The vision of 'free flight' trajectories is now on course to become a reality in Europe and the US by 2020. The technologies required to make this possible, and the financial benefits to airlines are explained.

Europe's & the US's new ATM plan for 'free flight' trajectories

The Air Traffic Control (ATC) system used around the world has been the same for decades. This has been based on pilots filing flightplans prior to a flight. These have indicated their desired routeing, altitude and speed. ATC is provided with this flightplan prior to an aircraft's departure, and is then tasked with maintaining aircraft separation via the use of secondary surveillance radar (SSR) identification and voice communication via radio while the aircraft is in flight.

The visions of a modernised ATC system is to have aircraft defining their own optimum flight paths in terms of a direct routeing, and the optimum altitude and speed. The complete trajectories of flights from the departure to arrival gate will be determined by upgraded flight management systems (FMSs) on the aircraft. These free flight trajectories will thus constitute 4-D 'free flight'. This will be accompanied by aircraft maintaining their own separation from others most of the time. Datalinks will make it possible for aircraft to communicate with each other, and pilots will see other aircraft in their vicinity by displays on flightdeck navigation screens. The main efforts aimed at modernising ATC are the Single European Sky Air Traffic Management Research (SESAR) in Europe, and NextGen in the US. The plan is to have these in place by 2020.

While avionics technology has constantly developed, aircraft are still restricted from flying optimised routes. The main technologies that have emerged which are central to making 4-D free flight possible are Automatic Dependent Surveillance Broadcast (ADS-B), Global Positioning System (GPS) satellite navigation, Controller-Pilot Data Link Communications (CPDLC), and upgraded FMSs.

Replacing radar

The vision of 'Free Flight', which allows aircraft to manage their own flight trajectories, has been around for many years. It includes the concept of aircraft being able to see other aircraft, and thus maintain their own separation.

With GPS navigation making it possible for aircraft to accurately know their position and altitude, it makes sense to broadcast this and other information to any other aircraft or ground station.

This is the idea behind ADS-B. Automatic because it is always on, requiring no operator intervention; Dependent on GPS for position information; Surveillance because it provides visibility of other aircraft; and Broadcast because the aircraft continually broadcasts its position and other data.

Broadcasting from the aircraft is referred to as ADS-B 'Out', while receiving similar information from other aircraft and the ground is referred to as ADS-B 'In'.

The current system of Mode A or C transponders to send four-digit squawk codes to transmit basic information; such as aircraft identification, heading, speed and altitude; will be replaced by Mode S aircraft addresses. These are ICAO 24-digit addresses unique to each aircraft.

"The technology for ADS-B is not as complex as for datalinks, which are also part of the new ATC system. Most aircraft already have a transponder which is ADS-B capable," explains Alex Wandles, head of the SES technology department with Eurocontrol. It is then a case of upgrading software, although the aircraft also needs GPS. "With datalinks it is as easy as sending an SMS (text message), but ADS-B is even easier, you just turn it on."

Mode S enhanced surveillance allows air traffic controllers to access the Downlink Aircraft Parameters. These are selected altitude, roll angle, track angle rate (or true airspeed), true track angle, ground speed, magnetic heading, indicated airspeed/Mach number, and rate of climb/descent. This is more information than that provided by Mode A/C transponders. Mode S also means controllers will have better situational awareness, and so there will be less need for voice communications.

Wandles says the EU Implementing Rule (IR) for introducing Mode S is still in draft form, so Eurocontrol is working with the EU and other stakeholders to get it introduced. It has been delayed because of a problem with agreeing aircraft identification. "Our intention was to mandate ADS-B by 2015, but that may slip a bit now," says Wandles.

To date there have been ADS-B trials with various European air navigation service providers (ANSPs) under the CRISTAL programme, which was completed in 2008.

Funding for fitting ADS-B has been going for around for four years, so there are a few with ADS-B equipment. All Ryanair aircraft are equipped, along with aircraft of Air France, KLM, Lufthansa, Turkish Airlines and Air Europa. This is under the CASCADE project's Pioneer Airline programme, which is following on from CRISTAL, where the greater situational awareness afforded by ADS-B is being proved.

ADS-B is cheaper, because ground infrastructure can be reduced. NDB and VOR beacons, for example, will be decommissioned over the next 10 years as aircraft are able to use GPS positioning for navigation, and ground controllers will be able to receive information via ADS-B.

