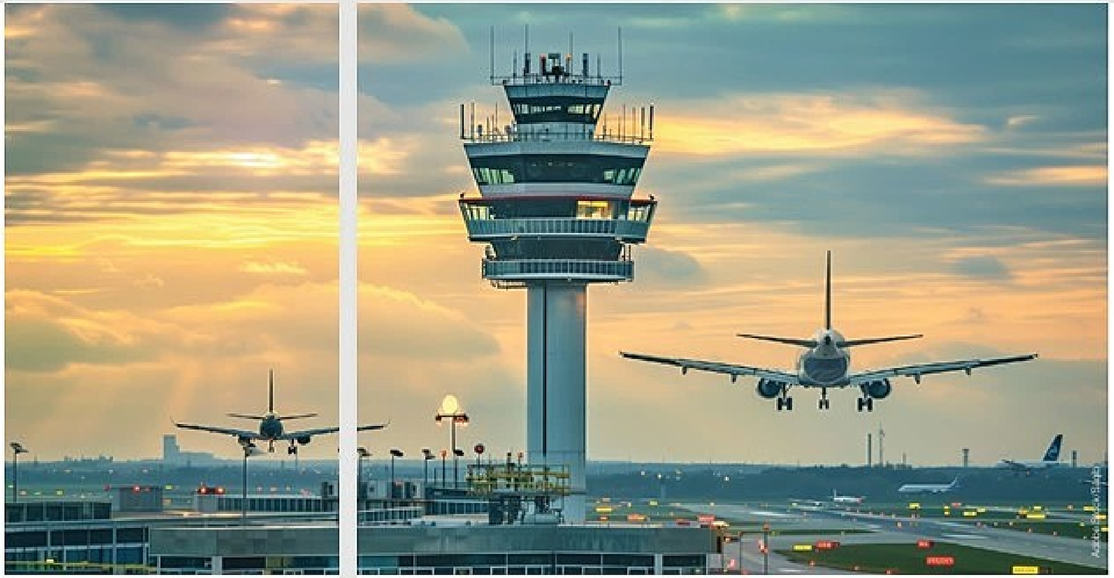
Taking flight: the digitalisation of civil aviation

Increasing airspace congestion is driving a transformation in air traffic control systems, including AI-powered digital platforms integrating multiple data streams. **James Atkinson** reports



Civil air navigation service providers (ANSPs) are facing a number of issues of which airspace congestion is perhaps the most immediate challenge. In 2025, flight numbers recovered to pre-Covid pandemic levels with 38.9 million flights recorded worldwide, according to the International Air Transport Association (IATA).

IATA predicts the number will rise to 40.3 million in 2026, with total passenger numbers expected to hit 5.2 billion. These numbers are putting increasing pressure on ANSPs.

"In aviation there is limited airspace and a limited number of air traffic controllers, and across the world there is the difficulty of holding onto controller staff," says Reinhard Grimm, executive vice-president ATM civil at Frequentis.

"At the same time, we have also seen an increase in delays, currently measured in millions of minutes," notes Robin Houtmeyers, R&D director at Octave Alto Products (Octave is a spin-off of various Hexagon divisions).

He says there are many reasons for this, including staffing issues. But it has led to a consensus that the digital transformation of air traffic control (ATC) systems is necessary to help streamline all the data and aid decision-making.

ANSPs are beginning to migrate their legacy monolithic air traffic management (ATM) and ATC systems to open digital data platforms. These platforms will integrate siloed ATM solutions and support a greater range of applications. This will help to make ATC safer, more efficient and more proactive, as well as lessening the burden on air traffic controllers.

Open standards

Houtmeyers says the kinds of open digital data platforms developed over the past decade provide a core architecture, which bring all the different data streams together and to which specific aviation applications can then connect. "You get a one-stop shop for all your data streams. This is essential."

How do the platforms work in practice? "The important thing is the availability of open interoperable digital standards that are capable of representing the complexity of the aviation world," says Houtmeyers. "Including flight plans, airport layouts, virtual routes in the sky, weather phenomena and so on.

"If you want to support digital transformation you also need standards and data formats that are capable of representing that specific aviation information in a digital way, so it can be used by applications rather than humans."

