While there are a large number of flightdeck and cabin connectivity systems for airlines to choose from, most aircraft are still restricted to using low-speed and high-cost communications channels. Broadband systems are available that increase transmission rates and reduce costs.

Improving connectivity for the future aircraft

Connectivity and e-enablement systems for aircraft continue to evolve. There are several developments that will influence aircraft connectivity in the future.

Existing connectivity

Aircraft connectivity systems are used in both the flightdeck and the passenger cabin. There are several types of connectivity systems, and each has a large number of possible uses or types of communications and transmissions.

Connectivity systems for the flightdeck and flightcrew are more varied and complex than those used in the passenger cabin. Several types of communications to and from the flightdeck utilise different connectivity systems *(see The applications of flightdeck connectivity systems, Aircraft Commerce, October/November 2013, page 13)*.

The first category of communications is air traffic services (ATS) messages, including air traffic control (ATC) and other transmissions. One development over the past 20 years has been controller-pilot datalink (CPDLC) data and text messages for use in ATC.

All ATS communications relate to safety-of-flight. All ATS messages have the advantage of having a low data volume and not requiring a high rate of transmission. All types of ATS data messages are listed *(see table, page 16)*.

The second type is airline operation communications (AOC), which relate to airline operations and associated tasks.

AOC transmissions include engine health monitoring (EHM), aircraft health monitoring (AHM), flight data monitoring (FDM) and flight operations quality audit (FOQA) data, central maintenance computer (CMC) fault codes, non-CMC faults, flight management system (FMS) database uploads, and communications to and from electronic flight bags (EFBs) and electronic technical logs (ETLs).

All types of AOC data messages are listed *(see table, page 16)*. Several types of AOC communications involve large data volumes, including the downloading of AHM, EHM data, FDM and FOQA data, graphical weather information, FMS database uploads, and EFB and ETL uploads and downloads.

The third category is airline administration communications (AAC), which relate to administration, rather than operational, issues. These include crew manifests and rosters.

AAC messages and communications involve large volumes of data like chart and loadsheet database uploads. These are summarised *(see table, page 16)*.

The fourth category is air passenger communications (APC), including the transmission of news and sports items for passengers' interest *(see table, page 16)*.

Connectivity systems

There are several flightdeck connectivity systems available to aircraft today, including very high frequency (VHF) and high frequency (HF) radio, Classic Satcom based on L-band frequencies offered by Inmarsat and Iridium, and higher-speed Swift broadband (SBB) Satcom offered by Inmarsat. All are for use while the aircraft is in the air.

In recent years Ku- and Ka-band Satcom systems, which have the highest Satcom transmission rates, are now being used for some flightdeck transmissions by a small number of airlines.

There is also WiFi and cellular for use when the aircraft is on the ground.

The aircraft communications addressing and reporting system (ACARS) was the first data transmission system to be developed. It entered service in the late 1970s, and is based on ARINC protocols. ACARS is robust and reliable. It is the only system approved for safety-related ATS transmissions.

ACARS messages can be sent by VHF and HF radio, and by Classic Satcom. Inmarsat SBB will be approved to send ACARS messages later in 2014. ACARS is not permitted to be sent via Ku- or Ka-band Satcom.

ACARS is also the data format that is used to send AOC, AAC and APC messages by most airlines. These message are not safety-related, however, and so there is no legal reason or requirement to send them in ACARS format. AOC, AAC and APC messages can be sent by VHF and HF radio, and all forms of Satcom.

The two service providers for ACARS are ARINC and SITA. The data transmission rates of ACARS over all currently approved connectivity systems are low at 2.4 Kilo bits per second (Kbps), which makes it a relatively expensive means of transmitting data. Its slow speed does not compromise safety-related communications, however.

The industry has evolved data transmissions over more than 30 years around ACARS. As a result, there is a lot of ground infrastructure associated with the ACARS network. ACARS is still the main data connectivity system used by many airlines and for most aircraft, so it is also used for most data transmissions relating to AOC, AAC and APC.