Instrument landing systems (ILSs) will

The vision of 'free flight' trajectories means pilots will be able to fly aircraft on the most optimised paths, speeds and altitudes. These will be shorter and burn less fuel than the current system of flying via airways.

remain as back-ups for landing, because satellites cannot be relied upon 100%.

"The next step with ADS-B is aircraft-to-aircraft communication for maintaining separation, but that will start with in-trial flights over the oceans," says Wandles. "ADS-B means that pilots only ask to climb when they can see it is possible". Beyond that, he says, separation responsibility will be delegated to aircraft from the oceanic controller. Suitably-equipped aircraft will manage separation using the information they have on other traffic. That is five to six years away still, says Wandles. "These advances will only be used over oceans, Africa and other remote regions with low traffic volumes, but not in dense traffic environments," he adds.

ATC use of datalink

While ADS-B promises a low-cost and universal replacement for radar and SSR, digital communications also offer the ability to communicate between aircraft and controllers on the ground without using voice.

The logic is that the majority of the requests and instructions passed between the two could be replaced by text-type messages carried by 'datalink'. CPDLC was conceived for this. This promises to overcome many of the shortcomings of voice radio communications, such as misunderstandings.

CPDLC relies on datalinks, and there is already an EU IR in place (Regulation 29/2009) making it mandatory for aircraft operating above FL290 to have compliant equipment by 1st January 2011, and for all other aircraft to have been retrofitted by 7th February 2015.

Wandles says that the IR for CPDLC required the use of ICAO VHF Data Link (VDL) Mode 2. The CPDLC can send text messages at 10 times the speed of the aircraft crew and reporting system (ACARS) links currently in service. He says that about 10% of aircraft are currently capable of VDL Mode 2. Wandles says that "Airbus and Boeing are basically ready in that new aircraft are equipped and retrofit options are available. The problem cases are Embraer and Bombardier aircraft, since they have been late in fitting VDL radios and implementing the pilot interface."

Wandles says that CPDLC has been operational with the Maastricht Upper Area Control Centre (MUAC) since 2002, allowing a large amount of experience to be gained with a small number of aircraft, from A318s to 747s.

According to Wandles "the cost of retrofitting compliant datalink capability is difficult to estimate. It is perhaps between Eur10,000 and Eur80,000 ($15,000-120,000) for old aircraft, which need some new wiring and aerials. The pioneering airlines have been funded by us for a long time to equip their aircraft, but we are now trying to get EU Trans-European Transport Network (TEN-T) funding. We are waiting for the final EC decision, but it looks good."

While datalinks/CPDLC have been a focus to reduce controller workload for a long time, aircraft systems have become far more capable. Modern aircraft have FMSs which can, for example, calculate 4-D, optimum flight paths that provide more direct routeings which save time and fuel. This also requires the aircraft to be able to 'de-conflict' itself from other traffic, rather than relying on the age-old method of using different assigned altitudes depending on direction of flight.

The ability to fly so-called 4D flight paths by flying in 3D space with added control over time is another aspect adding to the safety of using 'optimised' flightpaths. If the aircraft trajectory is known then it can be centrally 'de-conflicted' against other aircraft trajectories as they progress.

The Single European Sky

Europe has some of the most congested and inefficient airspace, and has suffered for many years from having numerous national Air Navigation Service Providers (ANSPs).

This led in the 1990s to the idea of a Single European Sky (SES), and a European Community SES Regulation followed in 2000. As the requirements for SES were defined by Eurocontrol, development also continued on the range of technologies that would make it possible. These included CPDLC, 4D flight trajectories and ADS-B.

Work on SES led to the launch of the SES Air Traffic Management (ATM) Research Programme ('SESAR'). This has the task of bringing all the technologies together to develop a single airspace system.

SESAR is the European ATM modernisation programme, which will use the EU SES legislation to synchronise the plans and actions of the different stakeholders. This, in theory, should overcome national boundaries and self-interest, and achieve the 'ATM Target Concept for Europe'.

Last year the SESAR definition phase (2005-2008) was completed and the programme moved into its Eur1.9 billion ($2.7 billion), seven-year development phase (2008-2015). This aims to achieve a 35% airspace capacity increase as a first step towards the ATM Target Concept in 2020. The main feature of this concept is the use of '4D' flight trajectories. This will require the current ICAO Flight Plan to be changed to incorporate time constraints. CPDLC underpins the ability to fly 4D, because it provides a robust, continuous link between aircraft and ATC as the flight trajectory is planned and managed.

