WHITE PAPER

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Enhancing extended arrival management with space-based ADS-B

The aviation community is facing complex challenges: surging air traffic, the imperative for efficiency, sustainability, and safety. ICAO, SESAR, and other initiatives drive modernisation, having yielded many practical solutions ready for deployment. At major airports, tools like the Arrival Manager are enhancing operations, yet traditional AMAN systems encounter limitations for example, if input data is insufficiently available to enable extended planning. Enter the Frequentis Extended Arrival Manager (E-AMAN) leveraging AireonFLOW™ — a global, high-fidelity, low-latency position data source.

By extending the AMAN horizon symmetrically upstream, smoother traffic management is possible. Controllers in the upstream sectors, which may be well beyond the Flight Information Region (FIR) or Area of Responsibility (AoR), receive AMAN advisories enabling pre-sequencing of aircraft at fuel-efficient altitudes. The space-based AireonFLOW data as input to E-AMAN fills surveillance data gaps. With it, a complete arrival traffic demand can be calculated, promoting stable sequences and enhanced controller situational awareness. With that, ANSPs have a robust system for efficient eco-friendly arrival operations.

In the face of rapidly growing air traffic, efficient traffic management is essential. Controllers need robust support from traffic synchronisation aids such as AMAN and DMAN to ensure efficient sequencing of the complex traffic flows into and out of busy airports with the runway systems and surrounding TMA airspace as constrained resources. Environmental and cost considerations are likewise important demanding reduced fuel consumption by flights.

For arrival management, AMAN systems are essential support tools that calculate optimum arrival sequences and times for flights approaching key cross-over points or fixes and runways while considering various constraints such as flight profiles, aircraft characteristics, and optimization preferences. Via suitable HMIs and displays, they present the planning results along with generated advisories and other information to the controller team to allow them to meet the planned inbound sequence and times.

Conventional AMAN systems work with an operational horizon, which provides a limited window of opportunity to optimise the traffic flow to an airport. Additionally, sequencing deficiencies arise if the required air traffic surveillance data is not available homogenously or symmetrically around the airport. This leads to a less stable sequence due to more frequent updates if some traffic is planned late while other traffic has been sequenced already.

E-AMAN offers a smart solution to alleviating congestion compared to the conventional AMAN horizon. Extended arrival management with E-AMAN refers to preparing further in advance the sequencing of air traffic destined for a particular airport. It allows controllers upstream to give early instructions to pilots to adjust their speed before initiating descent towards their destination, reducing the need for stacking and holding over the destination airport — an effective means for reducing fuel costs and lowering emissions for airlines. For this pre-sequencing, additional reliable data sources covering a sufficiently large horizon are required.

The goal of this paper is to emphasize the integration of Aireon's space-based ADS B data into the Frequentis E-AMAN to extend the horizon of arrival management into an airspace, waypoint, or an airport and enhance respective trajectory calculations. The high-fidelity AireonFLOW position data, combined with flight and airspace contextual information, enables enhanced prediction and robust arrival planning far beyond its own FIR or AoR without the need to sign data-sharing agreements with neighbouring countries.

After briefly describing today's challenges of ANSPs in terms of surveillance data for arrival sequencing, a proposed mitigation approach is outlined, followed by a high-level description of the contributing Frequentis E-AMAN and AireonFLOW data feed as solution components. Later, this white paper will discuss, in greater detail, how those elements can be used to enable and enhance extended arrival management, whilst mitigating current challenges. Important solution benefits are highlighted.

Problem definition

The air transportation industry is experiencing continued growth, leading to increased air traffic and congestion at airports worldwide. Hence, airports with dense domestic, regional, and international traffic flows face significant challenges in efficiently managing the traffic streams. There is the requirement for stakeholders to increase the efficiency of operations, on-time-performance, reduce delays, fuel burn and consequentially environmental impacts. As a result, ANSPs are seeking tool support for optimised sequencing to cope with escalating demands and ensure a seamless, efficient flow of arriving and departing flights.

