The number and capability of flightdeck and passenger cabin connectivity systems is steadily evolving. This is spurred on by the demands of pilots and operational crews, and fare-paying passengers for a wider range of more sophisticated services. The flightdeck & passenger cabin connectivity systems are reviewed.

Flightdeck & passenger cabin connectivity systems

The variety of flightdeck and cabin connectivity options continues to evolve. For many years there was no development, and only a few systems were available. However, the next few years will see several flightdeck and passenger cabin connectivity systems come into commercial service that will transform data transmission rates. This will inevitably lead to a change in the quantity and type of data that can be sent to and from the flightdeck during flight, and the type of services that can be offered to passengers.

Flightdeck transmissions

Flightdeck transmissions fall into four categories. The first, and most important are air traffic service (ATS) messages. These are safety-critical communications, which include all types of communications between the aircraft and air traffic control (ATC), either with air traffic controllers or automated data and simulated voice transmissions.

The second category of flightdeck transmissions is airline operational communication (AOC) messages. These are not safety-related, but include data sent by the aircraft to the operating airline's flight operations department, including: out, off, on and in (OOOI) messages; and data transmissions to and from the electronic flightbag (EFB) and electronic technical log (ETL), and from the aircraft's central maintenance computer (CMC). These include fault codes relating to technical defects in the aircraft's systems, and also live weather data, which can now be transmitted to the aircraft for use on EFBs.

AOC messaging and transmission volumes have grown in recent years, with increased utilisation of EFBs and ETLs by airlines.

Two smaller categories of flightdeck messages are airline administration communication (AAC) and air passenger communication (APC) messages. AAC messages include: database and library updates for EFBs and ETLs; crew manifests; connecting gate information for passengers; requests for medical assistance; and forwarding information on cabin defects to ground personnel while in flight. Some AAC messages are therefore relevant to the cabin crew, and originate from the cabin technical log.

APC messages account for a few small items of interest to passengers, such as news, weather and sports updates.

Up to the late 1970s, transmissions to and from the aircraft were limited to voice messages by radio transmissions, and were restricted to the flightdeck. Radio transmissions were limited to analogue very high frequency (VHF) and high frequency (HF) radio. VHF is limited to line-of-sight transmissions, over land and to a range of 250nm over water from a coastline. HF radio is used for long-distance transmissions.

The first change came in the late 1970s with the advent of the aircraft communications addressing and reporting system (ACARS). This is a text-based system, which operates on binary data, and is based on a protocol specified in ARINC protocols 618 and 620.

The first generation of ACARS messages are character-based, and known as plain old ACARS (POA) messages.

ACARS messages are transmitted

ACARS was the first non-voice connectivity system, and was limited to ATS- and AOC-related communications at a limited data transfer rate.

High data rate connectivity systems for the flightdeck are coming available that will make it possible to use a wider range of applications and systems. These include sending emulated ACARS messages from EFBs, and transmitting live graphical weather information to EFBs in real-time.

from the aircraft via the air traffic services unit (ATSU) box on Airbus aircraft, and by the communications management unit (CMU) on Boeing aircraft. These, and the other avionic units on the aircraft, operate according to various ARINC protocols.

The POA ACARS system has a transmission rate of 2.4 bits per second (bps) when being sent by VHF and HF radio.

ACARS messages are transmitted to the ground, and then channelled to the airline departments and ATC systems. This process of through networks is managed by SITA and ARIC which are active as service providers for airlines.

ACARS was originally used as a messaging service to complement voice calls to ATC by giving aircraft a communication link to their various departments. The very first use was for automatically sending AOC messages, in particular OOOI times. The use was then expanded for sending component and system fault codes from the CMC that was introduced on types like the A310, 757 and 767 in the early 1980s.

A second generation of ACARS messages are bit-oriented protocol (BOP) messages. These are a binary file, and contain a lot more information than POA messages. BOP ACARS messages can only be sent by digital VHF and HF radios, while POA ACARS messages can be sent by analogue or digital radio sets. Digital VHF radio is known as VDL mode 2 (VDL M2).

There are two categories of BOP ACARS messages. One category is a set of messages that is channelled into the ARINC and SITA networks, but do not go via the aeronautical telecommunication network (ATN). These ACARS messages are also referred to as ACARS over aviation VHF link control (AOA), so termed AOA ACARS. The transmission rate of BOP or AOA ACARS messages over VDL M2 and digital HF radio is 31.5Kbps. This is clearly a higher rate than POA ACARS. VDL M2 was introduced to relieve the data volume bottlenecks in Europe. ARINC and SITA later released a dual frequency VDL M2 system to relieve data transmission congestion that had become a problem.