Aircraft avionics

The basic architecture of an aircraft's avionics is that each avionics unit or box performs a particular function. Avionic boxes include items such as the autopilot, central maintenance computer (CMC), flight management system (FMS), AHM and EHM systems, and radios. These all communicate with each other via databuses. They are also linked to the

CATEGORIES OF FLIGHTDECK DATA COMMUNICATIONS & MESSAGES

Message category	Message type
ATS	Recorded DATIS messages Various ATC clearances Short- & long-range CPDLC messages
AOC	OOOI times Flight plans EHM & AHM data QAR/FDM data Crew messages CMC & nin-CMC fault codes Graphical weather Avionic uploads EFP uploads & downloads
AAC	Crew manifests & rosters Medical & airport requests Chart & loadsheet database uploads
APC	New items of interest to passengers Gate changes & connecting flight information

communication management unit (CMU) in Boeing aircraft, or the air traffic service unit (ATSU) in Airbus aircraft. The CMU or ATSU is linked to the various air-to-ground connectivity systems, such as VHF, HF or Satcom. The CMU or ATSU selects the available and cheapest connectivity system to send the ACARS message.

Internet protocol (IP) has been used extensively in various systems in the aircraft cabin, and to a lesser extent in avionics. IP's main advantage is that it has a higher data transfer rate than ACARS over Satcom. IP, however, has a different coding system to ACARS and ARINC protocols.

Ethernet is the physical link between devices and units that use IP. IP can also be transmitted wirelessly, by Inmarsat SBB and Ku-/Ka-band in the air, and by WiFi and cellular signals on the ground.

Some avionic units on new types, notably the A380, A350, 747-8 and 787, work on IP protocol. These types can only use a mix of ARINC and IP protocols, if they have a server-type avionics on-board network. An on-board network will become standard on 737NGs and 777s from 2014.

IP's weakness is that it is not as robust as ARINC protocol, so IP transmissions are not approved for ATS safety messages. IP can, however, technically be used for AOC, AAC and APC communications while in the air. The connectivity systems to make this possible would be Inmarsat SBB, Ku- and Ka-band. It has therefore become possible to avoid the bottleneck of ACARS's low transmission rate for AOC, AAC and APC messages.

"EFB communications use any connectivity system available, depending on the class of EFB," says Captain Michael Bryan, principal at Closed Loop Consulting. "Class 1 and 2 devices might use a combination of an ethernet connection, a USB stick, or WiFi or cellular on the ground to get their updates.

Improved Satcom

Inmarsat's SBB is a high-speed L-band Satcom system, and works on IP. It will also be approved to transmit ACARS messages later in 2014. It will have a transmission rate of 432Kbps.

SBB will send ACARS messages by encapsulating them in an IP envelope, and achieve faster transmission rates than ACARS over Classic Satcom. On legacy aircraft, this encapsulation process will be on a dedicated avionics unit functioning on ARINC protocols.

Inmarsat can be provided in several channels, each one serving a particular domain. These domains are, for example, ATS, AOC and passenger information and entertainment systems (PIES). The SBB terminal can address some or all of these systems, and the domains cannot mix with each other. This provides security between cabin connectivity and AOC communications.

Iridium has a new high-speed service for its L-band satcom called 'Open Port'. This will basically be a high-speed Satcom, with a transmission rate of up to 134Kbps in both directions. It will not be used for ACARS, however. It will be used for higher-volume transmissions, such as EFB uploads and cabin communications that will benefit from the higher transmission rate.

Iridium has additional services in development for 2016, including one where ACARS safety-related messages will be encapsulated in IP, and have a transfer rate of up to 1.5 mega bits per second (Mbps). This is about four times faster than Inmarsat SBB.