One of the challenges of a conventional AMAN is that the operational horizon provides a limited window of opportunity to optimise the traffic flow to an airport. The arrival management coordination is limited to the Terminal Manoeuvring Area (TMA) and adjacent enroute sectors. In some airspaces, this results in being unable to adjust upstream aircraft trajectories and give early instructions to pilots to adjust their speed at higher, more fuel-efficient altitudes, before initiating descent towards the destination airport (Top-of-Descent). This may result in undesired holding, radar vectoring and speed control inside the TMA.

Another limitation of conventional AMAN systems is the use of radar surveillance data as the single source of flight position data. Radar data may not be equally available in all directions from the destination airport. For example, flights could be over oceanic or remote areas where ground receivers are not available, and if they are available, they may not be sufficiently accurate.

This translates to an asymmetric AMAN operational horizon where it is difficult to compute a high-quality and stable arrival sequence. Flights from one direction may be known to the system early on and can be considered for arrival metering and sequencing, while the traffic from other directions, where no radar data is available, cannot be included in the planning and must be merged into the arrival stream later leading to updates and changes.

Surveillance data may be available from multiple sources (ADS-B, SSR, etc.), bringing about integration challenges for ANSPs as integration can be complicated and costly. As AMAN is extended outside the surveillance coverage of the ANSP, reliance on neighbouring surveillance or crowd sourced inaccurate data is used.

Arrival management using AireonFLOW

High-level Solution

To overcome limitations of traditional AMAN systems and to unlock additional benefits, ATM modernisation programs such as Common Project 1 (CP1) or ICAO ASBU are requiring further enhancements of the existing arrival management systems. One of such is the upgrade to extended arrival management where the arrival sequencing of air traffic destined for a particular airport commences further in advance.

The solution extends the arrival management coordination beyond the airspace surrounding the airport (Terminal Manoeuvring Area) to neighbouring enroute airspace. Extended AMAN can even be applied across national borders and ANSP AoRs. Air traffic control (ATC) services in the TMAs employing AMAN operations shall coordinate with Air Traffic Services (ATS) units responsible for adjacent enroute sectors.

A common challenge in the context of extended arrival management is the lack of reliable and timely position reports of aircraft outside the AoR of the downstream ANSPs. High-quality sources of upstream surveillance data are required for high-fidelity trajectory prediction commencing upstream. With this as the foundation of calculating arrival time estimates, an extended arrival sequence can be planned early.

This pre-sequencing is accomplished by integrating space-based AireonFLOW ADS-B data into the Frequentis E-AMAN. The planning based on the AireonFLOW data is independent from national boundaries and many of the challenges stated above can be addressed. Extended arrival management using AireonFLOW fosters greater accuracy and consistency in the E-AMAN computed target times promoting more efficient AMAN processes.

E-AMAN

The Frequentis Extended Arrival Manager helps air traffic controllers to efficiently manage incoming flights to make the best use of available runway and airspace capacities. Predictability is enhanced with E-AMAN providing decision support for all controllers managing arrival traffic and, if required, in a multi-runway configuration and multi-airport environment. The system offers a set of advanced features such as delay sharing, route and holding advice, extended arrival metering, or what-if probing. These allow for more efficient flight operations and help reduce arrival aircraft holding to a minimum.