These higher data rates increased the scope of the type and size of messages that could be sent from the flightdeck. The data transmission rates of POA ACARS over analogue VHF and HF radio have been sufficient for small data-based messages such as flightplan data and the receipt of automatic terminal information service (ATIS) messages.

The limited number of flightdeck connectivity systems meant that all ATS communication, navigation and operational procedures were based on voice calls by flight crew with ATC controllers. This included mandatory position reports for long distance, over water operations being made by voice via HF radio. Position reports could not be made by ACARS, because there were no connectivity systems available to send them.

The development, however, of ATC systems has led to the requirement for a higher-capacity system, in particular, controller-pilot datalink communication (CPDLC) messages, which replace voice calls between pilots and ATC controllers. In their most basic form they can be used for instructing or requesting flight level or routeing changes. At a more complex level they comprise an element of modern air traffic management systems. CPDLC messages are a subset of BOP ACARS messages, and are used in both overland and long-range navigation and ATM systems. They are an element of the Single European Sky ATM research (SESAR) system in Europe, NextGen system in North America, and Future Air Navigation System (FANS) for several long-distance and trans-oceanic air routes and operating regions.

CPDLC ACARS messages are transmitted to the air navigation service providers via the ATN, so they are referred to as AOA ACARS messages. The higher transmission rate of BOP ACARS messages is a bonus for CPDLC messages.

L-band satcom

The first significant development in flightdeck connectivity systems came in the late 1990s, with the advent of L-band satellite communication (satcom) systems. These are supplied by Inmarsat and Iridium, and were adopted from communications originally developed for maritime operations.

Inmarsat is a constellation of high-orbit, geostationary satellites, providing coverage almost worldwide, with the exception of the north and south ice caps.

Inmarsat L-band is referred to as Classic Aero, and was approved for ATS and small-sized AOC messages in 1991. Classic Aero was one of the elements necessary to make the new operational system for long-range navigation and ATC communications, termed future navigation air system (FANS), which was first adopted in about 1993. The core of FANS was to replace position reports made by voice calls over HF radio. Position information was provided by an inertial navigation system (INS). Other elements of FANS include a global positioning system (GPS) satellite navigation system, and an automatic dependent surveillance (ADS) avionic unit. Under FANS, position information from the GPS unit is sent automatically in the form of a CPDLC message via the Classic Aero system. CPDLC messages are therefore a subset of ATS transmissions. The use of CPDLC in FANS avoids the need to make voice calls, and frees HF frequency congestion.

Classic Aero can also be used to send small-sized POA ACARS messages, which originate from the aircraft's ATSU or CMU, for ATS purposes. The transmission rate of Inmarsat Classic Aero is 2.4Kbps. It can also be used for AOC messages of limited size, because of the low transmission rate. These cannot be full aircraft health monitoring (AHM) or engine health monitoring (EHM) data downloads, but can be aircraft system or parameter exceedences transmitted to airline operational, and maintenance and engineering departments.

Iridium is a constellation of low-orbit, orbiting satellites, and provides complete global coverage. The Iridium L-band system is referred to as 'Iridium Classic'.

It was approved for ATS messages, including CPDLC transmissions, in 2011. Iridium Classic is used for the same type of messages as Inmarsat Classic Aero. The system has the same transmission rate as Inmarsat Classic Aero of 2.4bps.

In addition to CPDLC and other ATS and AOC messages, L-band satcom systems can be used for voice calls instead of the traditional HF and VHF systems. While L-band satcom would more commonly be used for voice calls on trans-oceanic and long-distance missions, they are also used for voice calls for operations in countries and regions with limited VHF coverage, such as the polar regions and Africa.

In addition to Inmarsat and Iridium which operate the L-band satellite constellations, there are several avionic suppliers that provide specialist units for L-band satcom. Avionica provides its satLINK MAX box. This is the only four-channel Iridium avionic unit on the market. All of the channels can be used for either voice calls or data transmissions. It is also the first Iridium unit to get CPDLC FANS approval. The unit is also used for other ATS messages.

FLYHT of Canada provides its AFIRS 228S unit, which has two Iridium Classic channels that are used for a variety of ATS communications. The first channel is for FANS and CPDLC messages via ACARS, and the second is for voice communications.

