 Groupe Oesia acquired 100% of Tecnobit.

Today, Tecnobit is the engineering company of the OesÃa Group having grown consistently for 40 years. Its constant innovative effort has made it a clear international benchmark in the Avionics fields of Communications, Security and Defense. It supplies Aerospace & Defence OEMs with the most advanced developments in Avionics, Optronics, Secure and Tactical Communications, Simulation and Inhibitors.

Financials

In 2023, Oesia Group's total revenue was €221.7m (+21% vs. 2022), and subsequent EBITDA of €26.7m (+38% vs. 2022).

We estimate that Tecnobit's avionics related revenues were $30m in 2023.

Locations

Tecnobit's international operations centres are the corporate headquarters in Rivas (Madrid) and the main operating plant in ValdepeÃśas (Ciudad Real).

Capabilities

The Group's key aerospace solutions are to be found in the following areas:

- Optronics
- Displays
- IRST
- Tactical and Secure Communications
- Satellite Communications
- Simulation
- Avionics and Space

Within Avionics and Space, the following products and services are available:

- MIDS Interface Computer (MIC)
- Audio Management System (AMS)
- Wideband EPM Satcom
- Mission Computer
- Data Converter
- Deterministic Ethernet for Avionic Databuses
- RPAS / UAV Unmanned Vehicles
- Data Loading Unit (GLU)

- Air Data Sensor (ADT)
- In-Flight Data Logging Devices (BSD)

Tecnobit has equipment developed for the Eurofighter, both on board and in support of the operation. These teams use either Tecnobits own developments such as WHCU -Windscreen Heater Control Unit- , GLU -Ground Loading and Data Exchange Unit or are developed jointly in European consortia. These joint efforts include equipment such as FLIR / IRST -Forward Looking Infrared / Infrared Search and Track , BSD -Bulk Storage Device- , ADT -Air Data Transducer.

The MIC equipment is an evolution of the Tecnobit tactical data link equipment for use in Airbus A400M aircraft and Airbus A330 MRTT. It is a device of low weight and high processing capacity, designed to handle all the Link 16 information received from the MIDS (Multifunctional Information Distribution System) for subsequent communication with the on-board mission computer.

Tecnobit offers extensive experience in developing optronics products and systems, including thermal cameras and infrared applications and solutions.

In the Command and Control area, Tecnobit has a position in several technologies such as Tactical Communications, Communications Security, FFT & BMS ("Friendly Force Tracking" & "Battle Management Systems") and in Maintenance Services.

Customers and contracts

Tecnobit has designed solutions for major European programmes including Eurofighter and A400M, where they participate as Main Contractor and presence with other key companies such as BAE Systems, Airbus Military, Hensoldt, Leonardo and Thales.

Tecnobit is provider of the audio management system (AMS) for the A400M. This is one of the most advanced in the market owing to the number of integrated communication systems.

The A400M Audio Management System constitutes a platform where it is possible to separate the so-called “clear audio” (for unclassified audio communications) and “secure audio” (classified audio communications). All the interfaces in the system are made through fibre optic lines, which minimises crosstalk between audio channels (crosstalk, EMI / EMC) and compromised emissions.

Tecnobit has developed the mission control consoles for the MH60R maritime patrol helicopter.

Tecnobit are under contract to provide maintenance of the displays of the F/A-18 fighter-bomber of the Spanish Air Force.

The MHSD and MUFC are the two cockpit displays of the F/A-18 that were designed for the half-life adaptation (MLU) in order to increase the tactical capabilities. Tecnobit manufactured under license from Kaiser Electronics (Collins) 82 pairs of displays for the entire aircraft fleet between 2005 and 2009.

The Mission Interface Computer is tactical data link for use in Airbus A400M and Airbus A330 MRTT. It is a device designed to handle all the Link 16 information received from the MIDS (Multifunctional Information Distribution System) for subsequent communication with the on-board mission computer.

Strategy

Oesia, the parent of Tecnobit, states that Tecnobit is the engineering company of the OesÃa Group. Its constant innovative effort has made it a clear international benchmark in Communications, Security and Defense.

Recent developments

July 2023: Grupo Oesía and Indra have signed a strategic collaboration agreement by which they add key technological capabilities to improve the global offer of new generation systems and services for the Spanish armed forces and security forces, thereby strengthening national sovereignty while improving the positioning of both companies in the international market and European programs. The agreement encompasses the development of new systems and services related to command and control systems (C4I), air defence radars, electronic warfare, intelligence, surveillance, reconnaissance and target acquisition systems (ISR and ISTAR), as well as on-board electronics.

June 2023: Grupo Oesía and Lockheed Martin have signed a letter of understanding that reinforces the relationship between both companies and seeks to establish Grupo Oesía as a long-term strategic partner within the Lockheed Martin supply chain. The final objective of this letter is to enhance commercial opportunities for both companies in the national and international market by combining the activities of both in the field of secure tactical communications, intelligent image, simulation, on-board electronics, satellite components, mission systems, electronic warfare and other defense-related technologies. With a close relationship with Lockheed Martin for more than 20 years, Grupo Oesía is one of only two non-US companies that supply components for the North American giant to have been recognized as a Star Supplier by Lockheed Martin for the excellence of its work.

Counterpoint comment

A European defense contractor with exposure to defense programmes working in collaboration with other EU defense contractors. It has had some success attracting work via Lockheed Martin and Collins Aerospace but we suspect that this may be offset derived work (and therefore limited).

19.2.13 THALES

Thales, formerly Thomson-CSF, was founded in 1968 through the merger of the professional electronics businesses of Thomson-Brandt with Compagnie Générale de Télégraphie Sans Fil (CSF).

The group was renamed Thales in 2000 and it is still partially owned by the French government. In 2001, Thales and L3 Technologies (later becoming L3 Harris, featured in this report) entered into a Limited Liability Agreement ('LLC Agreement') concerning Aviation Communication & Surveillance Systems (ACSS featured in this report). In 2023, Thales acquired Cobham Aerospace Communications, taking full effect as of April 2024.

Thales Group had sales of €18.4 billion in 2023 and had 77,000 personnel operating in 68 countries.

Within the Aerospace division, two Global Business Units exist: Avionics, and Space, accounting for 18,400 employees in 31 countries. The main industrial footprint however is concentrated in six countries: France, Italy, Spain, UK, USA, and Singapore.

The company offers a range of flight deck, avionics equipment and functions, positioning itself as an onboard systems integrator as well as a more conventional avionics supplier. Their portfolio consists of:

- Flight deck systems
- Flight Management Systems (FMS)
- Flight controls
- Autopilot
- Integrated Modular Avionics (IMA), cockpit displays and computing platforms
- Eyes-out solutions from head-up displays to helmets and head-worn displays

Financially, there are three reporting divisions:

- Aerospace (including Avionics)
- Defence & Security
- Digital Identity & Security (DIS)

Thales claims that it is Number 3 in the world for avionics and Number 1 in Europe.

Financials - Aerospace

The Aerospace division reported a 10.8% rise in revenue from 2022, contributing 28% to total sales. Flight Avionics (including cockpit avionics, communications, electrical systems, training and simulation) sales for the period totalled €2,100m, representing 40% of total Aerospace sales. Civil (67%) was the bigger source of avionics revenue compared with military (33%).

FYE 31/12/23 - €million	2023	2022	2021	2020	2019
Sales €m	5,211	4,705	4,463	4,217.0	5,595.1
EBIT €m	371	235	202	(76.2)	520.8
Return on sales %	7.1%	5.0%	4.5%	1.8%	9.3%

Commenting on the sales performance of the division, the company stated: "Organic growth in all avionics activities was above 20%, despite a decline in sales for the microwave tubes business. Civil aviation activities were particularly strong (organic growth of more than 30%), with the original equipment business benefiting from an increase in aircraft manufacturers' production rates, while aftermarket sales were driven by the recovery in air traffic."

Regarding EBIT, the Aerospace division recorded EBIT of €371 million - 7.1% of sales in 2023, compared with €235 million (5.0% of sales) in the previous year. The company attributes this rise to the avionics segment, "where the margin was back to pre-covid level thanks to both positive volume and price effects."

Based upon Thales position in flight decks, navigation and connectivity, operating in both the civil and military sectors, we estimate that Thales generated avionics related revenues of $1,750m in 2023.

Locations

Thales has its main avionics facility in Meudon, just south of Paris.

Thales has subsidiary avionics operations in locations in France including Chatellerault, Vendome, Bordeaux, Vitrolles (Marseille) and Toulouse.

Thales Avionics Services Worldwide (ASW) Americas, based in Piscataway N.J. provides repair, retrofit and spare support for flight avionics equipment.

Thales has a significant presence in China with 3 JVs however these cover ATM, inflight entertainment and connectivity services. Thales sells avionics direct to Chinese Airlines but does not manufacture locally.

Thales has 9 sites in the UK, but these do not typically provide avionics solutions.

Capabilities

Thales summarises its avionics capabilities as follows:

- Flight deck systems, (FlytX large tactile displays)
- Flight Management Systems (FMS, PureFlyt leader in FMS)
- Thales Synthetic Vision System (3D representation on PFDs)
- Thales Remote Electronic Unit (REU)
- Autopilot, Thales autopilot main key features
  - Certified with TSO/ETSO, DAL A
  - Precision Approach modes up to ILS CATIIIB and including steep approach
  - Non-Precision Approach modes: LNAV, LNAV/VNAV, RNP-AR 0.3, LPV, GLS
  - Protection: flight envelope, Alpha floor, speed protection, windshear escape guidance, TCAS/TAWS AP coupling, sensor single source
  - Auto throttle / Auto thrust (Thrust Quadrant Assembly included)
  - Military modes including terrain following.
- Integrated Modular Avionics (IMA), cockpit displays and computing platforms
- Eyes-up solutions from head-up displays to helmets and head-worn displays.

  - "Designed by pilots for pilots, TopMax is a lightweight full-color Head-Worn Display System (HWDS) for business jets, commercial aviation, and cargo operators."
  - TopOwl is Thales helicopter pilot head-up display helmet
- InFlyt Experience IFE
- Connected Aerospace. Connectivity is helping to enable the proliferation of artificial intelligence, big data, cloud, mobility and social media components. These are key aspects of digital transformation with a cohesive portfolio in avionics, mission management systems, air traffic management and cybersecurity, Thales is well-equipped to achieve the digital transformation and deliver connectivity to the aviation ecosystem in a secure and seamless way.

The following capabilities are largely within the civil aircraft sectors.

Thales FlytX flight deck: FlytX achieves a 30 to 40% reduction in size, weight and power consumption compared to legacy avionics. This decrease is the result of the IMA's strong integration of avionics applications such as FMS (Flight Management System), HTAWS (Helicopter Terrain Awareness and Warning System) and RMS (Radio Management System) inside the display. There is no more need for specific hardware and the number of LRUs (Line Replaceable Units) has been dramatically reduced.

The FlytX solution has been developed to be integrated to the connected aircraft environment. It can securely link avionics systems with operation centres, other service providers, and the open world (third-party mission applications) making the cockpit more mission-oriented and flexible. FlytX can display and interact securely with a connected tablet (e.g. Electronic Flight Bag) thanks to a Cyber-by-design architecture which guarantees a strict separation between critical flight information and data coming from open-world sources (autonomous IT bubble).