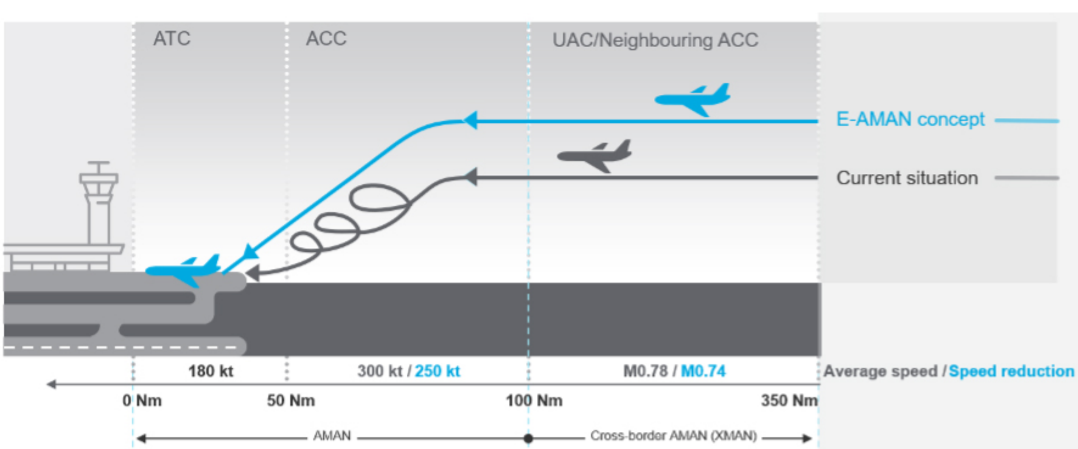
E-AMAN calculates estimated landing times (ELDT) or fix cross-over times (ETO) for arrivals using its trajectory prediction engine. The ELDT/ETO is the estimated time that an aircraft will touchdown on the runway or cross a fix assuming no limiting constraints e.g., spacing constraints due to leading flights.

The Frequentis E-AMAN supports pre-sequencing employing an extended AMAN operational horizon well beyond typical ranges of 180–200 nautical miles from the arrival airport given suitable surveillance and flight data sources. Pre-sequencing is applied for instance in the case of an unsymmetrical FIR with late availability of radar data for certain traffic flows. This can be achieved by utilising AireonFLOW data enabling the calculation of the arrival sequence in an early phase of flight. The E-AMAN sequence output provides the calculated sequence and delay information to neighbouring units to support in traffic control implementing the sequence plan.

Based on calculated ETOs/ELDT AMAN builds an optimised arrival sequence proposal given by scheduled times (STOs/TLDT) computed for reference points along the arrival routes. The difference between the ELDT and TLDT yields the delay of a flight. Based on the proposed sequence and required delay absorption, AMAN generates advice, such as time, speed, or holding advice that indicates how a controller can meet a planning time provided to him.

