The advanced cockpit of the Airbus A380 features the latest interactive displays and avionics. Satellite telecommunications will be an integral part of the new European air traffic management system for safety communications in most phases of flights (Airbus/exm company/H. Gousse)
SAFE SKIES

Iris: satellite communication for air traffic management

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On busy days, more than 33,000 flights are being controlled in European airspace, and the numbers are only expected to increase. By 2020, the number of yearly controlled flights is estimated to reach 17 million.

But while flights have increased, the way air traffic is managed has not progressed as swiftly. Communications between pilots and air traffic controllers are still mostly passed by voice over VHF or HF radio, which has been in use since the 1950s. Initial limited datalink services are starting to be introduced for safety communications with technology developed in the 1980s.

Management of European air traffic has not yet been fully integrated. In fact, Europe’s air traffic management (ATM) system is organised on the basis of more than 60 different sectors, all controlled individually.

SESAR

In recognising the need to modernise Europe’s ATM, the European Commission (EC) initiated the Single European Sky (SES) Policy. Part of the policy includes its technological pillar – the Single European Sky ATM Research Programme (SESAR). SESAR aims to develop a high-performance ATM system to
enable the safe and environmentally friendly development of air transport.

Through the planned improvements, SESAR has an objective to save between 8 and 14 minutes per flight, as well as, up to 500 kg of fuel and up to 1575 kg of CO2 on average. SESAR plans also to reduce the ATM-related cost by half.

Since 2007, a Joint Undertaking (SJU) manages the SESAR programme. The SJU, with Eurocontrol and the European Union as founding members, is funded one third by the EC, one third by Eurocontrol and one third from its members (industry, air navigation service providers and airports) with a budget of €2.1 billion. Fifteen members from the ATM industry have become members of the SJU. It coordinates and concentrates all relevant research and development, and is the design authority for the new European ATM System (EATMS). The SJU maintains the ATM master plan and the SESAR work programme.

In 2008, the value of satellite communications in the new ATM scheme was recognised through its inclusion in the ATM master plan. ESA played a large role in this recognition through its Iris Programme. ESA initiated Iris in 2007 as a means to support the adoption of satellite-based communications in the SESAR programme. It demonstrated the interest and feasibility of a satellite-based communication system to meet aviation’s requirements.

While satellite communications on board aircraft have been used for passenger communications for many years, they are not allowed as a primary means of communication for safety. What is fundamentally new with the concept of operations developed by SESAR is that it uses satellite communications as an integral part of the new European ATM system for safety communications, and in most phases of flights. Aircraft will be able to communicate while en route at cruising altitude, but also during take-off and landing, and while manoeuvering close to airports. This is fundamentally different from today’s use of satellite communications and was – until now – not guaranteed with existing technology.

ESA is now implementing the design phase of the Iris programme with the support of the EC, SJU, Eurocontrol, the European space industry, air navigation service providers and aviation stakeholders.

**A unique window of opportunity has been opened to develop a space-based solution to improve the safety of the European sky for citizens and benefit the European economy.**

With the inclusion of satcoms in the ATM master plan, a unique window of opportunity has been opened to develop a space-based solution to improve the safety of the European sky for citizens and benefit the European economy. Considering that any technology for aviation safety is expected to have a lifetime compatible with that of commercial aircraft, SESAR represents a once-in-a-century opportunity to introduce satellite-based communications in ATM.
New digital communications to increase air traffic efficiency

Provisions for the growth of air traffic and for the need of cost-reduction are driving aviation to adopt new digital communication technologies for the exchange of data between aircraft and ground control. A new concept of operation will be relying on the implementation of new features for aviation safety. One of the main elements of the ATM concept, known as ‘4D trajectory management’ will manage flights more efficiently, and provide better integration of aircraft in the ATM system. Other major pillars of the concept include the principle of system-wide information management and automation increase.

New air-ground links will be required to provide more capacity and higher performance. The design of these links, together with the necessary business case, will be assessed and their use validated during the development phase of SESAR. Since data communication exchanges will become critical to maintaining efficient operations, the service will need to be constantly available. The technology therefore needs to be resilient, and the best way to guarantee this resilience is to have several independent communication means operating simultaneously.