SESAR work packages

SESAR consists of 16 work packages (WPs) to make SES a reality. These include WP4 (En Route Operations),

While navigation beacons will no longer be required under the new ATC system, ILSs will remain in place for landings. Aircraft will be able to fly continuous and curved approaches, however.

WP5 (Terminal Operations) and WP9 (Aircraft Systems). These WPs will start to bring together the technologies required to achieve the ATM Target Concept, based on 4D flight trajectories. This will include advancing the use of datalinks for CPDLC, since this is a key enabling technology, and ADS-B for situational awareness.

Airbus is leading WP9 and so is coordinating the various projects which it contains, and the participants. Olivier de la Burgade, senior manager in the ATM engineering department at Airbus and the overall WP9 leader, says the manufacturer will be working closely with Thales, Honeywell and Alenia on the projects. "WP9 deals with the airborne segment of all the new capabilities in the ATM Master Plan. At the moment there are 30 projects, and we have launched 12 of them. We will launch 12 more in September and October 2009," says Burgade.

On 15th September 2009 Airbus delivered the WP9 Work Plan to the SESAR JU. It also signed technical cooperation agreements with several airlines; Novair, a consortium coordinated by EBAA including Netjets and Dassault Aviation; as well as IATA and IAOPA. This was part of the need for SESAR to fully engage the industry.

Equipment testing

Airbus's central role will include developing simulations and mock-ups. "We already have several projects with mock-ups in the aircraft results simulator. The second step will be the prototypes in the integration simulator, with real hardware," says Burgade. The last step in many of the projects will be flight trials, he adds, "probably on the A320 since it is the aircraft that represents most traffic."

The first flight trial will probably be in 2010 to test 'Initial 4D', which is the main project within WP9. As the name suggests, Initial 4D will be an interim capability on the way to 'Full 4D' capability. Much of the required functionality can be achieved via software upgrades, mainly to the FMSs, on the more modern aircraft.

Burgade says that 4D means that aircraft are capable of "time-constraint accuracy where navigation and communications are addressed together, which results in improved accuracy in flight trajectory and time of arrival". Coupled to this is the Reference Business Trajectory (RBT), where the airspace user agrees with ATC a flight trajectory and maintains that trajectory in space and time, and does not deviate beyond certain tolerances. The main benefit will be a Controlled Time of Arrival (CTA), which will allow ATC and airports to manage capacity better.

Achieving Full 4D will be "a very big step," says Burgade, "The aim is for both new-build and older aircraft, such as A320s, to be equipped for initial 4D. Equipment allowing Full 4D will probably not be retrofitable to aircraft such as A320s."

After 'Initial 4D', the second major project in WP9 is Airborne Separation Assistance System (ASAS). This will use ADS-B 'In' and 'Out' communications, with cockpit navigation displays showing other aircraft, and allow aircraft to 'self-separate' from others. This will mean that, provided all other aircraft are also ADS-B equipped, collision avoidance will be possible anywhere around the globe, since radar will not be required. This project will draw on the EC-funded ASAS Thematic Network 2 project.

Capability levels

WP9 focuses on the aircraft systems elements covering the development and validation of the airborne 'enablers' (the various technologies on the aircraft and within the ground infrastructure) to support operational improvements (OIs). This is in association with each of the capabilities in ATM capability levels CL1, CL2, CL3 and CL4, depending on the capability of the equipment fitted to a particular aircraft.

The Capability Levels (CL) are as follows:

CL1: Capabilities of existing systems and those delivered up to 2012/2013, having largely 'today's capabilities'.

CL2: Capabilities of systems delivered and in-service from 2013, having a range of new capabilities, but which do not fully meet the 2020 needs.

CL3: Main capabilities required by the key SESAR target date of 2020. These will be based on the SESAR concept needs at the time and a realistic assessment of potential capabilities.

CL4: The advanced capabilities that potentially offer the means to achieve the SESAR goals, in particular the very high-end capacity target. The timeframe for initial availability and progressive equipage is in the range 2025+.

According to Airbus, the principal evolutions of the aircraft platform within the 'CP' framework concern:

- 4D Trajectory Management functions will be progressively introduced. Initial steps include the improvement of the required time of arrival (RTA) function. Within aircraft CL3 is the ability to take into account multiple time constraints. Also, more complete and real-time meteorological data will be implemented, providing full gate-to-gate 4D trajectory management by CL4.