PureFlyt FMS: Thales has developed an entirely connected FMS, designed to offer safety, security, and fuel and operations efficiency. The FMS is able to draw on both onboard and open-world data, such as weather information. By combining the integrity of the FMS and the agility and power of Electronic Flight Bag flight functionalities, aircraft trajectory can be permanently controlled, adapted and enhanced, resulting in optimised flight, decreased fuel consumption and improved passenger comfort. Cyber-secure by design, PureFlyt has also been designed to be future proof, accommodating the implementation of concepts such as the Initial 4D (I4D) trajectory management methods currently being researched by SESAR (Single European Sky ATM Research) in the EU and NextGen in the US.

HUD Systems: Resulting from Thales' decades-long experience in military Helmet Mounted Display Systems (HMDS) and civilian Head-Up Display (HUD), TopMax provides additional operational credits in order to reduce take-off and landing minima. The product includes augmented reality and intuitive off-axis symbology features that strongly enhance situational awareness and safety.

The TopMax HUD operational capabilities largely exceed existing HUD solutions because of:

- 360°full color vision capability
- Unlimited Synthetic Vision System (SVS)
- Off-axis symbology including cross wind, synthetic runway and extended centreline
- 3D traffic display

Auto-Pilot: Thales has decades of experience both within civil fixed wing and rotorcraft applications for Auto-Pilot systems. Solutions includes single equipment and end-to-end autopilot system as well as software solution which can be installed on existing computing device. Autopilot software applications that implement several functions: stabilisation and control, guidance modes, auto throttle via the following:

- Control panels
- Auto throttle assembly
- Actuators
- Probes and sensors
- Computing device.

Navigation systems: The transition of current Air Traffic Management (ATM) to performance-based ATM systems has demonstrated the fundamental need for aircraft to have reliable and accurate navigation systems.

Thales designs all of the critical technologies across the navigation chain, from Air Data to high accuracy inertial systems. Thales designs and manufactures its own sensors for all these equipment types in France.

In addition to having a strong navigation presence on many civil platforms Thales has developed specific navigation solutions for mission based military platforms featuring the following capabilities:

- Operational mission success through state-of-the-art performance: accuracy, jamming resistance and integrity
- NATO operability: standardised user equipment and interfaces as well as specific concept of operation (e.g. NAVWAR)
- Compliance with civil air traffic regulation (CNS/ATM)
- Specific military environment: dynamic range, EMC, vibration
- Independence in operational capability
- Growth potential: low-cost inertial solutions through MEMS technology and GNSS evolutions (GPS M-Code, Galileo PRS, anti-jamming)

Thales Connected Aircraft: As connectivity becomes more prevalent across aviation ecosystem it is helping to enable the proliferation of artificial intelligence, big data, cloud, mobility and social media components. These are key aspects of digital transformation which Thales is leveraging for customers. With a cohesive portfolio in avionics, mission management systems, air traffic management and cybersecurity, Thales is positioned to achieve the digital transformation.

Service and Support: Thales has a global network of support and service centres that provides spares, repairs, and upgrades to airlines and end-users.

In addition to this Thales has a service support partner in Avio that offers a range of digital/software support services as follows:

- AvioCabin: fast, native and user-friendly application which will make cabin operations run like clockwork.
- AvioConnect : a secure communication application that improves the communication between different stakeholders around the aircraft to decrease turnaround times and make workflows more efficient.
- AvioTech: enables pilots, mechanics, MCC and cabin crew to review the status of the aircraft, report defects, review open and deferred defects.
- AvioCyber : AvioCyber security services allows to grow awareness on security matters and to build preventive and corrective actions to secure your airline operations.
- AvioIntegrations: Dedicated group of highly experienced software developers focusing entirely on the agile systems integration of your back-end systems with the AvioSuite.
- AvioData: AvioData provides efficient, reliable and qualitative data deliveries to your avionics and your AvioBook. AvioData also provides a business intelligence solution turning Airline operational data into enhanced and synthetic views leading to better operational awareness and optimisation.

Within the Defense and Security division of Thales there are a number of discrete mission and sensor related capabilities that are largely found on fighters, air transport and rotorcraft platforms.

These include the following capabilities:

- Electronic warfare systems
- Fire-control radars
- Mission computers
- Optronics

Specific examples of these capabilities are noted as follows:

Rafale scanned array EASA radar: The AESA RBE2 is the very high performance radar designed for the omni-role Rafale fighter. It has been designed in close collaboration with Dassault Aviation and DGA -French defense procurement agency- to meet expectations of Air Forces by combining advanced fire control radar detection and target tracking needs thanks to innovative technologies.

ECM: Protection of the Rafale is entrusted to the SPECTRA (Self-Protection Equipment to Counter Threats for Rafale Aircraft), a multi-spectral integrated defensive aids suite that has been developed by Thales in partnership with MBDA. SPECTRA works across the electromagnetic, laser and infrared domains, employing smart data fusion from multi-spectral sensors to provide identification, location, jamming and decoying against a wide range of threats.

Rotorcraft protection: Capitalising on this unrivalled experience in Radar Warning Receivers, Thales has developed the CATS family which provides a cost-effective solution for equipment of a wide range of helicopters. These include the following capabilities:

- hostile environment situation awareness
- helicopter self-protection and awareness both combined in a single equipment.

CORAC 2016: Thales is working on the Extended Modular Avionics (EMA) concept alongside Airbus, Airbus Helicopters, Dassault Aviation, Sagem and about 30 other partners who are all supporting research into onboard computer platforms as part of a project led CORAC. This R&D project aims to prepare the groundwork for second-generation IMA and covers all aspects of onboard electronics, including flight control and aircraft functions, operator services and passenger services. It is expected to deliver tangible results for commercial airliners, business jets and helicopters in service in 2020-2030.

Customers and contracts

For its range of commercial avionics and military mission product offerings the following programmes are supported:

In the civil transport:

- Airbus A320 family, A380, A350
- ATR42/72-600
- Boeing 787
- Bombardier Global Express, Global 5000, 6000, CRJ700/900/1000
- Dassault Falcon 6X
- Gulfstream G500, G600, G650

In the military domain:

- Airbus A400M
- Dassault Mirage 2000, Rafale
- Embraer C-390
- Eurofighter Typhoon

In the helicopter sector:

- Airbus Helicopter Tigre, H Force
- Boeing Chinook
- Leonardo A109, Wildcat
- NH Industries NH90
- Sikorsky Blackhawk, S76D

Thales began developing inertial navigation systems over 30 years ago, and numerous platforms rely on them today, from the Mirage 2000 and MiG-29 fighters to the C-130 military transport, Tiger helicopter and Ariane 5 rocket. More recently, these systems have also been selected for the Airbus A350, ATR 72-600 and Embraer KC-390.

Strategy

Thales's strategy has been to create a small structure capable of exploring and disseminating to the rest of the group what works: the Digital Factory. The Thales Digital Factory responds to a fundamental trend: to offer a superior service by relying on more connected, smarter, more collaborative technological systems, capable of partial autonomy. For Thales, the goal is nothing less than to become an essential digital platform within the global ecosystem of large civilian or military infrastructure projects where security is essential. And this does not matter what changes are taking place in geopolitical plate tectonics.

Recent developments

February 2024: Thales' motion (launched January 2024) for a preliminary injunction in aid of arbitration against L3 for its intended sale of its stake in ACSS to a private equity group was granted. Arguments relating to both public interest and balance of equities were upheld. The granting of the preliminary injunction preserves the status quo pending the outcome of the ICC arbitration process.

February 2024: Malaysia Airlines is embarking on a partnership with Thales which focuses on installing avionics equipment onboard 20 of its Airbus A330neo aircraft. The selected equipment includes Thales' signature avionics equipment - the Flight Management System (FMS) and ACSS' Traffic Collision Avoidance Systems (T3CAS). The Thales FMS includes powerful hardware and the latest certified Airbus Release 1A software. It has unmatched reactivity and unique features for flight crew, such as a secondary flight plan, realistic navigation trajectory computations, and FMS Landing System capabilities (FLS). To date, 7,000 aircraft are equipped with Thales' FMS. The avionics equipment will be installed and maintained from Thales' Aviation Global Services (AGS) centre in Singapore. The avionics expertise in Singapore dates back 50 years to 1973 when the facility started supporting the expansion of Airbus in Asia.

February 2024: Thales reinforces its Avionics industrial base in Singapore, through a Centre of Excellence that will work on industrialising new avionics products and Smart Factory transformation initiatives. The Group also strengthens its Digital Identity & Security (DIS) engineering footprint in Singapore, with the intent to establish a worldwide Cyber Security Hub and a CoE for Hardware and Embedded Software, and to create in Singapore the Transversal Centre of Excellence for Eco-Design & AI-assisted Technologies. With a strong focus on eco-design in development and manufacturing, these initiatives are undertaken in partnership with the Singapore Economic Development Board (EDB) and reinforce Thales' position as a leading and sustainable technology company in Asia.

February 2024: Thales is significantly expanding its investments as well as sourcing from India. A joint venture, Thales Reliance Defence Systems Ltd., in Nagpur is now the Group's global production centre for airport navigational aids, while Bharat Electronics Limited-Thales Systems in Bangalore manufactures high-tech products such as low-band receivers for the electronic warfare suite of Rafale jets. India is currently negotiating the purchase of 26 Rafale-M jets for the Navy. In addition, Thales will be establishing a Maintenance, Repair and Overhaul (MRO) facility in Delhi-National Capital Region for its Indian airline customers focused towards avionics.

January 2024: Thales took initial legal action against L3 through the International Chamber of Commerce to prevent L3 from selling its 70% stake in the Thales L3Harris joint venture Aviation Communication & Surveillance Systems, LLC (ACSS) to private equity buyer, Jordan Group. Thales contended that L3's sale of their stake violated the terms of the parties' LLC Agreement, would cause harm to Thales, and that the public interest favours a preliminary injunction stopping the sale in order to allow the arbitral tribunal to decide whether to award effective relief.

November 2023: Thales and StandardAero announced that the StableLight™ autopilot was granted a Supplemental Type Certificate (STC) from the US Federal Aviation Administration (FAA). This true 4-axis autopilot system is now available for retrofit on Airbus Helicopters AS350 and H125 platforms. This system significantly reduces pilot workload, improves mission capability and can help reduce risk in critical flight phases. Based on Thales' Compact Autopilot System, StableLight is a robust, feature-packed autopilot in a compact, lightweight package suited for light rotorcraft.

September 2023: Thales is studying the opening of an aircraft avionics MRO facility in India, hoping to capture market share in the rapidly growing market while maintaining its "hub and satellite" strategy in Asia. The French manufacturer

is also looking to expand its partnerships in China to reinforce its intellectual property position and prevent unauthorized companies from servicing its parts.

February 2023: Thales signed an agreement with AURA AERO, a pioneer in decarbonated aviation in order to jointly develop a new generation connected avionics solution, adapted to electric and hybrid regional aviation. Thales is committed to the development of tactical and connected avionics solutions which will revolutionize the flight experience by giving the pilot quicker and more intuitive access to information, for easier decision-making.

May 2022: Thales has been selected by Airbus to equip its commercial airliners with the most powerful and innovative flight management system on the market. The new flight management system, which is based on the PureFlyt product and has been adapted to meet the specific requirements of Airbus, will process and share vast amounts of data to optimise flight operations, enhance interoperability and reduce environmental impact. The new flight management system (FMS), which is based on the PureFlyt product and has been adapted to meet the specific needs of Airbus, will be developed by Thales to equip Airbus commercial airliners, and in particular the A320, A330 and A350, with service entry planned for the end of 2026. The new system will improve interoperability for airlines and pilots and optimise flight paths to help reduce the carbon footprint of airline operations.