K-band satcom

In addition to VHF and HF radio, and L-band Satcom, air-to-ground connectivity is also provided by K-band Satcom. There are two types: Ku-band and Ka-band. "Both types suffer from 'rain fade', or attenuation by water droplets," explains Bryan. "It is probable that weather patterns will interrupt transmission."

Ku- and Ka-band are totally separate from the flightdeck on most aircraft, and are only be used to provide CABIN connectivity. Both types of K-band Satcom are permitted, however, to carry AOC, AAC and APC transmissions. Some airlines have started to partition the Ku-band connectivity between the aircraft's cabin and its flightdeck. The flightdeck connection is being used for two-way AOC transmissions.

Ku-band is available globally, and it has a transmission rate of at least 1-2 Mbps. Ku-band is provided by Panasonic, Live TV, Row44 and GoGo.

Panasonic provides 99.6% coverage of all airline routes around the globe, primarily for cabin connectivity. Its Ku-band is also used by Singapore Airlines (SIA), however, to provide flightdeck connectivity for AOC, AAC and APC transmissions. This is done by splitting the Ku-band connectivity into two domains: one for the flightdeck, and one for the cabin. AOC communications include two-way data for its EFBs. They are also used for transmitting health monitoring data.

Don DeBlasio, senior director of business development at Panasonic Avionics, explains that it is also working to provide an updated weather service via its Ku-band product.

Ka-band has a higher transmission rate of at least 3-4Mbps. One provider is Inmarsat.

Connectivity limitations

Despite the availability of Inmarsat SBB, Ku-band and Ka-band Satcom systems, there are still several limitations of flightdeck communications. The main limitation is that ACARS is still the only main in-flight data communication system available to most aircraft. The cost of sending AHM and EHM data via ACARS while the aircraft is in the air is high. Some airlines are paying $4,000-5,000 per month per aircraft.

"Some AHM and EHM data are sent via ACARS," says Bryan. "This is even the case with new-generation aircraft, such as the 787 and A350, and to a lesser

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Most aircraft are limited to sending AOC, AAC and APC messages by ACARS because they do not have broadband flightdeck connectivity systems. Inmarsat SBB is an option, and a small number of airlines have begun using Ku-band for AOC transmissions.

extent the A380 and 777. These new aircraft can send large volumes (about 0.5TB) of AHM and EHM data. Speed is limited by ACARS, which is why broadband solutions are being sought. These data are used for trend analysis, and do not have to be sent in real-time."

Although it is technically possible to send AOC, AAC and APC data messages in IP format, most aircraft are not equipped with an IP connectivity system. This can be supplied by Inmarsat SBB, Ku-band or Ka-band Satcom systems, or by an on-ground connectivity system.

Few airlines, however, have aircraft with these systems. Even though it is an option, the majority of 787 customers have not selected Inmarsat SBB. Several thousand aircraft do, however, have cellular on-ground connectivity systems. Despite this, their operators are still sending AHM and EHM data in the air, which is not necessary in most cases.

A main issue is that in-flight IP data communications are only possible for new generation aircraft that have a server, or legacy aircraft that have an avionics retrofit. Either of these will convert data from avionic boxes into IP format.

All data communications for most aircraft are therefore still made in the ACARS format. ACARS has the limitation of being slow and expensive compared to other current and future connectivity systems, however.

There are many types of AOC and several types of AAC communications that involve large volumes of data, and for which ACARS is too slow and expensive. Several AOC communications involve large data volumes, such as the AHM, EHM and QAR/FDM data downloads. They do not actually need to be sent while the aircraft is in the air. They can be transmitted when the aircraft is on the ground.

On-ground connectivity

On-ground connectivity systems have higher data transmission rates than in-flight connectivity systems. On-ground connectivity systems can therefore be used to download and upload large quantities of data, especially AOC communications.

Gatelink WiFi is a wireless system used by modern aircraft types with an on-board network server. The A380 was offered with WiFi as an option, and the 787-8 was offered with WiFi as standard.