Three new wireless communication technologies for air-ground links are therefore being developed within the SESAR programme:

- a ‘ground-based segment’ using line-of-sight connections between aircraft and ground stations and between aircraft, which will be used in continental airspace;
- a ‘satellite-based segment’ connecting aircraft and ground systems through a satellite infrastructure, which will complement the ‘ground-based segment’ in continental airspace and be used as primary means of communication in oceanic and remote airspace;
- a ‘dedicated airport segment’ based on WiMax standards, which is connecting aircraft and ground systems while aircraft are at the airport.

In continental airspace, the new satellite communication system will be used together with the new ground-based system. Since these two technologies have no common point of failure, the service will be constantly available by using at least one of the links. Satellite communications will be needed for datalink in continental airspace, both in high-density airspace and in remote areas, as well as being foreseen to become the primary means of voice and datalink communications in oceanic airspace.

Once SESAR confirms this approach and recommends the deployment of the technology, implementation of these links for operational use will take place from 2018 onwards, depending on the maturity of the technology. In order to introduce new datalink applications that would improve air traffic flow for all, it can be expected that the use of datalink services would be mandated for all aircraft flying under Instrument Flight Rules.

Northern flights

Air traffic is increasing over polar regions. However, reception of signals from geostationary satellites is poor in these areas. To overcome this problem, the satellite system being designed in Iris opens the possibility to use the same communication protocols on satellites in highly elliptical orbits (HEO), which would complement geostationary satellites. Such a satellite constellation would provide good coverage of Arctic polar regions and could carry payloads for ATM communications. Projects of HEO constellations are being studied in Russia and Canada.

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Iris: a collaborative endeavour

Iris is a new type of initiative for ESA in which the space component is just an element in a much bigger system, and where ESA has to adapt to the schedule and constraints of a much wider initiative and a variety of stakeholders.

While SESAR is federating aviation stakeholders in the SJU, Iris is supporting and federating the European satellite industry to provide the most efficient space-based solution. The collaboration between ESA and the SJU is based on a clear definition of work packages and their interfaces, both technical and managerial. ESA’s approach is to ensure that most of its research and development funding goes toward the space industry, which ESA is meant to support.

At the technical level, Iris requires innovative developments to meet the stringent performance requirements of future ATM safety communications on the one hand, and the business requirements of the airlines on the other. The former requires a very robust communication system and specific design to guarantee service availability in all flight conditions and on a 24/7 basis.

The latter requires drastically reducing the overall cost of ownership of the aircraft terminals when compared to today’s most advanced satellite communication technology. An important issue to consider is that airlines would request that safety equipment does not require frequent exchange or major modifications during the aircraft’s operational lifetime, which is, on average, about 30 years.

The Iris programme covers the technical effort but also all the institutional coordination effort necessary to assure that the system fully meets users’ expectations. While it is part of the SESAR programme to standardise technology and to define the path towards service deployment for the new datalinks, for all matters concerning the satellite communication component, the Iris programme has to provide the necessary technical inputs and coordination support to the SESAR Joint Undertaking.

Since the inception of Iris, ESA has involved the best competences in the aviation, telecom research and industrial communities to make sure that the lessons of the past are applied and that a wide community participates and shares the decisions to be taken. Taking full account of the lessons learnt of previous programmes, Iris involves future users...
in consolidating technical requirements, and the European Aviation Safety Agency (EASA) in clarifying requirements for the certification process.

It is the first time that a communication system is intrinsically conceived to be made immediately available all across Europe once deployed. The space component is just one element among the technologies foreseen in SESAR. However, since space systems cannot be ‘test-flown’, and are pan-European by nature, the deployment of satellite communication services leads to more complex issues than for systems deployed on a national basis, notably in terms of governance of the service provision.

Taking due account of this complexity, ESA is carrying out analyses of the business case with several potential future service providers, analyses of options for future ownership and service governance with SJU and the EC, and analyses of options for liability schemes with legal experts.

Because the aviation world operates on a global basis, any new ATM solution must be supported and coordinated on a worldwide basis. ESA’s objective is to help the aviation authorities to deploy a globally valid solution that can be implemented in a modular way, supplied and operated by different parties. As a public institution, ESA sponsors the development of a truly open standard, fully in line with the Intellectual Property Rights rules of the International Civil Aviation Organization (ICAO), to promote a larger diffusion of space-based services than the quasi-proprietary and incompatible standards that are available in aviation today.