April 2022: Thales and Eve UAM, LLC, an Embraer company have teamed up to support the development of Eve's electric vertical take-off and landing aircraft (eVTOL) in Brazil. The strategic partnership involves a series of joint studies over a twelve-month period, which started in January 2022, on the technical, economical and adaptable feasibility of a 100% electrically powered aircraft. Thales will also contribute with its expertise in developing avionics, electric, flight control, navigation, communication, and connectivity systems.

Counterpoint comment

We believe that Thales claim to be number 3 in avionics is probably accurate. They do not yet have the global infrastructure to match Collins or Honeywell, however, they do have capabilities that are complementary to avionics with IFE, ATM and connectivity.

19.2.13.1 COBHAM AEROSPACE COMMUNICATIONS

The origins of Cobham Aerospace Communications began in 1923 with the founding of NEC Aero (reacquired in 2004), which focused on general use lighting, before specialising in aerospace in 1960. Further acquisitions occurred during the 1989-2001 period, during which the Cobham identity was adopted.

In 2020 Advent International became owners of Cobham, and since then a series of divestitures have occurred. The air-to-air refuelling systems provider Cobham Mission Systems (CMS) was sold to Eaton in 2021 for USD $2.83 billion. The Space Systems Division of Cobham Advanced Electronic Solutions (CAES) was sold to US private equity firm Veritas Capital and renamed as Frontgrade Technologies.

Three years later, in 2023, it was announced that Cobham Aerospace Communications was to be acquired by the French conglomerate Thales. Since the acquisition, it is now known as Thales Aerospace Communications.

The company offers products in the following areas:

- Audio Radio management
- SATCOM
- Antennas
- Internal and external lighting
- Aircraft clocks
- Human-Machine Interfaces (HMI)

Financials

Cobham Aerospace Communications's 2023 revenue was £204m. Counterpoint estimates that $225m was related to Avionics covered in the scope of this report.

Locations

Cobham Communications and Connectivity has its airborne products located within its facility in Fullerton, CA, USA. It also has a regional support office in Dourdan, France.

Capabilities

Cobham Aerospace Communications:

- Has more than 60 years of experience in design, development and manufacturing of aircraft avionics systems including radio and audio control and management, technical standard ordered radio, tactical radio, and airborne server and router solutions.
- Provides Audio Management (DACS, AMS), Radio Management (RCU, RMP), Audio & Radio Management (RMS, ARCDU, RAIMS), Aircraft Passenger and Cargo Address System (PCAS) and a wide range of additional equipment, allowing enhanced audio services with warning generator, Satcom dialler, SELCAL, etc.
- Radio and Audio Integration Management System (RAIMS) has been designed for Long Range (LR) and Wide Body (WB) aircraft. It consists of two to three Radio Management Panels (RMP) associated with two Audio Management Units (AMU4032) integrating SELCAL and cockpit amplifier functions. This controller provides functionalities: radio communication management, audio management, Satcom dialling, and radio navigation frequency management.
- Has recently developed a Radio Management System (RMS) based on a mature MMI display. It consists of a colour display, left/right buttons for radio selections, bottom buttons for quick access menu, upper buttons for navigation menu and setup, toggle switch for emergency function, an upper-right knob for bright display adjustment and an inner/outer knob for frequency selections. It is compatible with most of radios using ARINC429, RS422, RS485 and MIL-STD-1553 interfaces.
- Offer Satcom services by enabling the 'office in the sky'. Passengers stay connected using social media, email, fax and voice calling whilst logistical, navigation and safety functionality supports cockpit communications and safe and efficient operations for aircraft and fleet operators. The AVIATOR portfolio of Swift Broadband and Classic H+ systems provides voice and data connectivity for both cockpit and cabin communications, ensuring that passengers, crew and operators experience fast and reliable connectivity at all times.
- Has a wide portfolio of antennas on offer for Airborne applications: Multiple antennas are supplied by Cobham Antennas for civil and military aircraft to meet VHF, UHF, L-band, Ku-band and Ka-band applications. Also included are combination antennas that combine GPS or GPS WAAS and XM into a single radome.

Customer and contracts

Key contracts are noted as follows:

- Radio and Radio Management on the T-6 and T-38 trainer programmes
- Communication/avionics on the NH-90 platform
- GA-7001 SATCOM high gain antenna sub-system has been selected by Emirates Airline for its Boeing 777 upgrade programme.
- China's Shenzhen Airlines is also using Cobham SB-S and Inmarsat's digital airline operations platform with
- Cobham's Light Cockpit Satcom (LCS) has been selected by Airbus as a line fit solution on its A320 and A330 families.
- Cobham's Nextgen terminal, AVIATOR S, becomes available as a line fit option on major OEM platforms including Boeing's 737MAX and 777X; and Airbus' A320, A330 and A350.
- Aviator 200S Satcom system approved and certified for the Boeing 777X and the Boeing 737MAX
- Radio Management System fitted to Airbus H145M military rotorcraft.
- Cobham to provide Future Air Navigation (FANS) 1/A compliant AVIATOR 700D systems for integration in the C-130J Super Hercules fleets as part of the Block 8.1 upgrade programme.

- Provides low-band transmitters (LBT) for the AN/ALQ-99 jammers on the EA-18G aircraft.
- Cobham has a contract to supply Electronic Warfare (EW) training pods for NATO, worth over £50 million, as part of the NATO Joint Electronic Warfare Core Staff (JEWCS) capability package.

Strategy

It is not clear at this time the extent to which Cobham's parent, Thales, will continue to dramatically re-shape the Cobham portfolio.

Recent developments

June 2024: SkyFive IFC China, SkyFive AG and Thales unveiled a new Air-to-Ground antenna, which is designed for the specific system requirements of China. China has set out on an ambitious mission to connect their national skies with a high-performance Air-to-Ground (ATG) system. Given the high demand for extending broadband to the sky, ample radio spectrum was commissioned for ATG. SkyFive IFC China, SkyFive AG and Thales have teamed up to address this opportunity and designed an innovative passive aircraft antenna that caters to the specific ATGsystem requirements of the Chinese market. The first prototype of this antenna is now ready and qualified to be used for flight test campaigns.

May 2024: Thales Aerospace Communications and Collins Aerospace announced the first installation of Thales's AVIATOR 700S Inmarsat SwiftBroadband satellite communications system. Thales will provide the TSO'd A700S system to Collins Aerospace as part of a Collins' program to deliver communication and navigation systems for commercial aircraft.

March 2024: Cobham Aerospace Communications and Amelia (by Regourd Aviation) announce their collaboration on STC development for Cobham's latest SATCOM system (Aviator 700S) on Airbus A319 program. The certification is performed by S4A.

March 2024: Cobham Aerospace Communications has been selected by Dassault Aviation for the audio/radio communication system of French Navy's next generation Surveillance and Maritime Intervention (the acronym of which is AVSIMAR in French language) aircraft. This aircraft is based on a Dassault Aviation Falcon 2000 business jet plate-form, that is missionized with specific sensors and systems. One of the most relevant of these specific mission systems is the audio/radio management system combined with radio control. Cobham Aerospace Communications will supply this audio/radio management system, that manages the crew communications, both internal and external to the aircraft. This system features full compliance with French military requirements, together with significant weight savings and enhanced reliability compared with traditional technologies.

March 2024: Cobham Aerospace Communications and West Air have confirmed the delivery of the LCS system on West Air A320NEO. Cobham Aerospace Communications' AVIATOR 200S system represents a disruptive evolution in aircraft cockpit communications. Compared to previous legacy systems, AVIATOR 200S offers two separate aircraft communication network domains, up to 80 times the data transfer capacity and approved secure IP based ACARS/SATVOICE safety services with VPN/IPsec.

February 2024: Lockheed Martin Corporation and Cobham Aerospace Communications are continuing a long-standing partnership through a recent contract extension that includes Cobham's AVIATOR 700D safety Satcom system for the C-130J. Engineered for use in military, government, air transport, business, and VIP platforms, AVIATOR D provides critical safety, navigational, and performance data directly to the C-130J cockpit, expanding connectivity and reducing pilot workload for increased efficiency and overall operational safety.

February 2024: EasyJet became the first airline partner to use the Iris next generation air traffic communication service, powered by the Cobham Aerospace Communications Aviator S satcom system.

October 2023: Cobham Aerospace Communications and L2 Aviation have entered into an agreement for L2 to develop and deliver a Federal Aviation Administration (FAA) Supplemental Type Certificate (STC) package for Cobham's AVIATOR 200S SwiftBroadband Satcom System. This AVIATOR 200S configuration will ultimately be installed on end-user Boeing 777 aircraft.

June 2023: Cobham Aerospace Communications was selected by Airbus Helicopters to develop a new generation of dual-mode visible and infrared search and landing lights for the H160M GUEPARD developed in the frame of the light

multirole helicopter program led by the French Armament General Directorate. The system is based on a new innovative generation of headlights integrating a three-axis kinematics. Combined with a new generation of on-board computers and communication with the avionics systems, our solution allows an illumination without ground limitation and a wide range of operational possibilities.

May 2023: Embraer has selected Cobham Aerospace Communications for the next generation audio communication system of the multirole military transport C-390. Cobham Aerospace Communications will supply the system that manages the communications of the flight deck, both internal to the aircraft (with the crew) and external to the aircraft (through existing radios).

March 2023: Cobham Aerospace Communications has been selected by Airbus Helicopters for a critical mission system of the HIL program (French Armed Forces' multirole light joint helicopter, based on the H-160 platform), led by the French Armament General Directorate: the integrated audio/ radio management system. This system is an integrated audio management system that is fully compliant with the latest Avionics, Airbus and NATO Norms standards and that provides advanced functions for the communications of the pilots and the crew (SDIP-27, DO-160, SPX, DO178C). The system is based on innovative and new generation of audio computers and Audio Control panels allowing secure and protected communications combined with Cybersecurity requirements.

January 2023: As part of an ongoing series of avionics upgrades to the USAF fleet of Boeing C-17 transport aircraft, Boeing has selected Cobham Aerospace Communications' AVIATOR 700D Satcom System to provide global Inmarsat Aero H+ and SwiftBroadband services. The program, for +300 aircraft, is expected to be completed in 2025.

November 2021: Cobham Aerospace Communications and Boeing have teamed to install Cobham's NextGen/IRIS-capable AVIATOR S SATCOM system on a 737-9 operated by Alaska Airlines. The system is part of Boeing's ongoing, multi-aircraft ecoDemonstrator Program, which seeks to leverage a variety of emerging technologies to boost aircraft performance, maximize flight efficiency, and improve the passenger experience.

December 2020: Cobham Aerospace Communications won the Silver performance Excellence award for its constant high-level performance during 2019. This award recognizes Cobham Aerospace Communications outstanding performances in On Time Delivery, Product Quality & Performance of its SELCAL product, as well as Support to aircraft operators.

Counterpoint comment

We predicted that Advent might dispose more assets since acquiring Cobham. We think the 2024 acquisition by Thales will strengthen Thaless avionics portfolio, addressing the major trend towards connected cockpits. Cobham's avionics business is highly US-centric which is where the defence budget is greatest.

19.3 AVIONICS SUPPLIER PROFILES --- REST OF THE WORLD

19.3.1 AEL SISTEMAS (ELBIT)

AEL is a jointly held Brazilian company with 75% owned by Elbit Israel and 25% by Embraer's defence division.

It is located in Porto Alegre and is dedicated to the design, development, manufacture, maintenance and logistical support of military and space electronic systems, for applications in aerial, sea and land platforms.

Operating within defense technology since 2001, AEL participates in strategic projects of the Brazilian Armed Forces such as Gripen NG, KC-390, Guarani and SISFRON - Integrated Border Monitoring System.

Financials

We estimate that AEL generated $17m of revenues in 2023 based upon its core avionics offering of mission computers, navigation and terrain avoidance products.