The system uses standard IP, and requires the aircraft to be fitted with a terminal wireless LAN unit (TWLU), which is the transceiver equipment on the aircraft. WiFi antenna are also required at an airport terminal, however, so this has made the start-up costs high. The basic transmission rate is 11Mbps, but it can be as high as 54Mbps.

An alternative is using existing cellular signals. For cellular connectivity, the aircraft needs to be fitted with a unit that is an alternative to the TWLU used for WiFi. New generation aircraft, starting with the 787-9 and A350, will be fitted with a cellular avionic unit. The A380 and 787-8 were not offered with cellular on-ground systems as standard.

Legacy aircraft types can be fitted with units to provide cellular connectivity. This includes the wireless ground link (WGL) provided by Teledyne Controls, which has multiple cellular radios that turn on automatically when the aircraft lands. The WGL also has built-in applications so, unlike WiFi, does not need an aircraft server. WGL has a transmission rate of 100Kbps for uplink, and a higher rate for downlink.

The more advanced WGL Comm+ has four radios, an aircraft interface device (AID) and an ethernet switch. The ethernet switch allows it to connect with other devices that are based on IP, such as laptops or EFBs, and interface with the aircraft's avionics that are based on ARINC protocols. It also has server-like capabilities, and so can store data.

The server capabilities mean the WGL Comm+ can be retrofitted to a range of legacy aircraft. The ability to interface with the aircraft's avionics means that AOC, AAC and APC data can be transmitted on the ground.

The WGL Comm+ has a transmission rate of 23Mbps for uplink, and 84Mbps for downlink. These rates mean high volumes of data can be offloaded or uploaded to the aircraft in just a few minutes between flights.

The largest volumes of data to be downloaded post-flight include AHM, EHM, FDM, FOQA and QAR data. The largest volumes of data that have to be uploaded are for EFBs and ETLs, as well as navigation and other database data to the FMS.

Teledyne Controls now offers a hybrid TWLU, called the aircraft wireless lan unit (AWLU), that provides both WiFi and cellular on-ground connectivity.

Faster transmission rates

The introduction of the A380 and 787 saw much larger volumes of data being downloaded compared to previous aircraft types.

The highest-volume AOC data communications, as described, are EHM and AHM data downloads, QAR/FDM data downloads, CMC and FMS upgrade data uploads, and EFB downloads and uploads.

With the exception of weather updates, CMC faults, ETL transmissions and engine problems that have to be sent in real-time, and so would need to be sent by the relatively expensive ACARS channels, most of the data transmissions described can be downloaded from the aircraft post-flight using WiFi or cellular systems.

"QAR/FDM generates the highest volumes. This can be several terabytes.

EFBs of different classes do not use ARINC protocol connections, and can use any IP connectivity system available. They can use ethernet connection, WiFi or cellular to download data and upload revisions.

This is why most recorders store this information on board for later download by cellular," says Bryan.

Modern avionics architecture

The avionics architecture of legacy aircraft was based on an individual unit having a clearly defined function. ARINC protocols were used for all units, and updates or modifications to avionic functionality required the removal of one or several avionic units.

New generation aircraft have a different avionics architecture based on the use of a server. The aircraft that have this architecture are the A380, A350, 747-8 and 787. The server architecture on the Boeing aircraft is referred to as an on-board network server (ONS), while it is generally termed an on-board information system (OIS) by Airbus. The A380 was the first aircraft to feature a server architecture. It is called fly smart with Airbus (FSA) on the A350.

A server has several functions, the first of which is to interface with the avionic units. Some avionics on these aircraft operate on IP. The server determines what data is transferred between the avionics.

The server also has in-built interface devices to convert from one protocol to another. This makes it technically possible to make AOC, AAC and APC data transmissions, in the air and on the ground, in IP format, thereby avoiding the slow and expensive ACARS channels.