The data channel can also be used for AOC messaging, and has several other applications and uses, including the transmission of AHM and EHM parameters. This is an element of a the FLYHT Health product.

AFIRS 228S has many other functions, including a quick access recorder (QAR) function and memory for storing FOQA data.

High rate satcom

The protocol used for analogue and digital ACARS messages over VHF, HF and L-band satcom is ARINC 618 and 620. This is a robust protocol, which is not susceptible to interruptions from weather patterns, including clouds and water droplets. This is one of the main criteria for these systems being approved for ATS and transmissions. The main drawback of connectivity systems for analogue and digital ACARS messaging systems is the limited data rate, which has made transmissions to and from aircraft increasingly expensive as the volume and variety of data transmissions has steadily increased over the past 10 years.

Many of the avionic units of modern and new generation aircraft operate on internet protocol (I.P.). This is a different coding system to the ARINC protocol used in ACARS. Some avionic units can operate on both ARINC and I.P. protocols. An ethernet is used as the physical link between avionic units that operate on I.P. The I.P. protocol is also used as the basis for WiFi transmissions on the aircraft, and for a variety of message and transmission types.

The advantage of I.P. is that it has a faster data transmission rate than analogue or digital ACARS. I.P. transmissions can be made from the aircraft in flight with K-band-based satcom transmissions, and on the ground with cellular- or WiFi-based signals. These have the advantage of higher bandwidths and therefore data transmission rates than radio and L-band satcom transmissions. Transmitting data therefore costs a fraction of the cost of using radio and L-band satcom for traditional ACARS transmissions.

The disadvantage of K-band satcom and on-ground systems, however, is that they are subject to attenuation by water droplets, and so weather patterns. They will therefore never be certified for sending ATS and safety-related transmissions.

New-generation L-band satcom systems are coming available from Inmarsat and Iridium. These systems will be adapted to transmit ACARS messages at high data rates.

Inmarsat has launched three spotbeam L-band satellites. The use of spotbeams will provide a higher bandwidth and data transmission rate than regular L-band. The spotbeam system is called Inmarsat swiftbroadband (SB), and will have almost full global coverage. The system is configured to send more packets of information per second than standard L-band, and will have a data transmission rate of 432-480Kbps. This is 40 times faster than Classic Aero.

SB is an I.P.-based system, however, so it cannot ever be certified to send ATS messages on its own. It can, however, be used for the growing volume of AOC messages.

Inmarsat has cooperated with Cobham satcom to develop a system that has been certified to send ATS messages in ACARS format. The process is based on encapsulating ACARS messages in an avionic box developed by Cobham called the Aviator S for Safety unit. The encapsulated ACARS messages are then sent to the SB transceiver, and transmitted in I.P. format. The ACARS messages are unencapsulated after they have arrived on the ground, and then transferred into the ARINC and SITA networks. This system has been developed for ATS and CPDLC messages. The system has been trialled by Cobham Satcom on trans-Pacific and transatlantic operations with commercial airlines.

While the Cobham system for encapsulating ATS and CPDLC messages has been certified, Iridium is due to launch a system called Iridium Next. This will also be an L-band, high bandwidth system. The system will first work on ARINC protocols, and later on I.P. Iridium says that it anticipates supporting data rates of 352Kbps, and receiving speeds of 704Kbps. This will later increase to 1 mega bit per second (Mbps) and then later reach 1.4Mbps.

The system could be used in the same way that Inmarsat SB sends encapsulated ACARS messages. The Federal Aviation Administration (FAA) has said that the system will be certified for the transmission of CPDLC messages from day 1.

In addition to ATS messages, the higher bandwidth and transmission rate of the SB system also means it provides low-cost connectivity for the higher and growing volume of AOC messages that most airlines are now experiencing. The increased number of sensors and parameters on commercial aircraft types has led to an increase in the quantity of EHM and AHM data that is being transferred in real time and in flight.

Several other requirements and applications for flightdeck transmissions that require a bandwidth and data transmission rate have evolved in recent years.

The first of these is a low-cost connectivity system for EFBs and ETLs on the aircraft. These devices are mainly used to send and receive AOC messages and data. ARINC and Satcom Direct have developed applications and software

The bandwidth and data transmissionn rates of passenger cabin connectivity systems are steadily allowing more sophisticated in-flight services. These include live streaming of audio and visual content, and a large number of live TV shows.

that allow messages to be sent from EFB devices as emulated ACARS messages. These will fall into the AOC and AAC categories, since the EFB is not an avionic unit and is not certified to send ATS-related messages.