Locations

AEL has its main facilities in Porto Alegre located in the south of Brazil. it employed 230 personnel at the facility.

Capabilities

AEL has developed the following:

- Terrain Following / Terrain Avoidance system: a system that provides guidance symbologies for low-flying safely and improving situational awareness, even in low-visibility conditions. The solution is based on data fusion from radar mapping and a terrain and obstacle database, and considers aircraft performance and other operational factors to reduce the risks associated in low altitude missions.
- Helmet Mounted Display (HMD): The product presents navigational, guidance and aiming information on the helmet lens, increasing the pilot situational awareness.
- Advanced Night Vision System/ Head Up Display (ANVIS/HUD™): The system can be installed in any type of helicopter, with or without bus, and can communicate with other systems of the aircraft. Eliminating the need to constantly divide your attention between the panel and the external environment, using ANVIS/HUD reduces pilot fatigue and ensures better mission performance.
- Inertial Navigation System that will allow Brazilian independence in inertial navigation systems. EGI (Embedded GPS / INS) provides a navigation solution for aircraft according to the SNU-84 standard, including position, speed, acceleration and attitude, among other parameters.
- Wide array display (WAD) for the Saab Gripen platform. This prototype unit was first delivered in 2017 and is still under evaluation we believe.
- Weapon Systems: The weapon system for rotary wing aircraft has been developed for use in various operating environments. The system converts different helicopters into armed platforms, with minimal weight gain. This set allows current helicopters to broaden their purposes and operational missions, including attack, air support for ground forces, search and rescue missions in combat, and intelligence missions.
- Mission Computing: The X-86 is an embedded computer module, standard VPX, applied as a mission computer of the aircraft KC-390. With hardware, software and mechanic projects developed by AEL Sistemas.

Customer and contracts

AEL Sistemas is the main provider of the avionics suite of the A-29 Super Tucano, F-5M, A-1M and C / P-95M Bandeirante aircraft for the FAB and AF-1 for the Brazilian Navy. AEL also supplies electronic equipment for the T-27 Tucano training aircraft and the Brazilian Air Force (FAB) AMX subsonic fighter. The company currently provides advanced mission electronic systems for the KC-390 and Gripen NG programs.

AEL participates in the modernisation program of the C-95, P-95 and SC-95, aircraft widely used for cargo transportation, passengers, patrol and aerial surveillance. Using state-of-the-art technology, AEL developed, integrated, certified and installed the avionics display system.

Strategy

AEL appears to be a funded centre for the development of avionics technologies necessary to support indigenous Brazilian programmes.

Recent developments

January 2024; The Brazilian Army is receiving the first prototypes of RDS radios from the company AEL Sistemas.Software-Defined Radio (RDS Defesa) Project, a solution that is part of the strategic programs of the Ministry of Defense. The multiband radio equipment capable of executing various waveforms, promoting interoperability among the Armed Forces, was entirely designed and manufactured by AEL Sistemas, in accordance with the Joint Operational Requirements of the three Forces. The delivery of the units marks the consolidation of the 100% nationally produced RDS as a Strategic Defense Product (PED) and establishes a significant milestone in the technological development of the Brazilian Defense Industrial Base, with AEL Sistemas as the main partner in the development.

January 2022; AEL Sistemas was awarded a contract to supply additional Hermes™ 900 UAS (Unmanned Aerial Systems) to the Brazilian Air Force (Força Aérea Brasileira "FAB"). The contract is in an amount that is not material to Elbit

Systems and will be performed over a period of 16 months. Under the contract, the Company will supply its Hermes 900 UAS and spare parts.

January 2022; AEL Sistemas and the Brazilian Air Force (FAB) have flight-tested the E-LynX™ Airborne Software Defined Radio (SDR) onboard two F-5M aircraft. The tests were part of the Brazilian Link-BR2 strategic programme, which seeks to offer nationally secured datalink capabilities to allow digital connectivity among all aerial platforms and establish multi-domain interoperability. AEL Sistemas is the prime contractor of the Link-BR2 programme, which covers the integration of the system's capabilities onboard all FAB aircraft. In the programme's next phase, the technology will be integrated onboard Saab's Gripen NG aircraft.

December 2021; The Brazilian Air Force (FAB) announced the partnership with AEL Sistemas for the acquisition of two Remotely Piloted Aircraft (ARP) RQ-900. The contract aims to expand the fleet of RQ-900 aircraft, increasing the operational capacity of the Air Force, mainly in the task of intelligence, surveillance and reconnaissance, where it already operates, including, in a joint manner with other Forces and government institutions.

Counterpoint comment

We are not aware of any export sales to date and AEL is reliant upon indigenous military programmes. It is therefore a niche provider of avionics technologies dependent upon Brazilian military budgets.

19.3.2 AVIAGE SYSTEMS

Aviage Systems is a 50/50 joint venture between General Electric Company (GE) and Aviation Industry Corporation of China (AVIC) founded in 2012.

It was partly set up to allow access to the Comac 919 platform via a JV arrangement with Avic and GE agreeing to co-develop avionic solutions within their purpose built Shanghai facility.

Financials

We estimate that the JV, based largely upon supply to the current C919 programme, generated $25m of revenues in 2019, with similar sales in 2023.

Locations

Aviage has its headquarters in Zizhu Hi-Tech Park, Shanghai, China with a 36,000mš office to support the growing engineering and manufacturing needs, including world-class R&D, Integration & test lab facilities.

It also has sales and engineering support centres in Phoenix, USA and Toulouse, France.

Capabilities

Aviage was set up between GE Aviation and AVIC initially to support the Comac C919 programme with contracts to develop 5 main sub-systems including the IMA computing platforms, utility systems integration, FMS, display suite, flight recorder system, remote data concentrators, aircraft data network and in-flight connectivity (ICP).

In addition, Aviage offers the following capabilities to OEMs and Airlines:

- The Aviage High Integrity Computing Platform (HICP) solution provides a scalable open architecture platform that translates to reduced operational cost through simplified maintainability and service ability, and fuel consumption savings which come from low system power requirements and lower total system installation weight.
- Data concentration solutions provide configurable, flexible remote interfacing products for distributed Input/Output (I/O) and sensor management to actuation control.

Aviages Digital Solutions (DS) subsidiary business includes the following capabilities:

- Digital Information System (DIS) provides innovative solutions to improve airline on board operation environment. By offering reliable connectivity and hosting on-board applications, DIS helps to elevate airline operation efficiency.

- Data Analytics Solution offers local platform architecture design and consulting service. It provides analytics on airline operation and system performance based on advanced machine learning and AI technology.
- Cybersecurity offers security lab setup, testing for avionics products, network filtering, access control and web application firewall.
- Avionics and flight control solution for AAM

Aviage also operates a CCAR-145 maintenance organisation certificate issued by CAAC, which has the capability of testing, repairing, modifying and overhauling the accessories of the airborne products. This facility is co-located alongside the main operations in Shanghai.

Customer and contracts

Aviage's main customer contract is with Comac for the C919 aircraft for the products outlined above.

The Comac C919 flew in 2017 and is now in low rate production.

Aviage is well positioned to support this aircraft, which has over 1,000 firm orders from Chinese airlines, and it will undoubtedly be part of any future wide body or NextGen developments within China. The C919 has yet to achieve certification outside of China but there are close ties within Asian and African markets.

Aviage since 2020 has been supporting Chinese airlines, such as 787 operators, with MRO support.

Strategy

Aviage is building capability within avionics as noted by the move to expand into AAM and MRO services contained in "recent developments" below.

Recent developments

March 2024: AVIAGE SYSTEMS, the core avionics supplier for the C919 aircraft, proudly announced its receipt of the Supplier of the Year - Win-Win Cooperation Award at the COMAC 2024 Global Suppliers Conference. This marks the ninth consecutive year that AVIAGE SYSTEMS has been recognized for its exceptional contributions to the aviation industry.

February 2024; At the Singapore Airshow, AVIAGE SYSTEMS and SICHUAN AEROFUGIA TECHNOLOGY DEVELOPMENT CO., LTD. signed a MoU on Strategic Partnership on AAM Avionics System Development. The two parties will fully leverage their respective strength to collaborate in the areas of Avionics Suite joint design, integration, airworthiness certification, and other fields related to AEROFUGIA AE200 eVTOL (electric vertical take-off and landing aircraft) project. They will work together to accelerate the development and commercialization of AE200, and promote the development of China's low-altitude economy.

November 2023; AVIAGE SYSTEMS receives approval from CAAC for its maintenance capabilities of the C919 GPM (General Processing Module) . This means that AVIAGE SYSTEMS has officially launched its maintenance services for the C919 avionics equipment.

March 2023; COMAC 2023 Global Supplier Conference was held in Shanghai. As the core avionics supplier of C919, AVIAGE SYSTEMS was invited to participate in the conference, and won 'Team of Excellence for Type Certification of C919'.

March 2023; AVIAGE SYSTEMS and Boundary.AI signed the MoU on Joint development of AAM Avionics Suite and Flight Control System Solutions in Shenzhen. Two Companies intend to jointly develop airworthy, high-safety, cost-effective Avionics Suite and Flight Control System solutions for the AAM market, empower eVTOL OEMs realize commercial applications.

October 2022; COMAC 2022 Global Supplier Conference was held in Wuxi, Jiangsu. AVIAGE SYSTEMS won 2021 Customer Service Excellence Award.

Counterpoint comment

We see China as patient and collectively it will take the time necessary to achieve its five year plan of developing the necessary indigenous capabilities. Aviage should benefit in the long-term from its position in China.

Meanwhile Aviage will build its avionic knowledge rapidly via its repair and MRO business.

19.3.3 BHARAT ELECTRONICS

Founded in 1954 Bharat Electronics Limited (BEL) is an Indian state-owned aerospace and defence company with a number of factories and regional offices in India. It is owned by the Indian Government and primarily manufactures advanced electronic products for the Indian Armed Forces.

BEL today has nine major facilities in India covering a wide range of defense and non-defense sub-sectors including electronic warfare, communications and avionics.

BEL primarily services the Indian Defense Forces with a range of products that includes Electronic Warfare, Communications, Avionics, Electro-Optics and Radars.

Financials

BEL reported that it exported $92.98m worth of product in FY2024(March 2023-2024) the majority of which was defense related. The major products/systems exported include Radar Warning Receiver, Missile Approach Warning System, T R Modules, Data Link II, Coastal Radar Systems, Mechanical Parts, Communication Equipment, EO System, Smart Mail Box, Services, etc.

We estimate that BEL generated $19m in revenues for defense related avionics and sensors in 2023.

Locations

BEL has two main facilities supporting its Electronic Warfare design and manufacture and these are located in Bangalore and Hyderabad.

Capabilities

Electronic Surveillance Module: The lightweight ESM system is meant for fitment on small helicopters. This ESM system provides reconnaissance of ground based, airborne, ship-borne and subsurface Radars. The system intercepts, detects, identifies and displays various parameters of the intercepted radar signals. It provides threat warning from a large built-in radar library and accord threat prioritisation. BEL also has an ESM solution for large Air Transport aircraft.

Radar Warning Receiver (RWR): Designed for fitment on fighter aircraft and helicopters. It intercepts, detects and identifies all types of ground and airborne emitters (Pulse, CW, ICW, Pulse Doppler, Pulse agile, Frequency agile) and presents them on the Cockpit Display Unit with the help of alphanumeric/special colour symbols and audio tones.