Standardisation at the level of ICAO requires coordination with the international stakeholders leading to support for this new standard. It will ensure afterwards that various world regions can deploy their own compatible satellite system infrastructure to allow aircraft to operate worldwide with the very same communication equipment.

Through ICAO standardisation, Iris will promote a European-developed standard and the associated technology on the worldwide market. A decision to deploy the satcom component developed in the Iris programme will exploit a ‘first-mover’ advantage for Europe: SESAR will bring the benefits of innovative technology to improve air–ground exchanges within European airspace.

**Innovative technology at low cost to airspace users**

Overall, the system designed within the Iris programme has to address:

- development of technical specifications for a new satellite communication standard;
- design of the user terminals to be installed on board aircraft and of the satellite system infrastructure for service provision in European airspace;
- design and procurement of the validation infrastructure required.

Design of the satellite system started in 2009, after two years of feasibility analyses. Most of the technical challenges revolve around designing appropriate communication protocols that guarantee integrity of the information exchanged while serving all aircraft simultaneously and maintaining the delay and reliability requirements.

A major element to dimension the system is the maximum data traffic generated by all aircraft flying simultaneously at any peak time within the service coverage of the satellite system. This data traffic determines the bandwidth and the spectrum required by the system, and a map of its geographical repartition is required to optimise the satellite beam sizing. Considering the geography of European air traffic flow, the highest density of air traffic is currently confined within a small geographical area between London, Paris, Frankfurt and Amsterdam.

Overall, technical challenges originate from the fact that data are generated by a large number of users at unpredictable times, that messages are infrequent and very short, and that their timely delivery and their integrity is critical. This is a very different set of characteristics than what most communication systems deliver (notably internet access or telephony for passenger communications), and this requires developing very specific communication protocols. As the exact characteristics of individual messages for new SESAR concept elements (e.g. 4D trajectory management)
are currently under definition by the SESAR Programme, the
design also needs to be sufficiently flexible to accommodate
new types of messages to be introduced in the future.

The design of aircraft user terminals is focusing on ensuring
low cost. This includes procurement, installation, operations,
maintenance and communication services prices. The aircraft
antenna should be small and low cost, with minimal antenna
drag like today’s VHF antenna, as opposed to antenna used for
broadband satellite communications for passengers, which
are large, expensive and require more power. The location of
antenna on the aircraft fuselage and the location of indoor
units are being looked at on-board different aircraft types.

The aim is to minimise the cost of installing or retrofitting
equipment, and to ensure continuous availability of the
communication link even when the aircraft is manoeuvring.

User terminals are being given the central role in the system
design and every system-level design trade-off decision is taken
in view of reducing avionics equipment and service cost. From
a technology development perspective, the main enabler is a
High Power Amplifier technology with high efficiency gains and
low power consumption so that forced air-cooling of the indoor
unit can be avoided. This will allow installing terminals on many
different aircraft types, and would guarantee that they are still
usable in emergency conditions where onboard power is limited.
Aviation requirements for using a low-cost terminal moved the system complexity towards the space segment. The system relies on a satellite located in geostationary orbit, with necessary redundancies and spares.

The design and sizing of the satellite payload is a consequence of the maximum transmission rate from aircraft towards the satellite, which defines the size of the satellite antenna, and the number of simultaneous users coupled with the transmission rate from user terminals towards the satellite. Because there might be a need to have several service providers, the system has been designed with the capability to fragment the payload resources among several competitors. Because the service model has not been defined yet, the design has to cater for every option: there might be a single entity procuring the satellite communication system, but there might be competitive providers too, each with their own ground Earth station(s) anywhere within the service coverage area.

Two alternative approaches

Following a request from the European Commission, ESA split activities between those relative to the design of the system, and activities relative to operation/service provision. A system design study, called ANTARES (AeroNauTicAl RESources Satellite-based), defines a purpose-built system, while three competitive studies are preparing potential operators and service providers for future service provision. As an alternative approach, Iris also includes studies of adapting Inmarsat’s SwiftBroadband system for provision of a safety service (called SwiftBroadband-Safety). The main difference between these two approaches lies with the business model and the system’s governance.