These emulated ACARS messages are sent over the I.P. SB satcom transmission in the case of Inmarsat. Fault and defect messages that have originated from the aircraft's CMC have traditionally been sent as ACARS messages by VHF or HF radio or L-band satcom, but can now also be sent by SB and Iridium Next.

Another development is the use of real-time weather data for use on EFBs. Graphical weather data can now be superimposed on the flightpath displayed on an EFB screen, and superimposed over the flight track. There are several suppliers that now provide this service, including Lufthansa Systems, SITA and the Weather Co *(see Broadband flightdeck connectivity systems & their applications, Aircraft Commerce, August/September 2016, page 28).*

ATG systems

To date ATG systems have been used solely for passenger cabin services and activities, due mainly to data transmission rates being only being as high as 10Mbps. SmartSky networks will shortly launch a new ATG service in North America that will have a much higher data transmission rate equal to as much as 30Mbps in either direction to and from the aircraft.

The advantage of this high data rate is not only that it will allow all levels of passenger cabin activity, but it will be enough to allow large volumes of data to be transferred to and from the flightdeck.

SmartSky Networks will also launch a flightdeck data service called Skytelligence. This will provide the ability to perform data analytics, permit access to patented methods for flight path trajectory, and carry out airspace modelling. It will also help transform data into actionable knowledge to enhance situational awareness. There are also several EFB applications that can use the technology to allow five-dimensional trajectory-based applications to optimise fuel burns, save flight time, and use real-time weather and traffic data.

Associated products are SmartSky 4G and SmartSky Select. SmartSky 4G LTE is an on-ground connectivity system that provides the foundation of apps and services to save aircraft operating costs. The network delivers data to the aircraft with speeds comparable to satcom systems when getting data off the aircraft.

On-ground systems

The growth in the size of navigational and EFB database uploads to the aircraft, and the steady increase in size of AHM, EHM and FOQA data downloads from the aircraft has spurred interest in the development of WiFi and cellular connectivity on-ground systems. The data being uploaded and downloaded from the aircraft is categorised as AOC messages. Modern aircraft types may generate 1-3 mega bytes (MB) of EHM and AHM data per month, but as much as 200MB to 2.0 giga bytes (GB) per month of FOQA data. This is downloaded from the QAR device. This quantity of data can clearly only be downloaded from the aircraft at a reasonable cost by using high bandwidth connectivity systems.

The two main options for wireless on-ground connectivity are WiFi and cellular systems.

It was originally expected that WiFi would become the widespread on-ground connectivity system. Aircraft types such as the 787-8 and A380 were introduced to service with WiFi systems fitted as standard.

The 787 and A380 were to be WiFi-only aircraft based on the data connectivity projections of 2002/3. The reality was that when they entered into service, airlines demanded a cellular solution. This was because WiFi infrastructure at airports was not as widespread as predicted. Teledyne rose to this challenge, and produced the TCU for 787 and the GroundLink Comm+ 3G unit was made line-fit on the A380.