An element of the new vision for ATM is aircraft maintaining their own separation from other traffic. This will be possible by ADS-B, that will allow the position of other aircraft to be displayed on flightdeck navigation screens.

- ASAS develops progressively from the airborne traffic situational awareness (ATSAW) functions. That is, to give pilots a clear image of other traffic. This is to improve awareness, through spacing to optimise terminal manouevering area (TMA) operations, and finally traffic separation delegated to the cockpit.

- Approach functionalities are progressively enhanced to provide improved all-weather operations, through to the addition of new functions and technologies. These are items such as the ground-based augmentation system (GBAS). This makes GPS more accurate using known fixed points on the ground, and enhances visual systems (EVS) and wake vortex detection.

- Surface movement operations are improved through the introduction of functions to initially provide guidance, and then provide automatic taxi functionality such that pilots can be guided without voice instructions and with minimal involvement from ATC.

A key consideration for the 4D ATM philosophy to be successful is that non-4D equipped aircraft must be supported in their navigation. Whereas 4D equipped aircraft are generally able to cope with deviations from their planned trajectories, non-4D equipped aircraft are not capable of these deviations. Considering that a large portion of the total fleet will not be equipped with 4D FMSs between now and the year 2015, a ground supported navigation function to assist non-4D FMSs aircraft is being developed under Eurocontrol's PHARE programme.

NextGen in the USA

The US realised the benefits of rolling out similar technology nationwide across the US, and launched a modernisation programme in response. This ended in disaster, however, and was abandoned, after a cost of $3 billion, because of its centralised approach. The NextGen programme has made such good progress, however; the first stages coming in on time and under budget.

Paul Takemoto spokesperson for the Federal Aviation Administration (FAA) says: "Tests have already started over the Atlantic. ADS-B is already being rolled out here in the US. We have 11 ground stations in South Florida, and pilots with proper avionics are getting free uplinks."

He adds that countrywide ADS-B coverage will take place by 2013 "and there is a rulemaking coming" relating to aircraft equipage. A final rule can be issued in 2010, requiring aircraft to be properly equipped in controlled airspace by 2020.

"There is a 10-year compliance date, because everyone needs to retrofit, although newly delivered aircraft will be ready to go," says Takemoto. "It's a big deal for companies to figure out what to retrofit, including all the corporate and general aviation people."

United Parcel Service (UPS) fitted over 100 aircraft voluntarily to see if it could recoup the costs at its Louisville hub, which it did by using more efficient Continuous Decent Approaches rather than the traditional stepped approaches using ATC letdowns.

"Half of the current US radar structure will remain as a backup for the ground segment," says Takemoto. "All aircraft rolling off the production line now are close to being equipped with what you would need for NextGen."

Transatlantic cooperation

The FAA and the EC launched a co-operation programme at the 2007 Paris Air Show; the Atlantic Interoperability Initiative to Reduce Emissions (AIRE). This is aimed at ensuring commonality between NextGen and SESAR.

Initial participants were Airbus, Boeing, Air France-KLM, Delta Air Lines, FedEx, UPS, Virgin Atlantic, SAS and the Irish, Swedish and Portuguese aviation authorities.

Testing of the first aircraft equipped with NextGen avionics on Atlantic crossings was started in June this year on an American Airlines transatlantic flight.

American Airlines is investing $2.2 million per aircraft to allow datalinking and optimised flightpaths via short-term equipment upgrades, including FMS software. It has been testing the equipment on 777s out of Heathrow and Madrid to Miami," says Takemoto.

Takemoto does not believe the transition will be painful in the end, given that work between the US and Europe, and between the US and Asia Pacific is going so well. Japan is joining in trials soon, he adds.

"The trans-Pacific tests will be similar to the transatlantic tests. That is, geared towards optimised flight profiles, with enormous emissions savings." He says that there is not a large enough set of test data, or aircraft population, to be able to calculate the savings yet. "But the tests that have been done show that they will be substantial," says Takemoto.

He gives an example of the advantages of US airspace. "Over the Gulf of Mexico we have to sanitise 100 square miles of airspace for each aircraft (keep free of other aircraft), and wait 10 minutes after each aircraft." Satellite technology allows this to be virtually eliminated.

There is now real progress being brought about by NextGen and SESAR. Only when the majority of the fleet is flying optimised flight profiles will the full savings be realised, and that will not be until at least 2020. AC