Some crucial issues, of a non-technical nature, also need to be clarified for aviation to move ahead. These are, for example, long-term availability of the service, ability
to comply with ATM standardisation and certification requirements, stability of the airborne equipment during an aircraft lifetime, capability of the service provision model to comply with competition requirements and a fair rate charging policy to airspace users.

Other activities of Iris focus on detailed technical analyses; understanding aircraft manufacturers’ requirements, and facilitate the preparation of the safety case. Specific regulatory activities also support the worldwide effort to define aviation long-term requirements for satellite spectrum in L-band, in preparation of the ITU World Radio Conference of 2012.

For the past year, the system design studies have analysed the impact of the performance requirements defined in the document used as a baseline by SESAR, which had been developed jointly by Eurocontrol and the FAA and used as input by ICAO. The studies consider several possible system options and carry out a sensitivity analysis. The purpose of this trade-off exercise is to determine which requirements are driving the overall system design, and which requirements contribute most to the system cost and complexity. There are currently five main uncertainties on system-level requirements:

1 - Security requirements to protect the data transmitted i.e. integrity, authentication, encryption, non-repudiation and access control;
2 - Robustness to intentional and unintentional jamming of any given link of the satellite communication system;
3 - Capacity of the satellite payload in terms of amount of data traffic at peak times of use;
4 - Capabilities of the aircraft terminal in terms of power available while still fulfilling the constraint of operation without forced-air cooling;
5 - Architecture of the ground segment, considering either the possibility to have several service providers with distribution of elements among them, or concentration of ownership of all elements under a single entity in a single location.

Options for these five points are analysed in ESA studies and conclusions are provided to the SJU showing their impact in terms of spectrum requirements, complexity and cost of the satellite system infrastructure, cost of user terminals, etc.

Concerning availability requirements, a derivation of performance figures from safety considerations is performed in cooperation with EASA, addressing notably the software assurance level. Overall these requirements will be defined by SJU by iterating with the Iris design studies, to allow aviation to make informed decisions. This consolidation will allow Iris studies to define a technical baseline by end 2011, and to progress in detailing the design and its associated cost. Once these elements are known, ESA will be able to prepare its proposal for further funding of the Iris programme in due time for the next Ministerial Council in 2012.
Deployment plans towards service provision in 2020

The master plan produced by SESAR indicates initial operation of the datalink for high-density continental areas in 2020. Besides being technically optimised for the air traffic of high-density areas in European airspace, this satellite system has to be defined, procured and operated according to the Single European Sky (SES) legislation. But before operational deployment can take place, the system must first be verified and validated, and aircraft equipment must undergo the airworthiness certification process that ensures it is safe for flight.

The validation infrastructure needs to be as close as possible to the system to be deployed operationally, so that the service can be tested in representative operational conditions. It will be developed and procured in the Iris programme, with support from the future owner of the operational system. Given the inherent costs of deploying a GEO system, is it likely that this infrastructure will not be used only for technical validation, but will later support the certification of the service provider and become a first building block of the operational system. The early deployment of space assets will also have a positive effect on the take up of user terminals and facilitate the allocation of satellite spectrum.

The European Commission is currently working on a proposal for the deployment of SESAR. With Iris, ESA Member States are placing satellite communications at the forefront of the world aviation industry modernisation programme. Iris will contribute to societal benefits in terms of industrial growth, environment protection and especially aviation safety, and prepare European industry and operators to consolidate and further their leadership in the field. The use of satellites for ATM safety and communications will be a major confirmation of the value of space as a means to benefit European citizens. As a component of the future ATM system defined by the SESAR programme and endorsed by ICAO, satellite communications will contribute to the safety, economic growth and environmental sustainability of a very important economic sector.

ESA’s air traffic management programme is named after Iris, the swift messenger goddess in Greek mythology. Daughter of Thaumas and Electra, Iris was a winged figure, associated with communication, messages and new endeavours. Iris appears in Homer’s Iliad, when Zeus sends her to convey his orders to the other gods and to mortals, when Hera sends her to Achilles, and on other occasions appearing disguised as a human to convey information.

For more information: telecom.esa.int/iris