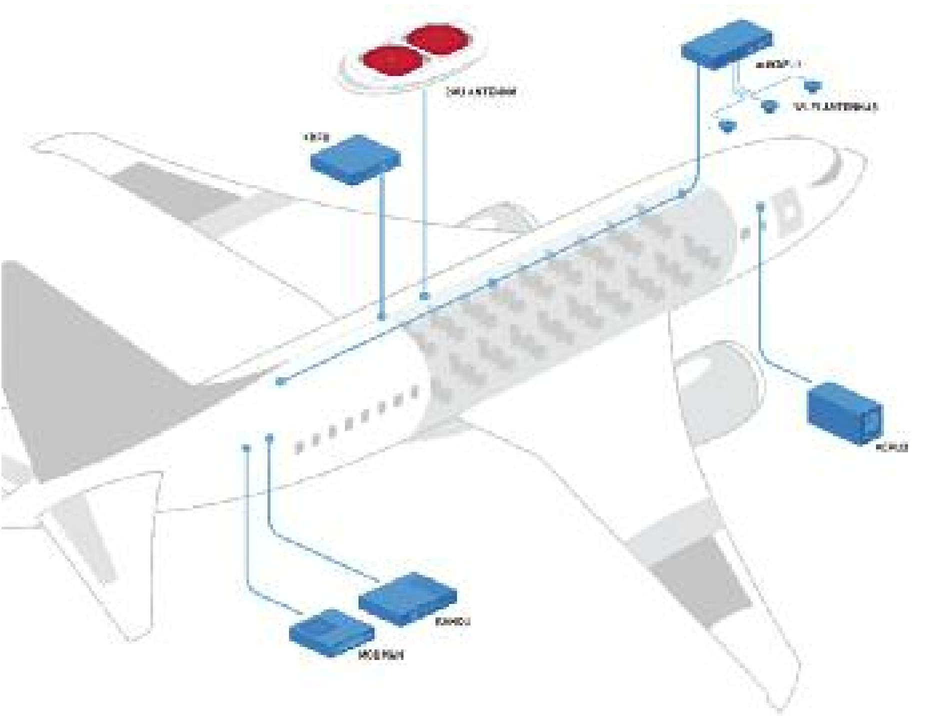
The use of WiFi, however, requires the installation of dedicated WiFi transceivers on the aircraft and WiFi access points (WAPs) at airport terminal buildings or remote stands. This requires high capital expenditure in infrastructure and equipment, and has been the main factor in limiting the acceptance of WiFi as an on-ground data transfer system by airlines.

The cost of WiFi at large commercial airports is prohibitive, since the scale of the installation at some of these sites requires hardware investment that makes the operating cost of WiFi greater than that of cellular in many cases. In an airline's hub location where the airline owns or leases much of the airfield real estate, like Emirates at Dubai, WiFi is a cost- effective alternative to cellular.

Cellular connectivity systems have proven to be more popular than expected with airlines. They use existing 3G and 4G cellular networks already in place for the use of mobile phones. These were offered as options on the first 787-8s and A380s, but have since been offered as standard fit on later types such as the 787-9 and A350.

Airlines can install all the necessary ground hardware and infrastructure for transferring data between the aircraft and its operator's flight operations and engineering departments. The alternative is for airlines to subscribe to a third-party service. ARINC, SITA and GigSky offer service provider products for on-ground WiFi and cellular connectivity services.

The WiFi and cellular avionic units on the aircraft, and their respective transmissions, operate on I.P. protocol.



Gogo's 2Ku-band system is a twin-aperture antenna for Ku-band connectivity. One antenna will be used for bi-directional internet connectivity, while the second will be used as a uni-directional connectivity link to provide on-board IPTV. Gogo's 2Ku-band complements its Gogo Vision servide to provide IPTV.

These units work together with a server that is an integral part of the aircraft's avionic architecture. Older aircraft types such as the MD-11, 747-400, 757, 767, 777, A320, A330 and A340 families had avionics units that operated on ARINC protocols, and were connected to each other and to relevant aircraft systems and flightdeck instruments with databuses.

Modern aircraft types, such as the A380, A350, 747-8 and 787, have a mixture of avionic units that operate on I.P. and ARINC protocols. The I.P. avionic units are connected to each other via an ethernet. The same aircraft types also have a server architecture. An avionics server operates as a hosting server, and has various functions, including: data storage; hosting applications; ethernet and AID switches to connect to the ARINC- and I.P.-based avionics, the ACARS and satcom external connectivity systems, and the EFB and ETL units used on the flightdeck. The server's applications determine what data to transfer between which avionic units.

Examples of server functions are database uploads, and FOQA and AHM downloads, and hosting ETL and EFB software. The server can also have an extension that is a WAP, which provides a WiFi signal on the flightdeck and in the passenger cabin. These can be used to connect the EFBs and ETL on the flightdeck and the cabin log with the aircraft's connectivity systems.

The servers on Boeing aircraft are known as on-board network server (ONS), while Airbus types are fitted with the Fly Smart with Airbus (FSA) or on-board information system (OIS). Later-production 737NGs and 777s from 2014 were fitted with an ONS as standard.

Much of the data generated in I.P. cannot be transmitted as ATS-related data on most higher bandwidth connectivity systems. Only data and messages that are AOC, AAC and APC can be transmitted over I.P.-based connectivity systems. These three types of messages may originate from ARINC-based avionic units, but can be transferred by the server to the higher data rate I.P. connectivity systems, to avoid the bottleneck of the traditional ACARS systems with low data transmission rates. All transmissions originating from EFBs and ETLs can be transmitted with any connectivity system.