The server also interfaces with the aircraft's various air-to-ground and on-ground connectivity systems, and selects the cheapest and most appropriate system. Unlike legacy aircraft, these modern types do not have separate ATSU or CMU units, but the server has the same functionality. The server is thus interfaced with the ACARS system.

The server also hosts several applications. The first is a function for uploading revisions to avionics. Modern aircraft require high-speed updating capability because they have thousands of pieces of software. A server requires a mix of ARINC and IP to allow faster loading of applications. Some avionics are ethernet-loadable, which allows faster loading of software updates and revisions. There is now a high-speed ARINC standard for data loading.

The server also hosts ETL software. The flightcrew will access and use the ETL on the EFB hardware on the flightdeck.

One particular requirement for storing and transferring a high volume of data is FDM, FOQA and QAR. The aircraft's server stores these data. They can be downloaded via WiFi or cellular connectivity when the aircraft is on the ground. The same functionality is used for AHM and EHM data.

With the appeal of this server, Boeing has also made it standard specification on the 777 production line. It will also become standard on the 737NG by the middle of 2014.

Boeing offers 'server-centric' crew solutions for the 737NG, which will be a server platform that allows several things. The server hardware is provided by Teledyne Controls, and is the same as that used on the 747-8 and 777.

"One of the server's features is that it provides multiple ARINC databus and Ethernet interfaces," explains Willie Cecil, director of business development of aircraft network & wireless solutions, at Teledyne Controls.

The airline can then decide what applications to have on the aircraft: for example, EFB and ETL software. The objective of the server platform is to allow the airline to use any form of EFB hardware, and to enable sharing of other aircraft system resources. That is, it could be a fully installed Class 2 or Class 3 device or a portable laptop, tablet with an ethernet port or an iPad.

The server system can also be expanded wirelessly. It will have an extension of the server called a 'wireless access point', which provides a WiFi connection through a signal on the flightdeck and cabin.

One important issue of avionic server architecture is the ability to upgrade and retrofit legacy aircraft currently fitted with only traditional avionic standards. Aircraft manufacturers are likely to provide retrofit modification options through service bulletins (SBs), to those airlines that are interested. One potential issue with this is the limited or lack of physical space on these aircraft.

Legacy aircraft retrofits

Teledyne Controls offers products that can be retrofitted to legacy aircraft, and can provide some of the same functionality of new-generation aircraft servers. One is its WGL Comm+ product that has on-ground cellular connectivity. It also has a device for interfacing with avionics, and an ethernet router. Finally, it has server-like capabilities that allow it to store data and run several applications. It is not as sophisticated as the server systems on the A380, A350, 747-8 and 787.

Teledyne Controls also offers two other products; WGL AID and WGL Fi.

WGL AID is a software upgrade to the WGL Comm+ unit, and this provides an interface between ethernet and avionic units working on ARINC protocols. "The WGL AID upgrade allows certified and non-certified devices like tablets to share data and communicate with each other," says Cecil. "The WGL Comm+ is a mini server, but does not have the full range of capabilities that servers on new generation aircraft provide. While the airframe manufacturers manage the applications offered on the servers of new generation aircraft, Teledyne manages what is on the WGL Comm+.

"WGL Comm+ and WGL AID, allows the aircraft to transmit AOC, AAC and APC messages by broadband

Satcom while airborne or by cellular connectivity on the ground," adds Cecil.

Despite being built with server systems, there are new generation aircraft that have been retrofitted with Teledyne's WGL and WGL Comm+ units. Airbus provided the A380 with WiFi and cellular as options for on-ground connectivity, as well as a server with, for example, QAR functionality. Many airlines, however, use WiFi to download QAR data, but have also achieved cellular connectivity by installing a WGL or WGL Comm+ on the production line, purely for the purposes of QAR download.

The 787-8 only has WiFi, but Teledyne is developing a cellular retrofit for the aircraft. The 787-9, however, will have both WiFi and cellular.