Electronic Warfare suite: BEL does not describe this capability for fighter aircraft in detail but it does list the following key parameters:

- Unified [Warning & Jamming]
- Radar Warning: 1 - 18 GHz; Digital Receiver based
- Wide Band Receiver with 100% by HPOI Receiver
- Selectable Narrow Band Receiver options
- Dynamic Range:65 dB
- DOA Accuracy: Coarse & Fine DF modes
- Jamming: 6-18 GHz, DFRM based jamming
- Active Phased Array (APA) steering with narrow beams for accurate/pin point threat jamming
- APA based with Solid State TR Modules

- Various mutually exclusive ECM technique generations & Multiple Threat handling.

Displays: The Multifunction keyboard display (used on the Light Combat Aircraft) is a combined control and display unit comprising alphanumeric keyboard and an LCD dot matrix display. It is used for data entry and management of the various aircraft systems. MFK also performs the Data loading, Selection and Display of relevant page information.

Electro-optic devices: The EOIR payload is a day and night surveillance system that includes a Daylight colour Camera, 3rd generation 3-5 ţm thermal imager, Eye-Safe Laser Rangefinder (ELRF) , Automatic video tracker, Grip and display, Video data recorder as well as command and control capabilities. It is distinguished by a wide variety of interfaces, enabling integration with various systems, such as Computer and GPS.

BEL offers a range of small discrete displays that are utilised on e.g. Light Combat Aircraft.

Ground Control Station and Datalink fot UAVs

Customer and contracts

We believe that much of the $92.98m of export sales noted under “financial” is related to land and coastal defense products.

BEL, within its annual report notes its strategic partnership with Global players like LIG NEX1 (Korea), Lockheed Martin (USA), Elbit (Israel) in the international segment.

Strategy

It appears that BEL is engaged in R&D work associated with Electronic Systems, however, it has not exported these for airborne applications nor been that successful in supporting India’s indigenous airborne platforms.

Recent developments

July 2023; BEL and CoRover Private Limited, a human-centric conversational and generative AI company, have signed a two-year, non-exclusive MoU to collaborate as partners and indigenously develop and deploy emerging technologies and technical solutions to address the requirements of AI-based solutions, especially Conversational AI-based virtual assistants.

March 2023; BEL has received Export orders worth 52 Million USD (approx.) in the month of March 2023. This includes Communication equipment, Electronic Assemblies, Micro Modules and Mechanical parts for various customers from France, Israel, USA, etc. This is reflective of the growing business interest and confidence among international customers on BEL and other Indian industries, which comes with the encouragement of the Indian Government and its policies aimed at an Aatmanirbhar Bharat.

March 2023; The Ministry of Defence (MoD), Government of India, has signed 10 contracts worth Rs.5,498 Crores with BEL. Amongst, avionics related contracts are: Air Force Projects: a) EW Suite Equipment for Medium Lift Helicopter (90 Nos.) has been signed with BEL-Bangalore. It is indigenously designed and developed by the DRDO lab, Combat Aircraft Systems Development & Integration Centre (CASDIC). It comprises Radar Warning Receiver (RWR), Missile Approach Warning System (MAWS) and Counter Measure Dispensing System (CMDS). b) AMC for Akash Missile System has been signed for maintenance of two Squadrons with BEL-Bangalore. The Akash Missile System (AMS) is a medium-range, surface-to-air missile (SAM) system, developed by DRDO and manufactured by BEL. AMS includes Surveillance Radar, Fire Control Radar, Control and Command Centre developed by BEL. ARMY PROJECTS: a) Automated Air Defence Control & Reporting System (Project Akashteer) has been signed with BEL-Ghaziabad. b) Instant Fire Detection and Suppressing System (IFDSS) for T 72 has been signed with BEL-Kotdwara. IFDSS is indigenously designed by DRDO and will be manufactured by BEL-Kotdwara. NAVY PROJECTS: Sarang (12 Nos.) will be installed on Kamov 31 Helicopters of the Indian Navy which intercepts, detects and identifies the Radar emitters comprising state-of-the-art technologies. The project is indigenously designed and developed by DLRL and manufactured by BEL-Hyderabad. d) Three more projects were signed with Indian Navy - INS-SA, CMS for P17 & P28 and Varuna EW system. All these are flagship projects showcasing the indigenous design and manufacturing capabilities of Indian Defence industry led by BEL, involving other Public Sectors, Private Sectors and MSMEs. These projects will add another milestone to the ‘Atmanirbhar Bharat Abhiyaan’ and ‘Make in India’ initiative of the Government of India.

February 2023; BEL has opened its new Software Development Centre (SDC) in Visakhapatnam to offer "Software as a Service" for various applications in the domains of both Defence and non-Defence. The Software division of BEL has successfully implemented many projects of national importance in the fields of Defence, Aerospace, e-Governance, Homeland Security, etc, over the last many decades.

Februay 2023; BEL has signed an MoU with Aeronautical Development Agency (ADA), DRDO, for the Advanced Medium Combat Aircraft (AMCA) programme. The Advanced Medium Combat Aircraft is a 5 th Generation, multi-role, all-weather fighter aircraft designed with high survivability and stealth capability. The MoU aims at leveraging the complementary strengths and capabilities of BEL and ADA, wherein both the parties will co-operate for the design, development, qualification, production and supply of Internal Weapon Bay Computer and other LRUs for AMCA and provide lifetime product support to the Indian Air Force.

November 2022; BEL has signed a Licensing Agreement for Transfer of Technology (LATOT) with Combat Aircraft Systems Development and Integration Centre (CASDIC), DRDO, for transfer of technology of Digital Radar Warning Receiver. This is a state-of-the-art, airborne Electronic Warfare system which would provide versatile Situational Awareness to a fighter platform in a dense signal scenario, offering excellent sensitivity, good parameter measurement accuracy and high Probability of Intercept against dense signal. The LATOT will enable BEL to manufacture and supply Digital Radar Warning Receivers to the Indian Armed Forces. Through this, CASDIC will transfer complete details of the technical know-how, testing and maintenance method for quality assurance to BEL with requisite data on the functioning of the product.

July 2022; Early this year a new Flight Control System (FCS) integration facility was constructed at ADE. The facility will support the Research and Development (R&D) activities for developing Avionics and FCS for the AMCA. (Express file photo) Defence PSU Bharat Electronics Limited (BEL) will be working along with Aeronautical Development Establishment (ADE) and Aeronautical Development Agency (ADA) on the development of critical subsystems for the fifth generation Advanced Medium Combat Aircraft (AMCA) program.

June 2022; BEL signed an MoU with Defense Initiatives (DI), Belarus, and Defense Initiatives Aero Pvt Ltd, India (a subsidiary of DI Belarus), in the august presence of Joint Secretary (DIP) and senior Indian Air Force officials. The MoU is aimed at co-operation between the three companies for supply of Airborne Defense Suite (ADS) for the helicopters of the Indian Air Force (IAF). BEL will be the prime contractor and will be supported by DI with ToT (Manufacturing and Maintenance) for supply of advanced EW suite for helicopters under 'Make in India' category.

Counterpoint comment

BEL is largely a state run organisation covering a diverse range of market sectors and products. We do not see it becoming a major player in defense electronics other than for indigenous development work.

19.3.4 ELBIT SYSTEMS

Elbit Systems was founded in 1966 by Elron Electronic Industries which combined Elbit's existing expertise within the Israel Ministry of Defense-Research Institute.

Elbit Systems is an international defense electronics company including Elbit Systems and its subsidiaries. It operates in the areas of aerospace, land and naval systems, command, control, communications, computers, intelligence surveillance and reconnaissance (C4ISR), unmanned aircraft systems (UAS), advanced electro-optics, electro-optic space systems, electronic warfare suites, signal intelligence (SIGINT) systems, data links and communications systems and radios.

Elbit's military fixed-wing aircraft and helicopter systems and products include a broad range of avionic systems, such as integrated flight deck systems, mission management computers, displays, digital maps and digital recorders. The portfolio also includes airborne electro-optic systems such as head-up displays, airborne intelligence gathering systems, precision guidance systems, aircraft structural components, nanosatellites and a range of aircraft tactical, virtual, appended and embedded trainers and simulators.

In March 2018, Elbit Systems and Universal Avionics announced that Elbit "is in the process of completing the acquisition of the privately owned Universal Avionics Systems Corporation [UASC] through an asset acquisition agreement."

Universal Avionics Inc. is run as an entirely separate subsidiary of Elbit and it is therefore covered separately within this report.

Elbit Systems of America also has a 50% interest in a joint venture with Collins Aerospace, a unit of United Technologies Corp., which is engaged in the area of helmet mounted display systems for fixed-wing military and para-military aircraft.

Elbit design and supply integrated UAS platforms for a range of applications. These include a variety of UAS platforms, including the Hermes™ 900, 450 and 90 family and Skylark™ families of UAS. It provides the majority of avionic and sensor suites integrated within these platforms.

Financials

Elbit generated $5,975m revenues in 2023 across the group.

We estimate that the avionics and sensors related revenues accounted for $435m in 2023.

Locations

Elbit Systems of America, LLC (Elbit Systems of America) and its subsidiaries provide products and systems solutions focusing on U.S. military, homeland security, medical instrumentation and commercial aviation customers. They have operational facilities in Fort Worth, Texas; San Antonio, Texas; Merrimack, New Hampshire; Talladega, Alabama; Roanoke, Virginia; and Boca Raton, Florida.

The Roanoke, Virginia facility includes the activities of Elbit Systems of America - Night Vision, which was acquired by Elbit Systems of America in September 2019.

C4I and Cyber - Headquartered in Netanya, Israel, Elbit Systems C4I and Cyber Ltd. (C4I and Cyber) is engaged in the worldwide market for C4ISR systems, cyber intelligence solutions, homeland security solutions, data links and radio communication systems and equipment.

Elisra - Based in Holon, Israel, Elbit Systems EW and SIGINT — Elisra Ltd. (Elisra) provides a wide range of electronic warfare (EW) systems, signal intelligence (SIGINT) systems and C4ISR technological solutions for the worldwide market.

Elop - Based in Rehovot, Israel, Elbit Systems Electro-Optics Elop Ltd. (Elop) designs, engineers, manufactures and supports a wide range of electro-optic systems and products mainly for defense, space and homeland security applications for customers worldwide.

Capabilities

Elbit's portfolio of electro-optic systems and products includes forward looking infrared (FLIR) systems for night observation, laser range-finders and laser radars, stabilised payloads and electro-optic-based ISR systems. Elbit supplies direct infrared countermeasure (DIRCM) systems for the protection of aircraft to payloads for space, airborne, naval and land-based missions, to head up displays (HUD) and advanced target acquisition systems (TAS), as well as laser, thermal imaging (TI) systems, HLS solutions, ground integrated sights and I2 night vision systems for intelligence, surveillance and reconnaissance (ISR).

Elbit produces C4ISR capabilities for land, airborne and naval and cyber intelligence systems providing networked combat solutions. Elbit provides a wide range of advance communications and network solutions for land, navy and air force applications, supporting a full range of military video, data and voice network needs.

Military and helicopter systems: Elbit provide systems and products, including helmet mounted displays, mission computers, cockpit management systems, helmet mounted sights and smart munitions kits. The range has been broadened to include advanced laser designators, range finders, optronic payloads and airborne reconnaissance systems.

Helmet mounted systems: Elbit's Helmet Mounted Systems (HMS) enable pilots to view flight data, sensor and 3D location-based information within direct line-of-sight (LOS). The HMS allows the pilot to slave the aircraft's sensors to its avionics systems and missiles simply by looking at the target. Suitable for both day and night operation, the HMS can be supplied as part of upgrade programs or on a stand-alone basis.