Major aviation authorities such as the FAA (Federal Aviation Administration) in the US and Eurocontrol in Europe have invested a lot of time and effort in developing these standards. The starting point for this was the SWIM (System Wide Information Management) project, a key component of the SESAR (Single European Sky ATM Research) programme.

SWIM set out to harmonise the exchange of aeronautical, weather and flight information for all aviation stakeholders. Its key aim was to increase common situational awareness by making available consistent information to different users such as pilots, air traffic controllers and dispatchers to support more proactive decision-making.

The idea was to pull together the main aviation communication tools such as VHF radios, data link systems/satellite comms devices and weather monitoring systems.

It also brought together ATM automation systems – including flight data processing – airspace usage, flight plans and traffic patterns, as well as surveillance and navigation aids such as ground-based radar and ADS-B (Automatic Dependent Surveillance-Broadcast). The latter is a satellite-based system that automatically broadcasts an aircraft's GPS position, altitude, velocity and ID to ground stations and other aircraft approximately every second.

Other key aviation standards include AIXM (Aeronautical Information Exchange Model), which is designed to enable the management and distribution of AIS (Aeronautical Information Services) data in digital format based on GML.

FIXM (Flight Information Exchange Model), meanwhile, provides harmonised data structures for flight information. WXXM (Weather Information Exchange Model) enables the exchange of weather-related information and is used by both Eurocontrol and the FAA.

Another major advance was the standardisation of digital NOTAMs (Aviation Information Nodes). Classic NOTAMs are text messages used to brief pilots about anything that might impact their flight ahead of take-off.

"But once they were in flight everything was already outdated," says Houtmeyers. "They had to rely on air traffic controllers to make corrections to their route if they entered reserved airspace or there was a thunderstorm coming up. So, it was reactive behaviour."

Air traffic control is key to ensuring civil aviation runs safely and smoothly

Digital NOTAMs act as a 'node' within the SWIM network, replacing text-based messages with machine-readable, data-centric information. They enable automatic processing, filtering and graphical display of information in the cockpit.

"These new standards are no longer meant to be read by a human being," says Houtmeyers. "Instead, they are interpreted by a system that can automatically filter thousands of NOTAMs and just pick out the ones that affect that particular flight. It can also visually show data on the screen. If a taxiway is no longer available, for example, it is marked red to show the pilot not to go there."

Much more proactive

This kind of technology allows pilots to be much more proactive, as they can check all the data and make changes to their trajectory if necessary. It also eases the pressures on controllers, as they now know the pilot is seeing and using the same data as they are.

"These new standards and data formats are key enablers for the new data-oriented platforms and architectures that we see being used more and more," observes Houtmeyers. "But at the same time, we also see an increasing focus on applications that can connect with these platforms, which can also handle a wide variety of data streams."

He continues: "Typically in the past you had one application for each use-case. One for flight planning, weather analysis, NOTAMs, and so on. Now you see the need for applications that can handle everything. That can integrate not just static aviation data but also dynamic aviation data like airspace reservations."

A good example of this is the Lido suite of applications developed by Lufthansa Systems using Octave Alto Products, which uses a model known as trajectory-based operation (TBO). Lido's core system calculates the most efficient and cost-effective route to reduce fuel consumption and emissions. It integrates with real-time data including weather, aeronautical data and air traffic management restrictions.

But once in flight, it can also recalculate the optimal route if the aircraft needs to change course for some reason. "The Lido system takes about 70 data streams into account, not only aviation and weather data but also fuel prices, passenger delays, back-ups at airports. All these factors can be taken into account to calculate the new optimal trajectory," explains Houtmeyers.

Integrating all these complex aviation data streams onto one platform and enabling information to be displayed visually onto a single screen is hugely beneficial. But one key application is still largely kept separate – voice, which has been isolated by design to provide a safety fallback for controllers.

Frequentis's Grimm explains that air traffic control still largely works by establishing a flight plan and then the air traffic controller guides the aircraft by voice through the trajectory of that plan. "At the moment, the primary connection to the pilot is largely by analogue radio, so it is voice-based instructions to manage air traffic."

However, Grimm is clear that a much richer communication environment can be achieved if voice communication systems (VCS) are integrated with the new ATM digital systems to provide a unified aeronautical communications (UAC) system accessible via a single interface.