In addition to servers for new generation aircraft, Teledyne has sold about 5,000 WGL and WGL Comm+ boxes, the majority over the past six or seven years. Many of these have been installed on the aircraft on the production line. Cecil explains that most have been bought for QAR/FDM downloads.

Teledyne's WGL Fi product will work with the WGL Comm+ unit to provide a wireless signal on the flightdeck to provide connectivity to wireless devices such as iPads. "The WGL Fi unit also interfaces with the aircraft's avionics, provided the aircraft is also fitted with the WGL Comm+ and WGL AID," says Cecil."

The variety of devices available for use as an EFB means that airlines need to consider where ETL software and records are stored. The server of a new generation aircraft will be used to host ETL software. ETL data can also be kept on the EFBs of legacy aircraft that have been modified with a device, such as the WGL Comm+. Some airlines want the ETL records to remain on the aircraft, which presents an issue for portable EFBs that can be removed. Provision then has to be made to store the ETL records on the aircraft server, even if the ETL software is hosted on the EFB.

Data processing

In addition to providing improved connectivity systems that make it faster to download aircraft data, there is the issues of the processing it.

A main problem is that raw data from different parts of the aircraft and from different manufacturers is not in a standard, homogenous format. This presents a problem for airlines, since the raw data has to be processed, usually by a third party. This can take several weeks before it can be analysed by IT systems designed specifically for analysing safety, flight operations and maintenance data. The ultimate objective is make data usable by M&E IT systems that include Ultramain, Swiss AMOS, and Trax.

iJet Onboard has developed an open software platform service that processes binary aircraft data and transforms it into a format that is easily consumed by modern, often mobile, applications. Its service has an airborne component that makes real-time data available to airline processes that require it, which includes the ability to transmit over the most efficient communications link. Once moved off the aircraft, iJet's Cloud-based platform services process and store the data for, use by back office systems.

"Think of our platform as middleware, with the aircraft and all of its complexity on one side, and an airline's IT systems on the other," explains John Schramm, vice president commercial and product strategy at iJet Onboard. "There are two basic processes, the first being data manipulation, as data are transformed from the binary ARINC formats to formats usable by modern application developers, and unified across heterogenous aircraft fleets. The second is 'state detection and assessment', which allows decisions to made on when (if ever) data elements should be sent to the ground."

An advantage of the product is that it operates on any type of hardware. iJet

Internal cabin connectivity systems are based on WiFi and GSM cellular signals. A WiFi signal allows e-mails, internet browsing, streaming media, and using the internet and sending e-mails with smartphones. A GSM or cellular signal allows the use of mobile phones or smartphones.

Onboard is currently trialling its system with a 757 operator that is exploring the possibility of hosting the software on its in-flight connectivity (IFC) server. Alternatively iJet Onboard will recommend an AID and aircraft server unit for airlines. Most of its development has been concentrated on legacy airframes which benefit from applying software to achieve modernisation.

Cabin connectivity

Connectivity for the cabin requires external and internal connectivity.

Internal cabin connectivity is achieved through the use of Ku- and Ka-band Satcom, since these have the highest transmission rates currently available.

Ku-band makes television, high-speed internet and telephone calls all possible inside the cabin.

As described, Panasonic provides virtually a complete global coverage. Its system is used by SIA, Lufthansa and several other carriers for their external cabin connectivity. It is also an external cabin connectivity providers on the A350.

Panasonic is working on a high-throughput Satcom system with Intelsat. “This will use spotbeam technology in regions where there are high concentrations of aircraft,” says DeBlasio. Widebeam technology is the only way to segregate the Satcom connectivity into two parts, one for one-way communication for Live TV, and the other for two-way communication for Internet access.

Ka-band, as described, has a higher transmission rate of 3-4Mbps. It makes the same services in the cabin possible that Ku-band does.