Unmanned Aircraft Systems (UAS): Elbit's portfolio of UAS includes integrated UAS (sometimes referred to as remote piloted vehicles, or RPVs) in various categories and for a range of applications as well as UAS training systems. The systems include airborne platforms, ground control stations, communication systems and various payloads, including

stabilized electro-optic, electronic intelligence (ELINT) and communications intelligence (COMINT) payloads that can be adapted for various types of UAS.

Family of Starlite data communications are noted as follows:

- Starlite SR: An advanced, short-range digital data-link system, Starlite SR is designed for small manned and unmanned platforms. The lightweight system is suitable for mini-UAVs, loitering munitions, VTOL applications, handheld transceivers, and other small tactical platforms.
- Starlite MR: An advanced digital data-link solution for mid-range manned and unmanned aerial, naval and land platforms including medium UAVs, USVs, UGVs, loitering munitions and mission helicopters. The lightweight, compact system has an operational range of up to 150km. Starlite MR complies with leading international aviation regulations and standards.
- Starlite ER: An advanced, extended-range, line-of-sight digital wireless communication system for manned and unmanned aerial, naval and land platforms. Starlite ER is designed for long-range vehicles including MALE UAVs, USVs, mission helicopters and aircraft. The flexible, lightweight, and compact system has an operational range of up to 250km.

Customers and contracts

Elbit supports a number of significant platforms including F-16, F-18, F-15, F-35, V-22, T-7A, C-17, AH-64 and UH-60.

Specific contracts include:

- MRTT A330: Direct Infrared Counter Measures (DIRCM) and Infrared (IR) Missile Warning Systems.
- F-35: Elbit provides the laser designator to Raytheon for the Multi Spectral Targeting System (MSTS)
- F-35: Integrated Helmet display system in partnership with Collins Aerospace.
- KC-390: Electronic Warfare suite.
- F-16: Infra-red missile warning system.
- C-130/AC-130 Common Lightweight Digital Rangefinder (CLDR).
- F-18: Large Area Displays, JHMCS Helmet display.
- F-15: Large Area Displays.
- Gripen: electronic warfare suite
- Hermes UAS: Laser G MIST™ , WAPS SkEye, 20/MX15 Wescam marker/designator, Radar Maritime MPR and Radar GMTI / SAR: Radar, COMINT, ELINT.
- Skylark UAS: stabilised dual EO/IR payload

Strategy

Elbit states that its vision is “to be a world leading source of innovative, technology-based systems for diverse defense and civilian applications.”

Recent developments

November 2023; Elbit Systems Ltd. was awarded a contract by Airbus Defense and Space to supply the Direct Infrared Counter Measures (DIRCM) and Infrared (IR) Missile Warning Systems for installation on the MRTT A330 refueling aircraft for Canada. The contract will be performed over a period of five years.

September 2023; Elbit Systems will produce and provide the Artillery Corps of the Israeli Defense Forces (IDF) with the Skylark™ 1Transitional Vertical Take-Off and Landing Small Tactical Unmanned Aerial Systems (Skylark 1 eVTOL), combined with through-life maintenance services for all the IDF Ground Force’s STUAS systems (Skylark 1 & Skylark 3).

September 2023; Elbit Systems has unveiled its latest development in the world of unmanned aerial systems: The Find-and-Strike (FAST) Capsule, combining the Skylark III and SkyStriker Loitering Munition (LM).The Skylark III is a leading Small-Tactical Intelligence UAS, equipped with the most advanced intelligence gathering sensors and with extensive endurance of up to 18 hours, it is designed to support ISTAR missions in GPS denied environment. The Skylark III is capable of integrating a range of payloads including high-resolution Electro-Optical gimbaled payload, SIGINT sensors, laser designators and more.

September 2023; Elbit Systems delivered a self-protection suite to the Royal Netherlands Air Force's (RNLAF) Gulfstream G-650ER VIP Aircraft. The delivery was carried out within a year of signing and after comprehensive flight acceptance tests. The aircraft was equipped with an advanced protective suite that includes Elbit Systems' Direct Infra-Red Counter Measures (DIRCM) and Infra-Red-based Passive Airborne Warning System (IR MWS), a configuration with an EASA supplemental type certificate (STC).

July 2023; Elbit Systems announced that it was awarded a contract worth approximately $114 million with an Asian-Pacific country to supply two long-range patrol aircraft (LRPA) equipped with an advanced and comprehensive mission suite. The contract will be carried out over a period of five years. The two LRPA aircraft will be based on new ATR 72-600 and Elbit Systems will integrate in each aircraft a mission suite that includes a Mission Management System, Electro-Optics, Radar, SIGINT, Communication and more.

June 2023; Romanian Minister of Defense Angel Tilvar met with Elbit Systems President and CEO Bezhalel (Butzi) Machlis to sign a purchase order to supply the first three of maximum seven Watchkeeper X tactical Unmanned Aerial Systems (UAS) under the framework contract signed in December 2022. Under the purchase order, Elbit Systems will provide upgraded WatchKeeper X tactical UAS with advanced capabilities including the Spectro XR™ multi-spectral electro-optical payload, new communication capabilities and others.

June 2023; Elbit Systems is unveiling a new and unique Electronic Warfare (EW) capability at the Paris Airshow as part of its Unified EW suite. The new capability is provided via the digital Radar Warning Receivers (RWR), one part of Elbit's proven Airborne self-protection EW suite, and enables drone detection and identification as well as locating Personal Location Beacon (PLB) of ground forces and pilots.

June 2023; Elbit Systems is unveiling the Nano SPEAR™ at The Paris Airshow, an advanced, digital and miniature system designed as a countermeasure against radar-guided air-to-air and surface-to-air missiles that threaten aircrews and their platforms.The Nano SPEAR™ is part of the Self Protection Electronic Attack and Reconnaissance (SPEAR) product family, which includes the Micro SPEAR™ for very small installations; Light SPEAR™ for installation on medium-large sized helicopters and UAVs; and the Advanced SPEAR™ ECM Pod currently on contract for providing active self-protection for the C-390 transport aircraft. The SPEAR product family is based on advanced hardware, including Digital Receiver Exciters, that are modular and provide ease of scalability.

June 2023; Elbit Systems announced that it was awarded an additional contract by Airbus Helicopters for the Federal Office for Bundeswehr Equipment, Information Technology and In-Service Support, for the provision of Airborne Electronic Warfare (EW) self-protection systems for the CH53 GS/GE transport helicopters, as part of the platform upgrade program led by Airbus Helicopters. Under the contract, Elbit Systems, supported by Elbit Systems Deutschland, will provide digital Radar Warning Receivers (RWR), EW Controllers (EWC) and Counter Measure Dispensing Systems (CMDS).

April 2023; Elbit Systems announced that it was awarded a follow-on contract worth approximately $100 million to convert commercial aircraft into Intelligence and Electronic Warfare (EW) aircraft for an international customer. The contract will be performed over a period of three years. As part of the contract, Elbit Systems will equip the aircraft with advanced Intelligence Mission Suite and EW capabilities.

March 2023; Elbit Systems was awarded four contracts to supply the Romanian Ministry of National Defense with aircraft upgrades as well as electronic warfare suites, electro-optical infrared (EOIR) payloads and Brightnite™ systems for the IAR 300 helicopters. As part of one of the contracts, the Company will integrate Elbit Systems SPECTRO XR™ payload onto IAR 330 helicopters to enhance the Romanian Navy's operational capabilities. In a second contract, Elbit Systems will supply a comprehensive electronic warfare (EW) suite including Radar Warning Receiver (RWR), Laser Warning System (LWS), Infrared Missile Warning System (IR MWS) and Counter Measure Dispensing System (CMDS). The suites will be supplied to a domestic supplier for the installation and integration onboard six PUMA helicopters with an option for an additional six in the future. The contract is a follow on order to additional EW suites that are already installed other Romanian Armed Forces' platforms. It will be carried out over a period of three years.. The Company will also provide, as part of a third contract, Elbit Systems HDTS type head systems, SPECTRO XR electro-optical systems and an aircraft

mission package that includes smart displays, digital maps and reconnaissance systems. Elbit Systems will also supply Brightnite™ systems to IAR Brasov for the Romanian Air Force's Puma 330 SAR helicopters. This contract will be carried out over two years. Under a fourth contract, Elbit Systems will supply advanced avionic suites, live training embedded virtual avionics system, advanced monitors, overhead display, navigation system and weapons activiation systems to Avioane Craiova that is upgrading the Romanian Air Force's (RoAF) IAR99 advanced fighter trainer aircraft.

March 2023; Elbit Systems was awarded a contract to supply Electronic Warfare (EW) self-protection suites for a fighter aircraft that is being supplied to a NATO member country in Europe. As part of the contract, Elbit Systems will equip the aircraft with its EW self-protection suite, including Radar Warning Receivers (RWR) and Countermeasure Dispensing Systems (CMDS).

January 2023; Elbit Systems announced that it signed a contract in an amount of approximately $95 million with the Israeli Ministry of Defense (IMoD) to supply and maintain advanced electro-optical systems for the Israeli Defense Forces (IDF) infantry forces. The contract will be performed over a period of 10 years. As part of the contract, Elbit Systems will supply long-range deployable observation systems and tactical target acquisition systems. In addition, the contract includes maintenance services for the electro-optical systems produced by the Company.

November 2022; Elbit Systems announced that it was awarded a contract valued at approximately $200 million to supply Electronic Warfare and airborne laser technologies to protect military helicopters of a country in Asia-Pacific. The contract will be executed over a four-year period. Under the contract, Elbit Systems will supply self-protection suites comprised of the Infra-Red Passive Airborne Warning Systems (PAWS IR) and the Mini-MUSIC Direct Infra-Red Counter Measure (DIRCM) Systems.

September 2022; Elbit Systems announced that it was awarded a contract valued at $120 million to supply Hermes™ 900 Maritime Unmanned Aircraft Systems (UAS) and training capabilities to the Royal Thai Navy. The contract will be performed over a three-year period. Under the contract, Elbit Systems will provide the Rroyal Thai Navy with Hermes 900 Maritime UAS featuring maritime radar, Electro Optic payload, Satellite Communication, droppable inflated life rafts and other capabilities.

July 2022; Elbit Systems announced that its subsidiary, Universal Avionics Systems Corporation ("Universal Avionics") was awarded a contract valued at approximately $33 million from AerSale Corporation, to supply Enhanced Flight Vision Systems (EFVS) for Boeing 737NG aircraft. The contract will be executed through 2023.Under the contract, Universal Avionics will supply the ClearVision™ EFVS systems featuring the SkyLens™ 360-degree field of view Head Wearable Display and the EVS-5000 cameras.

July 2022; Elbit Systems was selected to supply a Direct Infrared Counter Measures ("DIRCM") system and an airborne Electronic Warfare ("EW") system for a Gulfstream G650 aircraft of The Netherlands Ministry of Defense. Elbit Systems will provide J-MUSIC™ DIRCM system together with the Company's Infra-Red-based Passive Airborne Warning System (IR-PAWS), for a Gulfstream G650 aircraft, providing high levels of protection and redundancy.

July 2022; Elbit Systems unveils an innovative technological vision suite for military helicopters (a fifth generation aircraft technology). The new suite integrates a sophisticated sensor array, an Artificial Intelligence (AI) powered mission computer and a unique Helmet Mounted Display (HMD) system. The new suite enables helicopter pilots to see through the body of the aircraft and provides them with a real-time, clear, colored wide field of view, during day and night, in challenging weather and visibility condition.