The server also interfaces with the aircraft's WiFi and cellular systems. These can only operate on aircraft that have servers fitted.

WiFi

Older legacy aircraft types do not have these avionic servers, but can have units fitted to provide them with almost identical capability. For the use of a WiFi system, the aircraft also needs to have a terminal wireless LAN unit (TWLU), which also interfaces with the unit that provides the server function, as well as the QAR that stores FOQA data.

Teledyne Controls provides its Gatelink WiFi unit, that together with the TWLU, provides WiFi connectivity, but does not provide any server capability. There are two standards of gatelink WiFi, the unit using IEEE 802.11b has a maximum data transmission rate of 11Mbps, and the unit using IEEE 802.11g has a maximum data rate of 54Mbps. As cellular reaches LTE/LTE advanced, and 5G devices are already being produced, cellular data transfer rates are expected to exceed that of WiFi. WiFi is stuck with 2.4/5.0Ghz. The combined channel speeds of that technology reached its maximum level at 600Mbps, but next gen cellular is set to reach 1-10 Gbps starting in 2020.

Miltope provides a Gatelink WiFi box called the nMAP2, and uses 802.11 and 802.3 I.P. protocols.

Rockwell Collins provides its Gatefusion unit for WiFi, which is fully interoperable with the TWLU installed on the aircraft. Gatefusion supports data transmitted over multiple user-defined formats and protocols. The 802.11g standard is preferred for greater throughput. The system uses either ARINC's Gate Fusion or SITA's AIRCOM I.P. The system is designed to operate with airport WiFi infrastructure.

Cellular

Teledyne Controls first product to retrofit legacy aircraft with an on-ground cellular capability is the wireless ground link (WGL). This has multiple cellular radios for cellular connectivity. It has several other functions that include mass data storage, and built-in applications. These applications remove the need for a separate hosting server, so the WGL can support data uploads and downloads by itself.

The WGL has a data transfer rate of 120-300Kbps, depending on the cellular radio service available locally.

Miltope provides a gatelink cellular avionic box called the cTWLU, and uses 802.11 and 802.3 protocols using I.P. addressing, as well as 3G and 4G

Retrofit servers

Teledyne Controls followed the WGL with a GroundLink Comm+ unit, and has advanced and added more features than that of the WGL. WGL Comm+ has four radios, an aircraft interface device (AID) to connect ARINC-based avionic units, an ethernet switch to connect to I.P.-based devices and the external connectivity systems, server-like capabilities, data storage, and a server to run applications. This has been fitted to legacy aircraft, and provides many of the server capabilities that the 787, A380, A350 and 747-8 have. Teledyne has more than 11,000 GroundLinks at 204 customers, and will have 400-500 AID+ aircraft delivered/in progress by the end of 2017.

GroundLink Comm+ can therefore be used to transmit AOC, AAC and APC data and information. It has an uplink rate of up to 23Mbps, and a downlink rate of 84Mbps. This can be 120-300Mbps if all four radios are combined, which is not common. With this capacity it takes a few minutes to offload large volumes of AHM, EHM and FOQA data.

Despite its comprehensive range of capabilities, WGL Comm+ does not provide all of the server-like capabilities that the 787, A380 and A350 have. These are extended by GroundLink AID+ and GroundLink Wireless Access Point.

GroundLink AID+ is a software upgrade to GroundLink Comm+, and provides it with an interface between the I.P.- and ARINC-based avionic units on the aircraft. This means that the AOC, AAC and APC messages can be transmitted over the high bandwidth I.P. connectivity systems.

GroundLink WAP is a unit that works with GroundLink Comm+ to provide a WAP on the flightdeck for connectivity for wireless devices, such as iPads, that are used for EFBs and ETLs. It also interfaces the wireless devices with the aircraft's avionics with its AID function.

As a follow-on from the WGL and Gatelink WiFi units, Teledyne introduced the aircraft wireless LAN unit (AWLU). The fifth-generation/variant of the AWLU is a hybrid unit that provides both WiFi and cellular capabilities, so either can be used depending on what is available at the aircraft's location. The data transmission rate for this unit is 120-300Mbps.

Teledyne plans to introduce a LTE GroundLink Comm+ early in 2018 due to cellular obsolescence.