FIGURE 1

Extended Arrival Management concept



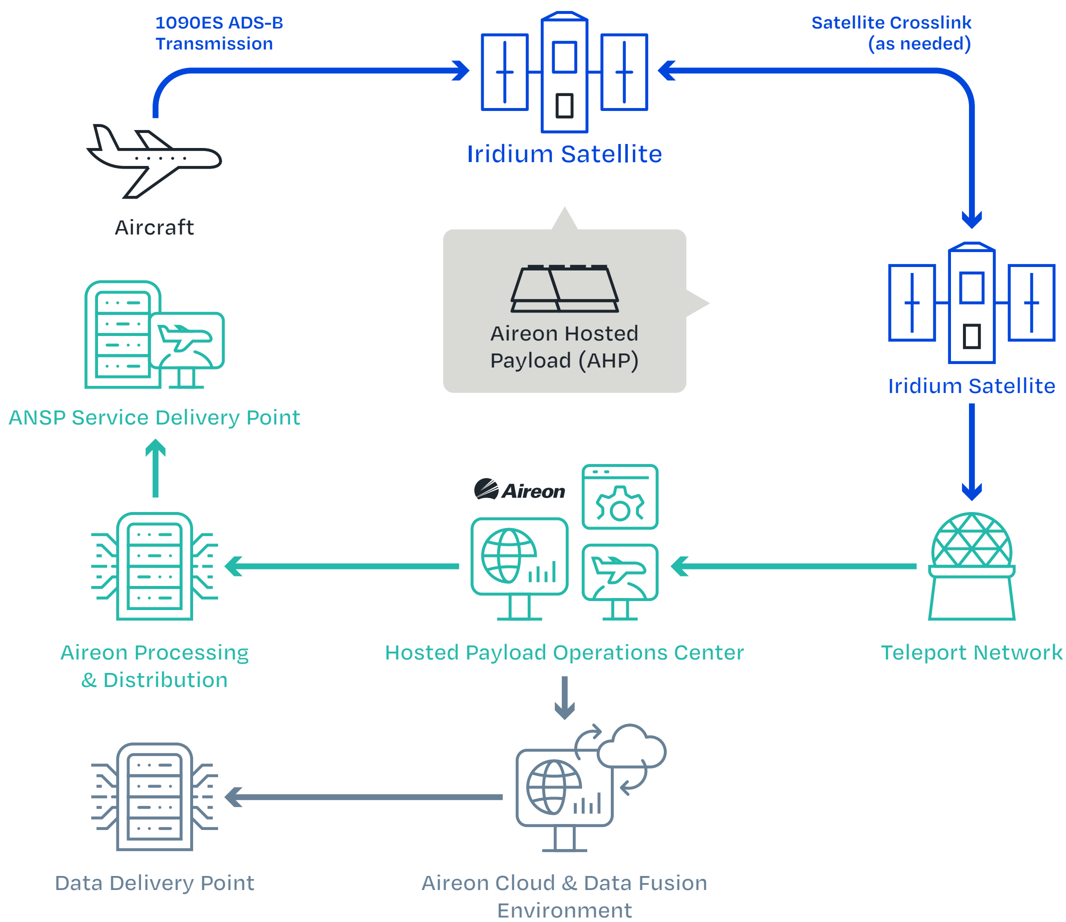
Source: NATS

AireonFLOW

AireonFLOW is a data service that provides ATM surveillance quality data within a designated primary AoR service volume, typically up to 3000 NM (i.e., long-range area service volume) to support arrival management with AMAN. Customers can define their service volume to meet their unique operational objectives. Leveraging Aireon's streaming platform, customers receive a stream of space-based ADS-B data in their AoR of all available aircraft.

Aireon's ADS-B system is made up of two segments: the Aireon space segment and Aireon Ground Segment. The Space Segment involves a network of satellites provided by the Iridium NEXT constellation. Each of the sixty-six satellites carries an essential component called the Aireon Hosted Payload (HPL) which receives and processes Automatic Dependent Surveillance-Broadcast (ADS-B) messages from aircraft that are equipped with ADS-B technology. These messages contain important information about an aircraft's position, altitude, and other relevant data.

FIGURE 2
Aireon space-based ADS-B Network



Once the HPL receives these messages, it sends them to the Aireon Ground Segment. This transfer happens via the Iridium main mission payload. The data travels through crosslinks between Iridium NEXT satellites and is then downlinked to an Iridium teleport. From there, the downlinked data is routed through a terrestrial network to reach the Ground Segment.

The Aireon Ground Segment is comprised of the Hosted Payload Operations Center (HPOC) and the Aireon Processing and Distribution (APD) Center. The HPOC provides all the functions required to monitor and control the HPL. The APD provides all processing of ADS-B mission data and delivery of mission and status data to ANSPs. The data available may be customised for a consuming system by applying geographic, time, and aircraft filters.