July 2022; Elbit Systems announced that it was awarded a $80 million contract to supply Direct Infrared Counter Measures ("DIRCM") and airborne Electronic Warfare ("EW") systems for a country in Asia-Pacific. The contract will be performed over a two-year period.Under the contract, Elbit Systems will provide C-MUSIC™ DIRCM systems together with the Company's Infra-Red-based Passive Airborne Warning Systems (IR-PAWS), for several aircraft types, providing high levels of protection and redundancy.

May 2022; Elbit Systems was selected by Airbus Defence and Space to provide J-MUSIC™ DIRCM (Direct Infrared Countermeasures) including the Company's Infra-Red-based Passive Airborne Warning Systems (PAWS IR), for Airbus A330-200 MRTT aircraft of additional European Air Force.

January 2022; Elbit Systems announced that its subsidiary in the United Arab Emirates , Elbit Systems Emirates Limited, was awarded an approximately $53 million contract to supply Direct Infrared Countermeasures ("DIRCM") and airborne Electronic Warfare ("EW") systems for the Airbus A330 Multi-Role Tanker Transport aircraft of the UAE Air Force. The contract will be performed over a five-year period.Under the contract, Elbit Systems Emirates will deliver a

multi-turret configuration of the J-MUSIC™ Self-Protection System together with the Company's Infra-Red-based Passive Airborne Warning System, providing high levels of protection and redundancy.

Counterpoint comment

Elbit has established itself in the US market via the acquisition of Universal Avionics and L3Harris's night vision business. It also has a strong presence in the UAV/UAS sector which reflects Israel's strong presence in this market sector.

It's strength in the civil market is reflected within the lower value GA, bizjet, rotorcraft sectors serviced by Universal Avionics.

In the past two years Elbit has won significant amount of new contracts both locally and internationally.

19.3.4.1 UNIVERSAL AVIONICS

In April 2018 Elbit Systems completed the acquisition of the assets and operations of the privately-owned U.S. Universal Avionics Systems Corporation for a purchase price of approximately $120 million. Universal Avionics is now a wholly owned subsidiary of Elbit Systems located in Israel.

Universal Avionics was founded in 1980 when Hubert L. Naimer, formulated the details of a "Master Navigation System", which led to the development of the world's first Flight Management System (FMS).

Today Universal Avionics is a leading manufacturer of innovative avionics systems offered as retrofit and forward-fit solutions for the largest diversification of aircraft types in the industry. Markets served include Business, Special Missions, Government / Military, Airline (regional / commercial), Helicopter and OEM.

Universal Avionics lists its primary products as including Enhanced Flight Vision Systems, Flight Management Systems (FMS), Primary Flight and Multi-Function Displays, Data Link / Communications Management Unit (CU) Systems, Cockpit Voice & Data Recorders.

Financials

In 2023 we estimate that Universal Avionics employed 450 personnel and generated $84m in revenues across its range of avionics products.

Locations

Universal Avionics' main facility is located in Tuscon Arizona and it has support facilities in Blagnac, France and Singapore.

Universal Avionics conducts all of its design, test and manufacture within its Tuscon facility.

Universal Avionics also has engineering facilities located both in Georgia and Washington.

Capabilities

FMS: The UNS-1Lw features a standard set of I/O capabilities for interface with essential components of the flight deck. The system is comprised of a 4- or 5-inch Flat Panel Control Display Unit (FPCDU) along with a remotely mounted Navigation Computer Unit (NCU). The NCU is contained in a 2-MCU LRU which includes an internal GPS/SBAS receiver.

Platform for NextGen and SESAR: Universal Avionics' SBAS-capable FMS features a precise, internal SBAS Global Positioning System (GPS) receiver that improves accuracy and integrity of GPS-derived position information. The Receiver Autonomous Integrity Monitor (RAIM) prediction requirements in US airspace are thereby removed and navigation capabilities for all classes of aircraft in all phases of flight are increased. The embedded SBAS GPS receiver provides ILS-like guidance down to near CAT I ILS minimums. In addition, the SBAS-FMS meets stringent internal monitoring requirements to provide guidance to any of the Minimum Descent Altitude (MDA) levels for Area Navigation (RNAV) (GPS) approach guidance.

Flight Decks: Universal Avionics specialises in flight deck upgrades, providing flexible options for over 50 aircraft types ranging from the Pilatus PC-12 to the Boeing 747. Customised from an SBAS-capable FMS upgrade to one, two, three

or a full suite of Advanced Flight Displays configured in Primary Flight Display (PFD), Navigation Display (ND) and Multi-Function Display (MFD) formats for the utmost in flexibility.

Integrated flight deck display suite: The InSight Display System is designed as an integrated flight deck solution, featuring embedded synthetic vision with advanced mapping capability, electronic charts, and radio control. As an integrated solution, InSight retains the ability to interface with a large number of federated components such as attitude/heading sensors, air data computers, radars, traffic systems, radios, and autopilots. InSight translates into lower operating and maintenance costs while providing enhanced safety, situational awareness, and functionality for pilots.

Enhanced Vision Systems: ClearVision is a complete Enhanced Flight Vision System (EFVS) solution providing head-up capability combined with enhanced vision (EVS) and synthetic 3D terrain display (SVS). It features a large field-of-view, with the brightest and highest resolution HUD for commercial aircraft in the market.

Database services; Navigation Database subscription service is offered to provide current, accurate navigation information for operators of Universal Avionics's Flight Management System. Subscriptions are available in worldwide and regional coverage areas to meet the requirements of flight operations. A special helicopter database is also available for rotorcraft operators.

Software: Universal Flight planning allows for the user to perform offline GPS FDE predictions for remote/oceanic operations (including Minimum Navigation Performance Specifications (MNPS) airspace), making it possible to obtain approval for remote/oceanic operations using GPS as a primary means of navigation. The program uses a GPS almanac text file in the YUMA format obtained from the U.S. Coast Guard GPS website.

Universal Avionics offers repair and overhaul services together with loaners and exchange units from its FAA/EASA approved repair centre in Tuscon Arizona.

Universal Avionics also offers an integration service for flight deck retrofits and upgrades, however, these services are offered via 3rd party specialists located throughout the US and EU.

Customers and contracts

- Airbus CN235 (airtech) military — Universal Avionics FMS and multi-mission FMS
- ASI Aviation F 406 — EFIS display suite.
- Cessna Citation — UNS-IEspw Flight Management System
- Dornier 228 — Flight Management Systems, EFI-890R display suite
- Gulfstream G550 — Flight Recorders, solid state cockpit voice and flight data recorders.
- Gulfstream G650 — Flight Recorders, solid state cockpit voice and flight data recorders.
- LET 410 — EFIS — 890R dual display
- MD900 Explorer — EFIS, IFR capable integrated flight deck, Next Gen flight deck.
- Shaanxi Y-8 — UNS-1K Flight Management System
- TAI Hurkus — EFI 890R display and radio control unit
- XAC MA600 — UNS-1M nav system EFIS display suite.

Strategy

Universal Avionics does not appear to state its strategy per se, however, they believe every operator should have the benefit of advanced technologies in their aircraft, for the freedom to fly in airspace around the world efficiently and safely.

Recent developments

June 2024; Universal Avionics announced that the InSight™ Display System is now available as a modification for Hawker 800 models equipped with Honeywell SPZ-8000 avionics. The FAA granted the Supplemental Type Certificate (STC) amendment for the modification, completed by Southeast Aerospace (SEA). The InSight Display System

brings a glass cockpit experience and advanced navigation to modernize Hawker 800 series aircraft. The upgrade replaces legacy CRT displays, resolving maintenance and repair challenges while improving functionality and situational awareness. The InSight installation on the Hawker 800XP includes three high-resolution displays and two touchscreen-enabled control displays, integrating with the Universal FMS to enable Data Communications and LPV approaches.

May 2024; Universal Avionics announced the expansion of its customer support offerings with new Flight Recorder Readout Services. Now available for 25-hour KAPTURE™ and 5th-generation Cockpit Voice and Flight Data Recorders (CVR/FDR), readout services ensure optimal flight recorder performance and compliance, improving maintenance activities.

March 2024; Universal Avionics announced that Eirtech Aviation Services, a leading aircraft modification provider, has selected UA's cutting-edge data link solution for its Airbus A320 fleet upgrade program. The upgrade features Universal's UniLink™ Communications Management Unit (CMU), which enables air-to-ground digital communications between pilots and Air Traffic Control (ATC), as well as Airline Operational Control (AOC) through its database of Aircraft Communications Addressing and Reporting System (ACARS) messages.

January 2024; Universal Avionics and Trimec Aviation have achieved FAA Supplemental Type Certificate (STC) for the Falcon 2000/EX equipped with the InSight™ Flight Display System. The upgrade replaces legacy Pro Line 4 avionics with the latest-generation displays and industry-leading synthetic vision to resolve obsolescence issues, maintenance challenges, improve operational efficiency and performance, and enhance safety.

December 2023; Universal Avionics announced that the FAA has granted Supplemental Type Certification (STC) approval for AerAware™ on the Boeing 737NG, an Enhanced Flight Vision System (EFVS) powered by ClearVision™ . This achievement marks the world's first EFVS to achieve a 50% reduction in minimum visibility requirements and the first aircraft to be certified with a complete dual-pilot EFVS solution featuring a wearable Head-Up Display.

December 2023; Universal Avionics successfully completed initial flight tests of its NexGen, software-based interactive Flight Management System (i-FMS). The flight tests were conducted in Austria on a government-owned Bell 212 helicopter as part of a joint effort with Elbit to improve flight management and navigation capabilities for the customer. The i-FMS adds onto mission computers delivered by Elbit and is controlled using the existing Human Machine Interface operated by the customer.

October 2023; Universal Avionics announced that Mid-Canada Mod Center, an Authorized Dealer, has been awarded Supplemental Type Certificate (STC) approval from Transport Canada and the FAA for NextGen flight deck upgrades on the Dassault Falcon 50. The upgrade program from Mid-Canada Mod Center installs the InSight™ flight deck solution to modernize Falcon 50 aircraft with latest-generation displays and NextGen capabilities for Data Comm including domestic Controller Pilot Datalink Communication (CPDLC), FANS 1/A+ and ATN B1.

October 2023; Universal Avionics has been selected as a lead supplier of integrated flight decks for De Havilland Canada's firefighting aircraft. Following an exhaustive search and through discussions with its base of operators, De Havilland Canada selected Universal's retrofit and forward-fit solutions for the CL-215T, CL-415, and DHC-515 to support aerial firefighting operations with NextGen flight display, flight management, data communication, and connectivity systems.

October 2023; Universal Avionics announced Performance Package capabilities for FlightPartner™ Connected Avionics in a new partnership with Aircraft Performance Group (APG®). The new package fully integrates with the existing workflows of the Connected FMS and relies on APG's performance for take-off and engine-out calculations, obstacle analysis, landing factors, and more. APG's engine allows for accurate weight and balance calculations that can enhance aircraft ground handling and increase fuel savings for the efficient flight operations.

October 2023; Universal Avionics has been selected by Widerøe Airlines, the largest regional airline in Scandinavia, to equip its fleet of Dash 8-400 aircraft with Connected Flight Management Systems (FMS). This fleet upgrade package increases efficiency and safety with newly developed supplementary iPad applications.

August 2023; Universal Avionics has partnered with AerSale to develop and certify AerAware Enhanced Flight Vision System (EFVS). Following an intensive development effort by both parties, Universal Avionics is pleased to announce the successful conclusion of the certification flight test program with the U.S. Federal Aviation Administration (FAA).