He argues that interoperable voice, surveillance and digital services can be achieved without compromising safety to provide reduced workloads, improved situational awareness and additional levels of automation.

"For example, we use AI for speech recognition confirmation, so if the air traffic controller gives instructions to ►

the pilot, they have to read it back. If there is a difference between the two, we can spot it, highlight it and bring it to the attention of the controller, so they can check out where the misunderstanding is. It provides additional information and a safety net."

Another feature involves integrating the VCS with the ATM automation system to enable a controller of one air sector to contact the next sector controller. "With one keystroke or mouse click we can implement a feature to automatically call the next sector controller," says Grimm. "That makes life much easier for the controller."

Or, if a plane transmits a radio call, the aircraft can be highlighted on the radar screen. "That is done by integrating our voice system with the automation system and the radar system. So, things come together very conveniently for the controller, but voice is still the main way of communicating between the controller and the airplane," says Grimm.

Heavily regulated environment

In contrast to the heavily regulated environment of on-board systems, it is easier to deploy new technology at airports to aid air controllers overseeing take-offs and landings, and ground controllers managing aircraft movements on the stands and taxiways.

Take, for example, the Demand and Capacity Balancer (DCB) developed by Frequentis in partnership with the UK's National Air Traffic Service (NATS). "DCB calculates the optimum slots for the planes by checking out what capacity is available and squeezing in as many planes as possible," says Grimm.

"When used with our Integrated Arrival Management and Departure Management (IAD) tool, the limited airspace is used to the maximum extent."

IAD is designed to enhance predictability and increase runway throughput by jointly planning arrival and departure sequences, which is especially useful for single-runway airports.

AI algorithms compute optimised target times at runways, taxiways and aircraft stands to ensure maximum utilisation of available capacity. This helps minimise departure intervals, improves departure and arrival sequencing, and enhances air traffic flow management.

Or take stand planning, which is complex, reactive and often a cause of delays. New stand allocation solutions, such as the Intelligent Stand Manager from Searidge Technologies (owned by NATS), use "AI-enabled advanced algorithms and predictive analytics to deliver dynamic stand plans that automatically adapt to real-time events.

"This enables plans to be recalculated in minutes, not hours, helping airports to reduce delays, improve punctuality and enhance the passenger experience," according to NATS.

Perhaps the most transformative airport solution is the digital control tower. Remote cameras, sensors and radars are mounted around the airfield and combined with flight data, airfield lighting, weather surveillance and unified communications to provide controllers with a clear view of all

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ground and airspace operations. Digital towers may be used as back-ups at airports with traditional control towers, or to extend the physical tower by covering blind spots at the airport. Or, they can entirely replace the traditional control tower and be operated either on site or from another location.

For example, London City Airport is fully controlled by a digital tower provided by Saab and managed from NATS' air traffic centre in Swanwick, Hampshire.

"Operating airports is not cheap and skilled air traffic controllers are rare, so digital towers are a way for ANSPs to deal with limited resources and capacity," notes Grimm.

A final major trend that ANSPs are having to contend with is the exponential rise in the number of drones. To deal with this, the European Union Aviation Safety Agency (EASA) has designed the U-space framework, an unmanned traffic management (UTM) system, in collaboration with the EC and SESAR. U-space's overarching goal is to safely integrate large volumes of drones, particularly in congested low-altitude urban areas, alongside traditional crewed aircraft.

While drone hobbyists do not have to file flight plans, any proposed drone flight over a certain height or going beyond visual line of sight has to submit a flight plan, and the drone must have a transponder to enable it to be tracked continuously in real time.

Globally, civil aviation is still at a relatively early stage in its digitalisation. Huge investments have been made in legacy systems and they cannot be written off quickly.

As Grimm points out: "Changing everything to run on a data centre architecture costs a lot of money and it is not that easy to migrate from an old ATM system to a new one. It is also important to understand that it is not just a technology shift, it is an organisational shift for the ANSP.

"But I think we are at a very interesting time, because now technology can make so much more possible. I see us at the verge of a new era and ANSPs are willing to do new things because they lack capacity, regulators are willing to support that process, and technology providers have already got the means at hand to improve aviation. So, I think a lot of new things will happen in the near future."