Solution details

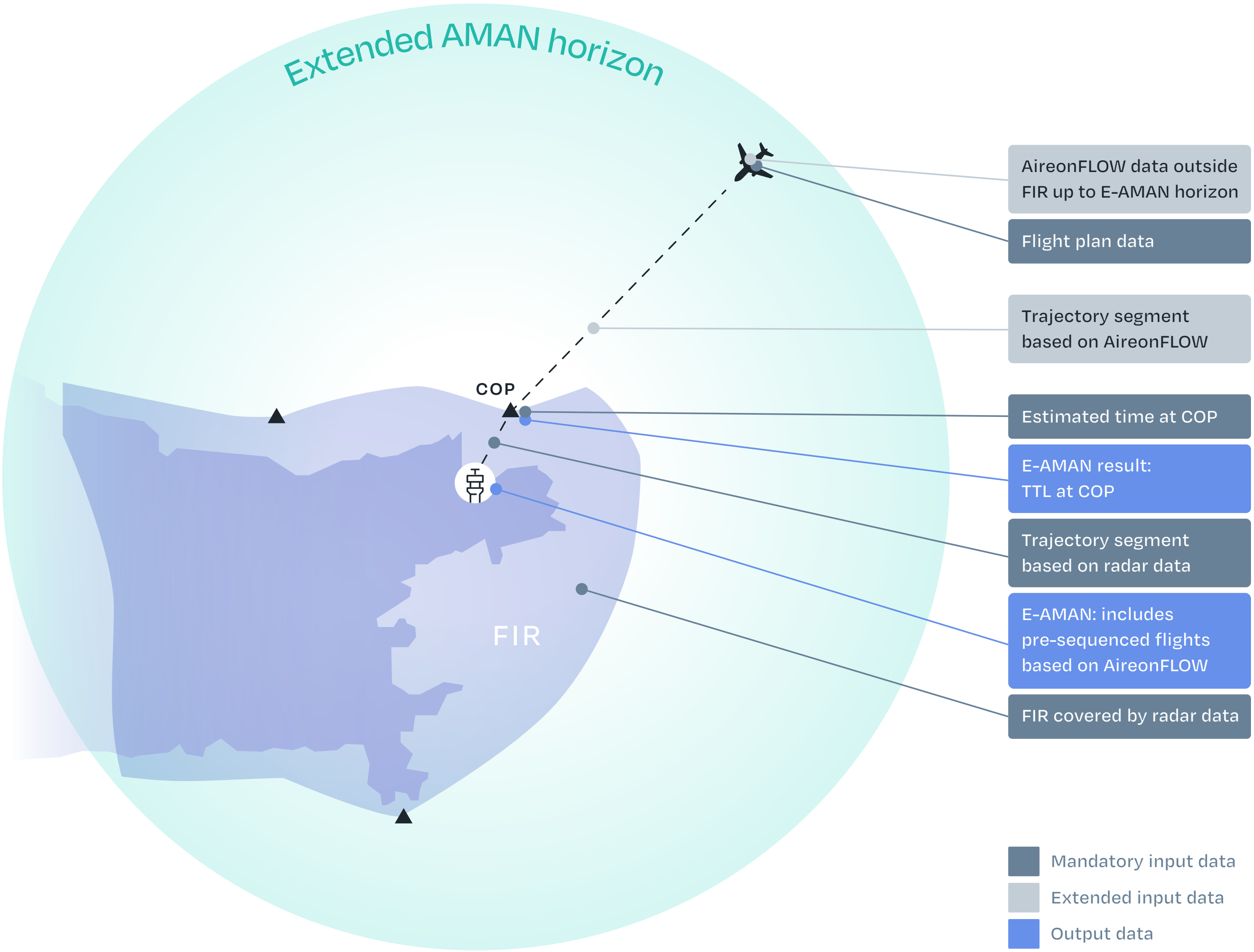
Arrival manager systems provide such controller tool support for efficiently metering and sequencing arrival streams and managing associated delays, and maximising runway utilisation. As a planning tool, E-AMAN enables the controller to efficiently organise flights and share the planning decisions with other controllers, which ensures common situational awareness. For this, high-fidelity trajectory modelling is key. It allows to accurately describe the estimated flight progress which is used as the basis of building an optimised arrival sequence.