Avionica is a vendor of several units that provide on-ground connectivity and an on-board server. It used to provide secureLINK, which was in effect a TWLU and operated as a transceiver for WiFi and Cellular on-ground transmission units. Avionica now provides its aviONS unit which is similar to Teledyne's WGL Comm+ unit. aviONS has three main units. The first is avRDC, which is a remote data concentrator. This is basically an AID, which provides a bi-directional data transfer between I.P.-based avionic units connected via ethernet, and ARINC-based avionic units. Besides allowing data flow between these units, avRDC also gives the aircraft the capability to transfer data via the Iridium satcom link into the EFB device. It is also possible for avRDC to use the EFB to acquire data, such as a position report from the aircraft's flight management system, from the avionic units.

The second module of aviONS is the AvWiFi, which is a Gatelink WiFi box. The third module is a Gatelink cellular unit.

In addition to aviONS's three main modules, it includes an ONS that can host applications and software, and a QAR functional unit.

Avionica also supplies its miniWQAR unit, which is a standalone QAR device.

Cabin connectivity

The uses of cabin connectivity systems for passenger entertainment and amenity contrast to the applications of flightdeck communications. The number of different uses steadily increases, and with it the demand for higher bandwidth and data transmission rates.

While there is an ever-increasing variety of external connectivity systems, passenger cabins also require internal connectivity systems for passengers to use personal electronic devices (PEDs), such as tablets and smartphones. This connectivity is provided through WAPs that provide the WiFi signals that make the link between passengers' PEDs and the external connectivity systems.

The simplest uses of external connectivity are for passengers to make phone calls, send text messages, and send and receive e-mails with PEDs. These activities all require the aircraft to receive a data downlink rate of 1-2Mbps via its external connectivity systems.

The next level of passenger activity is internet surfing, browsing website pages, and online shopping and credit card transactions. This includes viewing websites with audio and visual content such as YouTube, and requires the aircraft to receive a higher downlink rate of 3Mbps via the external connectivity systems. The transmission rate per passenger device needs to be 50-150 kilo bits per second (Kbps).

The highest data rates are required for live streaming of audio and visual content, for example watching films via Netflix.

Another service that requires a high data transmission rate to the aircraft is providing several live TV channels. In most cases, each live TV channel requires 1-2Mbps from the satellite, regardless of the number of passengers watching the channel. An airline supplying 10 channels would therefore need to receive a downlink rate of up to 20Mbps.

There are two main types of live TV for aircraft: direct broadcast satellite (DBS) TV; and I.P. TV (IPTV).

DBS TV is the same as TV transmitted to domestic residences in a large area from specially-configured satellites. These have a bandwidth high enough to provide 100-200 live channels. The DBS TV system on an aircraft is basically adapted from the domestic TV system. DBS TV is used extensively in large countries where a single language is common, such as the US, Canada, Brazil and Australia.

With the use of satellites for domestic TV, the service is only available over large land masses. Most countries and all oceanic areas do not have DBS TV coverage. Moreover, about 90% of the satellites used are widebeam Ku-band satellites, and they have uni-directional data transmission to the aircraft. This causes another disadvantage, which is that the aircraft will require external connectivity from a second satellite system to provide bi-directional data transmissions for internet connectivity, and so needs a second satellite antenna.

The large bandwidth of the widebeam satellites provides a large number of live domestic TV channels, but many airlines restrict their services to a relatively small number because of the cost of data transmission.

IPTV is technically the same as watching a TV show through an internet page. IPTV channels are bespoke TV shows, and they are only available to licensed users, such as airlines, hotels, shipping companies and oil rigs. IPTV channels are broadcast to airlines by a select number of providers, including Gogo, Global Eagle, and Panasonic.

Since IPTV is provided as an internet service, it can use the same cabin satcom system that is used for cabin internet connectivity. This means that IPTV is available to airlines globally because satellite networks are already in place to provide on-board internet services.

IPTV can therefore be provided through Ku- or Ka-band satellites. Ka-band satellites are configured with spotbeam configurations, and have a high bandwidth per beam, which covers a small area. The use of multiple beams means replicating transmission of the same TV channels in each beam, thereby increasing the overall cost.

The highest downlink rate will be required to live stream audio and visual content, referred to as video on demand (VoD). This most commonly involves passengers logging on to their individual accounts for services such as Netflix and Amazon Prime. The issue is that while each channel needs a similar data rate to a live TV channel of 1-2Mbps, the fact that each passenger using the service is logging on to their individual account

Global Eagle is one service provider of IPTV. Coupled with its Ku-band provisioning service, one user is Southwest Airlines.

and using the service just for themselves puts a large demand on the downlink rate to the aircraft. Depending on the number of passengers using their devices to live stream films, an aircraft may need 70-100Mbps just for this service.