Inmarsat is one supplier of Ka-band, and has its own brand, known as Global Express, which will be available from 2015. Hardware will be supplied by Honeywell. This will have a high transmission rate of up to 50Mbps for download, and up to 5.0Mbps for upload. This compares to a typical domestic broadband rate of 6.7Mbps. Global Express will provide one of the highest transmission rates for external cabin connectivity.

GoGo is US a provider of cabin connectivity systems. Its first product is a line-of-sight, air-to-ground (ATG) cellular network. This is made possible by a network of antennae across the US, which projects the cellular signals skywards, to be picked up by antennae on the underside of the aircraft.

The transmission rate is about 10 Mbps, and has made internet browsing and TV viewing possible when operating over the US. The system has been widely adopted, and about 3,000 aircraft that operate domestically in the US are fitted with the system. Long-haul aircraft will need to be fitted with Ku- or Ka-band capability, since they will not be able to provide the in-cabin service once they have left US coastlines. Some US carriers have therefore equipped their domestic fleets with GoGo’s cellular system, and have equipped their long-haul aircraft with Ku- or Ka-band.

The success of the system has led to congestion, and GoGo developing Ku- and Ka-band services.

There are currently two main systems for providing internal connectivity for the passenger cabin. These are with WiFi and global system for mobile communications (GSM), referred to as 3G cellular.

A GSM or cellular signal allows the use of mobile phones or smartphones. Cellular signals are currently not permitted in the cabin in US airspace, however. The system provides a roaming service through several service providers, and requires an external system for air-to-ground connectivity. It requires the aircraft to be fitted with a pico cell, which links the Satcom to passengers’ phones.

The service providers include Aeromobile, which works with Ku- and Ka-band for air-to-ground connectivity; OnAir, which works with Inmarsat SBB; and Row44, which provides a GSM in the cabin.

A WiFi signal allows e-mails and internet browsing, and streaming media, and using the internet and sending e-mails with smartphones. A WiFi signal service requires the aircraft to be fitted with a router and access points along the length of the cabin.

There are several WiFi service providers, each of which requires an external, air-to-ground connectivity system. Service providers are: OnAir, which works with Inmarsat SBB; Row44, which works with Ku-band; and GoGo, which uses the US terrestrial cellular network when operating over the US, but will use Ku-band Satcom in the future.

Aircraft of the future

The A350 represents one of the highest levels of advancement in aircraft connectivity. As described, the A350 will have a server avionics architecture.

The A350 will have three types of Satcom air-to-ground connectivity: Inmarsat SBB, Ku-band provided by Panasonic, and Ka-band provided by Thales. The latter two will be used to provide connectivity for the cabin. The A350 will also have three types of on-ground connectivity systems.

Airbus will provide in-flight entertainment (IFE), mobile telephony, internet access, and an overall platform through four different permutations of IFE, connectivity solutions and service providers. The suppliers of these four options are Panasonic, OnAir, Thales and Airbus’s own connectivity platform: airline network architecture (ALNA).

One choice is for Panasonic to provide all four services, including the platform. Another, for example, is for Thales and OnAir to provide the IFE, mobile service and internet access, ALNA provides the mobile telephony platform,

The A350 will have Inmarsat SBB, Ku-band provided by Panasonic, and Ka-band provided by Thales Satcom systems for air-to-ground connectivity. The aircraft will also have WiFi, 3G cellular and Gatelink wired for on-ground connectivity. The A350 will also have a docking station for mounting a Class 2 EFB. This dock will also allow the EFB to be integrated with the aircraft's avionics.

with the whole package via OnAir as a service provider.

The entire system works on IP, so it is connected via the ethernet. Airbus will provide internet access in the cabin via a WiFi signal. The main internet service providers are OnAir, Panasonic and GoGo.

For the flightdeck and overall aircraft operations, Airbus's plan is to e-enable the A350 with the long-term aim of having a paperless operation, so-called eOperations. There are three main areas of operations where this issue has to be addressed: flight operations, maintenance operations, and cabin crew operations.