While the operational horizon of a conventional AMAN is typically identical to the FIR or the area where radar track data are available, E-AMAN permits an earlier and more uniform planning, from an extended operational horizon (e.g., 90 minutes) onward. For this, additional data sources providing flight position data need to be available to substitute the radar data. By including AireonFLOW data, E-AMAN can take advantage of a more complete traffic picture allowing for a more harmonised arrival management. Besides flight plan, aircraft performance and weather data, the system processes continuously reported AireonFLOW data and radar surveillance data jointly to accurately compute estimated flight profiles (e.g., lateral, altitude, speed). With the two data sources a multi-part trajectory is composed with a merge of the transition at defined horizons (e.g., where sufficient radar data is available).

With the increased requirement for accurate and earlier position reports for traditional and Extended AMAN, Aireon will supply a filtered stream of global ADS-B data for all flights relevant to the TMA and aerodrome which the AMAN system is supplying airspace or runway sequencing for. This data is sourced from the Aireon satellite network (no other surveillance integration is required) and will be for all flights inside the ANSP FIR and at a customer configurable AoR outside of the FIR. Typically, this data will be supplied at one-minute intervals, however this parameter is configurable depending on the customer requirements. The data is transmitted in CSV format (or other typical surveillance formats) allowing for easy integration into the AMAN system. The data is transmitted via the internet allowing for easy access.

As can be seen in Figure 3, AireonFLOW data is available from the E-AMAN horizon onwards whereas previously, radar flight position reports were only available from the FIR boundary of the downstream destination FIR.

FIGURE 3
Integration of AireonFLOW into AMAN system.



Solution benefits

Optimised aircraft metering of traffic allows air traffic controllers to efficiently manage incoming flights to make best use of available and airspace capacities. E-AMAN provides decision support for all controllers managing arrival traffic. With the precision and consistent supply of position reports of flights, the accuracy of trajectory modelling for flights is greatly enhanced. The E-AMAN system will use the ETOs to calculate the sequence of aircraft arriving at a TMA or an aerodrome. Efficient sequencing will relieve controllers from making excessive speed adjustments, radar vectoring, or levelling-off (disrupt CDO) for arriving flights. This will lead to less stress placed both on ATC and pilots. Capacity of airspace and throughput of runways will also be increased. All this leads to more efficient operations.

It is quite evident that using accurate upstream flight position reports contributes significantly to optimised AMAN practices.

Further benefits are listed:

- Upgraded TMA planning and management by extending the AMAN planning horizon to the enroute environment.
- Global space-based air traffic surveillance grade ADS-B data supplied with low latency and configurable update rate.
- Single source of data reducing costly integration.
- Easy transmission of data via the internet.
- Increased efficiency in highly complex TMAs due to early and small speed adjustments during the enroute flight phase.
- Increased terminal airspace and runway capacity enabled by longer-term optimised streaming and sequencing of arrival flights.
- Reduction of speed adjustments, radar vectoring and extended downwind legs inside terminal airspace.
- Increased predictability and sequence stability due to decreased uncertainties in the terminal demand prediction.
- Associated early-delay-reductions minimise the required time in fuel-intensive holding stacks.
- Improved environmental sustainability resulting from significant fuel savings, reduced emissions, and noise.

Summary

This paper has shown that arrival management can be significantly more efficient with the Frequentis Extended Arrival Manager integrating AireonFLOW globally-available, high-fidelity, and low-latency ADS-B data as the source of position data. By deploying this solution, the operational horizon of E-AMAN is symmetrically extended well beyond the FIR or AoR. Thus, arrivals are sequenced earlier by speed adjustments during the enroute phase of flight, at more fuel-efficient altitudes. Delay is absorbed enroute rather inside the TMA resulting in enhanced safety and capacity, reduction in fuel, and environmental impacts.

With Extended AMAN powered by AireonFLOW, ANSPs have a robust planning system in place to achieve significant improvements to the efficiency and environmentally friendliness of their arrival operations.

FREQUENTIS AG
Innovationsstraße 1
1100 Vienna, Austria
Tel: +43-1-811 50-0
frequentis.com