June 2023; Universal Avionics has been selected by Amelia to provide Flight Management System (FMS) upgrades for its fleet of 13 Embraer jets. This modification will allow the airline to meet operational airspace requirements while enabling complex procedures. The installation includes a dual UNS-1Lw FMS configuration, replacing previously fitted

UNS-1K Flight Management Systems. The STC issued by EASA allows Amelia to upgrade aircraft to the latest Satellite-Based Augmentation System (SBAS) FMS model, which provides operators with precision navigation for increased reliability and advanced capabilities. The later addition of a Localizer Performance and Vertical Guidance (LPV) monitor will bring additional efficiencies, enabling LPV approaches with a descent as low as 200-250 feet above the runway.

June 2023; Universal Avionics announced that Authorized Dealer Southeast Aerospace has received Supplemental Type Certificate (STC) approval from the FAA for InSight™ flight deck upgrades on the Hawker 800.

May 2023; Universal Avionics International has opened a new office in Blagnac, France. The company moved from its previous Toulouse office to a larger workspace in the InSitu Business Centre - Pythagoras Residence. The move extends Universal's capabilities in Europe to meet growing demand in the air transport, business aviation, helicopter, and government/special mission markets.

April 2023; Universal Avionics announced that it has successfully completed Technical Standard Order (TSO) certification for its Connected FMS. This effort also validates the cloud-based Connectivity Ecosystem's maturity, robustness, and compliance with applicable cybersecurity requirements.

February 2023; Universal Avionics obtained Technical Standard Order (TSO) authorization of the first Aperture™ visual data management solution as it initiates serial production for a major avionics OEM and is seeing strong interest from aircraft manufacturers and operators. The authorization clears the way for initial delivery of the system for enhancing safety and improving decision-making for flight crews and mission specialists. Introduced to the market at NBAA-BACE 2021, this authorization from the United States' Federal Aviation Administration (FAA) allows delivery of the unit to an OEM for use in their flight deck offering on new aircraft. In this instance, Aperture can process eight video inputs and support four video outputs with near-zero latency, at the highest level of integrity in commercial aviation (Design Assurance Level A). Imagery from an Enhanced Vision System (EVS) camera and other sensors is presented to the flight crew, enhancing situational awareness.

Decemver 2022; Universal Avionics has established repair capabilities for ClearVision™ EVS-5000 in its Tucson, AZ Part 145 Repair Station. The addition of multispectral enhanced vision cameras to the UA Repair Station capability list augments the worldwide support for EVS-5000 and will support its growing North American customer base.

September 2022; Dassault Aviation has received FAA Supplemental Type Certificate (STC) for Universal Avionics' (UA) InSight™ Flight Deck upgrade on the Dassault Falcon 900B. Dassault's unique STC for the Falcon 900B allows owners to upgrade to a 4-display InSight System while maintaining existing factory-delivered and OEM-supported Flight Management Systems (FMS). The solution is fully compatible with the FANS 1/A+, CPDLC, and ATN B1 solutions already provided by Dassault Aviation and Dassault Falcon Jet.

July 2022; Universal Avionics has been selected by Everts Air Cargo (EAC) to supply cockpit upgrades for installation on its fleet of McDonnell Douglas MD-80 aircraft. Fitted in partnership with LB Aviation, the addition of Universal Advanced Flight Displays, SBAS-Flight Management Systems (FMS) with LPV capability, integrated GPS, and UniLink™ Communications Management systems will provide safety enhancements and operational efficiency for Everts' MD-80 fleet. EAC will also be a lead customer of FlightPartner™ , UA's recently unveiled Connectivity Ecosystem.

July 2022; Universal Avionics was awarded a contract valued at $33 million to supply ClearVision™ systems Enhanced Flight Vision Systems (EFVS) from AerSale (NASDAQ:ASLE). The solution featuring the SkyLens™ Head Wearable Display (HWD) and EVS-5000 cameras for the Boeing 737NG, is part of the AerAware™ installation, developed by AerSale.

June 2022; Universal Avionics has been selected by Aeronaves TSM to supply cockpit upgrades on 15 McDonnell Douglas MD-80s and 11 Douglas DC-9 aircraft. The addition of Universal SBAS-Flight Management Systems (FMS) improves the efficiency of cargo operations with Localizer Performance with Vertical guidance (LPV), among others, while bringing safety enhancements and compliance with the Automatic Dependence Surveillance-Broadcast (ADS-B) mandates.

June 2022; Universal Avionics in partnership with Heli-One (Norway) AS and the Bundespolizei German Federal Police (BPOL) has successfully completed test flights of its SkyVis Helmet Mounted Display (HMD). The partnership is aimed at the development of a European Aviation Safety Agency (EASA) Supplemental Type Certificate (STC) for SkyVis on H215 (AS332L1e) helicopters. At its completion, it will be the first civilian certification of a helmet-mounted display.

June 2022; Universal Avionics has been selected by Airbus Helicopters to supply its EVS4000 multispectral Enhanced Vision cameras for installation on 8 new Airbus H145 helicopters destined to the Bavarian Police. The addition of the EVS4000 improves safety by increasing situational awareness in low-visibility situations including inclement weather and during night missions.

May 2022; Universal Avionics has joined forces with Trimec Aviation to provide integrated avionics solutions for all Dassault Falcon 2000/2000EX aircraft equipped with Collins Aerospace's Pro Line 4™ . The solution will include UA's InSight Flight Display System, SBAS-Flight Management Systems (FMS), SkyLens™ head-wearable display (HWD), and UniLink™ Communications Management system. Completion of the Supplemental Type Certificate (STC) is expected on the First of Type aircraft in the 1st quarter of 2023.

Counterpoint comment

Universal Avionics sees itself as a provider of hardware solutions, however, it is supported by integrators, STC certification processes, database service provision, training and repair stations. Universal Avionics has won a significant number of new contract in the past two years.

19.3.5 HINDUSTAN AERONAUTICS

Hindustan Aeronautics Limited (HAL) develops a range of defense platforms for use by the Indian Defense ministries in addition to export sales to foreign military operators.

These include the Hawk (under licence from BAE), Light Combat Aircraft, SU-30 Mk1, Intermediate Jet Trainer (IJT)/HJT-36, Light Combat Helicopter, Light Utility Helicopter.

Much of the avionics required for these platforms are sourced from HAL's two avionic subsidiaries located in Korwa and Hyderabad.

Avionics Division Korwa was established in the year 1983, to take up the production of Display Attack Ranging and Inertial Navigation system for Jaguar International aircraft for Indian Air Force followed by manufacturing & supply of avionic systems for Russian origin MiG-27 & Su-30MKI aircraft. Division at present is manufacturing & repairing various Avionics Systems fitted on MiG-27M Upgrade, Mirage-2000, LCA, Jaguar upgrade, AJT-HAWK aircraft. Division is also engaged in the maintenance of UAVs Systems since 2001 onwards.

Avionics Division, Hyderabad was established in the year 1966 for manufacture of MiG 21 Avionics equipment. Co-located Design Division, Strategic Electronics Research and Design Centre (SLRDC) has indigenously developed more than 40 types of Avionics systems for LCA, ALH, IJT, SU-30 MKI , HTT-40, Jaguar Darin II & III, LCH,LUH and Hawk trainer Aircraft. SLRDC provides Design, Development and Engineering support to several Avionic products which are manufactured for fitment in a number of fixed and rotary wing Aircraft like MiG 21, Jaguar, MiG 27, MiG 29, Cheetah, Chetak, ALH, Su-30 MKI, Hawk, Do-228, LCA. HAL is involved in the manufacture and repair & overhaul of a wide range of avionics equipment, including airborne radars, communication, navigation equipment and on-board computers fitted on fixed and rotary wing platforms of Russian, Western and Indian origin. In addition to catering the requirement of Defence services, Division also supplies avionics equipment to Civil and Export customers.

Financials

We estimate that HAL generated $46m in avionic related sales in 2023 from its two subsidiaries located in Korwa and Hyderabad.

Locations

HAL's avionics capabilities are located in its Korwa, India facility where design and manufacturing takes place under one roof.

HAL also has avionics capabilities within its Hyderabad facility. All avionic related design and manufacturing processes are contained within this facility.

Printed circuit board (PCB) work is outsourced from both facilities.

Capabilities

Within the Hyderabad facility HAL provides the following:

- Radar Control System (RLSU - 30MK) which has Passive Electronic Scanned Array sensor for Su-30 MKI aircraft.

- Identification of Friend or Foe (IFF) & variants with advanced technology
- Omni Range/Instrument Landing System (VOR/ILS)
- Tactical Air Navigation (TACAN)
- Solid State Digital Video Recording System (SSDVRS)
- Very High Frequency (VHF) Radio set & Data Link
- Ultra-High Frequency (UHF) Stand by Radio set
- Mission Computer (MC)
- Display processors (DP)
- Open Architecture Computer (OAC)
- Open System Architecture Mission Computer (OSAMC)

Within the Korwa facility HAL offers the following avionics capabilities:

- Inertial Navigation System (INS): The inertial navigation and attack system uses an inertial platform with a compactly packed fast computer for generating in-flight navigation and weapon aiming parameters.
- Weapon Control System (HUDWAC): Preparation of aircraft armament to combat applications which provided guided tracking of weapons until hitting the target Microprocessor based head-up Display & Sighting System.
- Combined Map and Electronic Display (COMED): The head down display is a cockpit mounted navigational aid with multifunction facilities. It displays the ground map as stored in a filmstrip superimposed with symbols generated in a CRT.
- Flight Data Recorder (FDR): The Flight Data Recorder is installed in the aircraft to monitor, process and record signals from avionics systems and sensors for subsequent analysis on the ground.
- Inertial Navigation and Global Positioning System (INGPS): An inertial system with an embedded GPS receiver that provides aircraft peripheral equipment with all necessary inertial inputs.
- Multi-Functional Display (MFD) : A small LCD screen used to display information to the pilot in numerous configurable ways. It is available in different size and nature.

HAL is party to a number of Joint Ventures with the following of note:

- Samtel (India) HAL display JV: Design, Development and Manufacture of various types of display systems for Airborne, Military and ground applications for sale in India and International markets.
- BAE/HAL software JV: Design, Develop & Market Computer Software, Firmware Programs and provide software solutions & service to the customer

Customers and contracts

HAL lists its export customers as including Airbus, Boeing, GE Aviation, Honeywell, Moog and a number of Air Forces around the world.

It has provided avionics for LCA, ALH, IJT, SU-30 MKI, HTT-40, Jaguar Darin II & III, LCH, LUH and Hawk trainer Aircraft.

Further services include Design, Development and Engineering support to several Avionic products which are manufactured for fitment in a number of fixed and rotary wing Aircraft like MiG 21, Jaguar, MiG 27, MiG 29, Cheetah, Chetak, ALH, Su-30 MKI, Hawk, Do-228, LCA.

HAL states that more than 500 HUDs have been supplied for various Indian platform such as Su-30MKI, Jaguar and MiG-27M upgrades.

Strategy

HAL has been focused upon increasing it export sales for a number of years. It has had some success with exporting avionics. However, this is often as part of a platform sale. India has a reputation for engineering and software capabilities, and this may provide it with a stronger growth path than with product offerings.

Recent Developments

Feburary 2024; Central Scientific Instruments Organisation (CSIO) and Hindustan Aeronautical Limited will establish a cutting-edge Centre of Excellence (CoE) for Avionics in Chandigarh for advancing research and development in avionics technology to boost aerospace industry.

December 2023: Hindustan Aeronautics opened over Rs 2,000 crore this year on research and development in line with its overall approach towards indigenisation of critical avionics and related hardware, a senior official of the state-run entity.

Counterpoint comment

HAL has invested R&D in avionics but has enjoyed limited success with commercial export sales. We see its strength in developing affordable platforms for many nations that have limited defense budgets.

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