For the issue of the flightdeck, the A350 will be fitted with docking stations for Class 2 EFBs. This will allow the EFB devices to be portable, which will have several advantages. First, the docking stations will allow the EFB to be integrated with the avionics, such as the cockpit display system, and the air-to-ground connectivity systems. It will also allow the EFB applications to be updated easily. It also means that EFB content can be displayed on the large cockpit displays, and managed inflight via the aircraft keyboard and the keyboard cursor control unit (KCCU).

The system will effectively be a Class 2+, since by definition a Class 2 EFB can only take data from the aircraft's avionics. The A350's EFB will be based on a laptop, and because it is a portable device it can be used by the same crew member all the time. A pilot can therefore receive its flight briefing, flight plans and charts all on the laptop, and then carry the EFB to the aircraft and install it at the docking station. The flight plans, or any pertinent data, can then be synchronised with the relevant avionics aircraft data.

The other option is for pilots to leave the EFB on the aircraft docking station. In this case the pilot will need to carry the mission data (electronic flight plans and all other information to the aircraft) on a separate tablet device, a USB stick, or send it to the aircraft via the aircraft's embedded communications. The information will then be downloaded onto the EFB system.

Connectivity systems for the flightdeck eOperations will be provided by Inmarsat SBB, for connectivity in the air; and Gatelink WiFi, Gatelink 3G cellular and a new system called Gatelink wired for on-ground connectivity.

Gatelink Wired is a new offering from Airbus, and will be used to provide on-ground connectivity via a cable connected to an ethernet port on the outside of the aircraft. This is likely to be used mainly when the aircraft is in the hangar, where it is simplest to deploy. This, however, depends on service providers. Gatelink Wired is likely to be used by mechanics to download maintenance data, as well as upload software updates and data to items such as the FMS and EFB.

All four eOperations communications systems are based on communications using IP. The aircraft's server, including interface devices, will thus connect these various systems with avionic units.

The aircraft will also have VHF, HF and Classic Satcom systems, since ATS/ATC messages and transmissions are not yet approved to be sent by Inmarsat SBB or Ku-/Ka-band. A large portion of the flightdeck communications - that is AOC and AAC - can be sent via SBB and Ku-/Ka-band, however. AOC communications also tend to involve the highest volumes of data.

Airbus will also add a data compression function in the avionics message exchanger (AMEX), implementing the new industry standard MIAM protocol (ARINC 841 standard). Thanks to the AMEX data compression, the volumes of data sent to the ground to the flight will be dramatically reduced, thereby allowing communications cost savings for the airline operators.

Several eOperations applications can benefit from AMEX data compression, such as the aircraft condition monitoring system (ACMS), AOC and CMC. Another feature of the A350, which was first featured on the A380 is field loadable software (FLS). This can be used for on-board uploading of software to various avionics throughout the aircraft, without having to remove any hardware from the aircraft when performing the update. An example of the use of FLS is for uploading data to the aircraft's integrated modular avionic (IMA) line replaceable units (LRUs).

The IMA architecture will be a system of hardware which has no particular avionics function, until software has been loaded onto the system. The software loaded onto the hardware will then provide the avionics functionality.

The objective of this modular avionic device is that it will reduce the number of avionic units, allowing hardware commonality and fewer spare parts. This will indeed be different from the traditional system of each avionics box having a separate particular function. Data loading and configuration report system (DLCS) is a system that stores software, and sends it to the final hardware equipment that will host it. DLCS overall manages the uploading and downloading of data and software.

It also provides a more efficient system of managing the aircraft's avionics configuration, since software can be updated or removed relatively easily. It will even be possible to import data to the aircraft wirelessly and therefore remotely. Management of the configuration changes via updates, revisions, removals or uploads can be done through IP communications, which include the use of a USB stick. AC