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Trends in the Avionics Market 2025 – 2035

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**Table of Contents**

[Effects of the COVID-19 Pandemic on the Aerospace Supply Chain 3](#_Toc177036747)

[The trend toward longer in-service lives for older aircraft 3](#_Toc177036748)

[Supplier investment in OEM constructor programs 4](#_Toc177036749)

[SFE/BFE 4](#_Toc177036750)

[Greater standardization in the cockpit and avionics systems across platforms 4](#_Toc177036751)

[Tightly coupled avionics and other systems and components 5](#_Toc177036752)

[Business Aircraft Market Trends 5](#_Toc177036753)

[Avionics growth in the aftermarket 6](#_Toc177036754)

[Performance Based Navigation (PBN) 7](#_Toc177036755)

[CPDLC 8](#_Toc177036756)

[Head-Up Displays 9](#_Toc177036757)

[Challenges 9](#_Toc177036758)

[GPS Spoofing 9](#_Toc177036759)

[Clear Air Turbulence Detection 11](#_Toc177036760)

[B737 Max Influence on Certification 11](#_Toc177036761)

[Single-Pilot Operations & Extended Minimum-Crew Operations 12](#_Toc177036762)

[International Air Traffic Services (ATS) Evolution 12](#_Toc177036763)

# 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 labor 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 materiel 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 8500 aircraft, while the Boeing backlog stands at just over 5600 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.

# 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.

# 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.

# SFE/BFE

Another 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.

# Greater standardization in the cockpit and avionics systems across platforms

Further, OEM constructors are moving to greater standardization 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.

# 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.

# 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 XX new aircraft programs (G600, G700, G800) in the last ten years. Textron Aerospace (Cessna, Beechcraft) have unveiled YY new aircraft programs (Latitude, Longitude, Denali, …)

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 standardization.

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 the following table:

|  |  |
| --- | --- |
| Very-light jets | |
| 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 |

# Avionics growth in the 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, primarily:

* New technology mandates
* Aircraft lifecycle extensions
* Operational improvements
* Safety improvements
* Efficiency improvements

In general, mandates are the most reliable aftermarket growth predictor and the least difficult for decision-makers, since all users of regulated airspaces 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 are anticipated to drive aftermarket changes over the next ten years, primarily the following two:

1. Performance Based Navigation
2. Controller Pilot Data Link Communication

## 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 and India.

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% 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.

## CPDLC

Controller–pilot 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.

## 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 of situational awareness for 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.

# Challenges

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 growth 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
5. Global Air Traffic Services (ATS) Evolution

## 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 1350 flights have encountered spoofing. Flight crews also report that the intensity of the spoofing is increasing.

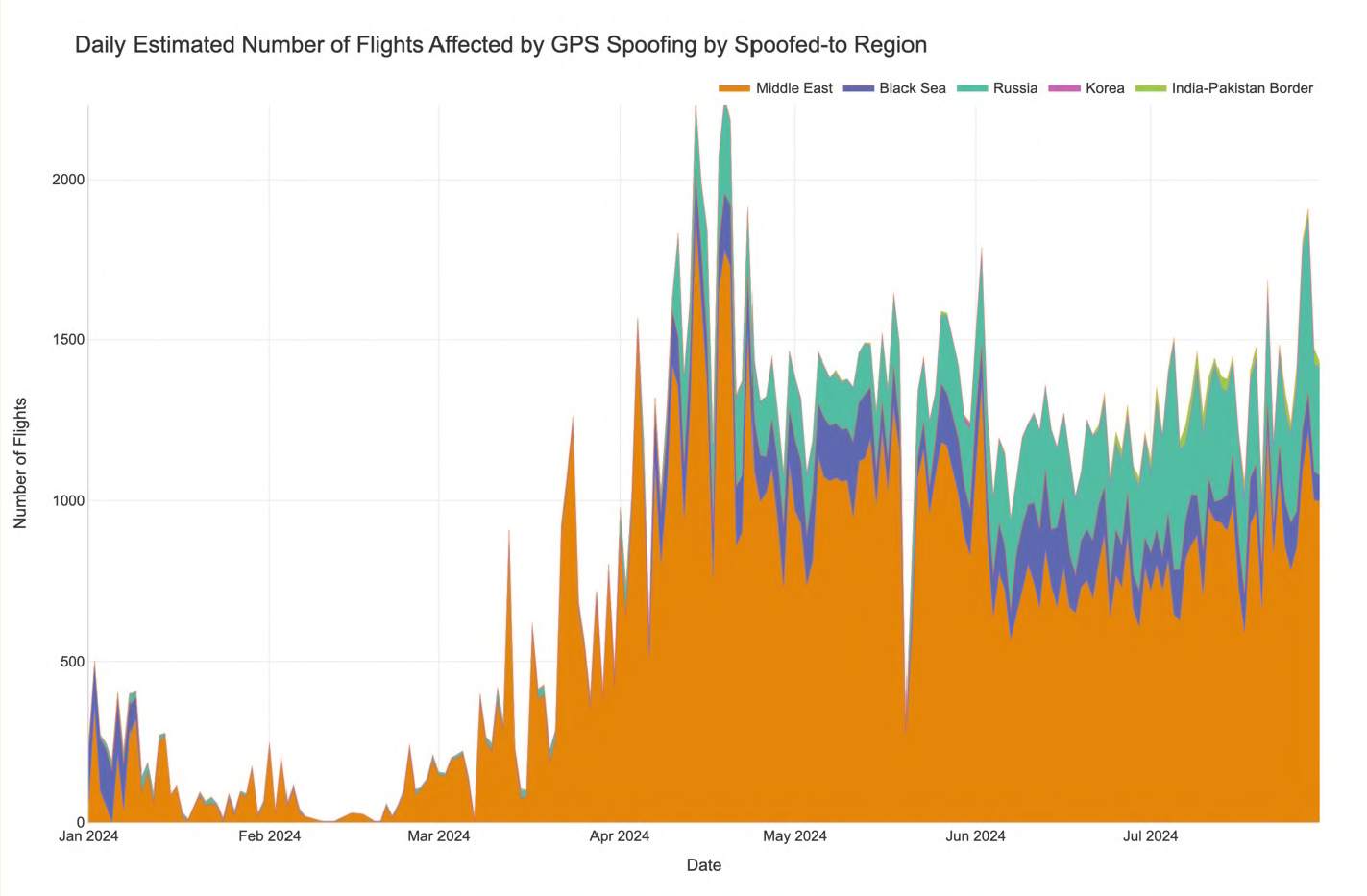


Figure : Graph shows number of flights affected by spoofing, broken down by location. Data from Zurich University of Applied Sciences & SkAI Data Services. Credit OpsGroup.

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.

## 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.

## 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 organizations, 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.

## 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 operations (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 ofDragonfly 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.

## Global Air Traffic Services (ATS) Evolution

TBD…