External connectivity

There are three main categories of external connectivity systems for cabin entertainment: air-to-ground (ATG) systems transmitting to the aircraft from ground-based transmitters; satcom systems that transmit to the aircraft from orbiting satellites; and a hybrid of ATG and satcom.

To date, only North America has an ATG system, and this is provided by Gogo. This has been available to airlines since 2008. There have been two variants of Gogo's ATG system launched.

Satcom is the system used globally for cabin connectivity, and satellite service for cabin entertainment is provided either by Ku- or Ka-band systems. There are several levels of each of these satellite systems, and some have the data downlink capacity to supply airlines with all the in-cabin services and amenities required.

The world's first hybrid ATG and satcom system for cabin connectivity is the European Aviation Network (EAN) system. This covers the geographical area of the 28 European Union (EU) countries, plus the adjacent oceanic areas of the Bay of Biscay, and the Mediterranean, North and Baltic Seas.

ATG systems

North America is the only continent to have a standalone ATG system, although the EAN system entered service in Europe in 2017 as a hybrid of ATG and satcom.

Gogo launched the ATG system in the mainland US, Canada and Alaska in 2008 with ATG1. Gogo was given a bandwidth of 3MHz to supply ATG cellular transmission external connectivity services to commercial aircraft. The signals were originally transmitted from 200 ground-based towers, and provide a data transmission rate of 3.2Mbps. It should be noted that cellular signals are not permitted for internal connectivity on aircraft flying over the US. Only WiFi signals are permitted in the cabin, so aircraft must also be equipped with WAPs.

This data rate is sufficient for text messages, e-mails and voice calls. Voice calls on phones in flight were briefly made, but there was a backlash with passengers complaining on most airlines. The data rate was also sufficient for some internet surfing.

ATG1 was subscribed to by most major passenger airlines, which charged passengers for the service.

Because ATG1 was the first and only in-flight connectivity service, it attracted a high rate of uptake by airlines, and by 2011 the airline users had equipped about 845 aircraft with the system.

Gogo launched ATG4 in 2012, which used a higher bandwidth of about 10MHz that had been licensed to Gogo. This provides a downlink rate of about 9.8Mbps, and the number of transmitter towers has been increased to 250.

ATG4 has been as successful as ATG1, with major US airlines subscribing to the service, and equipping 1,800 aircraft with the system.

While Gogo has had a monopoly on ATG systems for the North American market until now, SmartSky is due to enter the market within the next year. SmartSky will offer a high bandwidth ATG system, first across the 48 states of the continental US, with the system entering service in the second half of 2018. SmartSky will lease space on 230 transmitter towers, eventually rising to more than 250 towers in the continental US. The ground network is scalable, and will support about 20,000 beams at launch, with each aircraft having a dedicated beam. The network is also incrementally scalable to provide extra capability in high-demand areas.

SmartSky claims that airlines are experiencing latency and low bandwidth problems on existing ATG services, in addition to heavy onboard equipment for the aircraft. The system will be based on 4G technology, and will provide a bi-directional connectivity link for the passenger cabin. SmartSky has a licence for a bandwidth of 60MHz wireless spectrum, and this will be split about equally for uplink from, and downlink to, the aircraft. This high bandwidth will provide a generous and cheap data transmission rate for passenger activities, and cure latency problems. The equipment on the aircraft will also be small and light.

SmartSky says it expects the system to meet demand for data of as much as 4.0 GB per hour to each aircraft, and nearly the same amount of data from the aircraft. This means it should be able to provide access to any live TV channel that is available through the internet. It will also be high enough for an airline to provide live TV, and allow passengers to access their Netflix accounts.

SmartSky is in the process of selecting partners to manage the accounts with the airline clients.

Following launch of the system across the continental US, SmartSky has plans to add towers and extend the service to Alaska, and possible plans to extend the service to Canada, Mexico and the Caribbean.

Ku-band

Ku-band was the first of two frequency sets of K-band satellite systems developed to produce high bandwidth transmissions.

K-band transmissions have the disadvantage of being attenuated by water droplets, and so can be disrupted by clouds and weather patterns. They cannot therefore be approved for ATS-related transmissions to and from the flightdeck. They can, however, be used for high data volume transmissions for in-flight entertainment (IFE) and passenger activities.

The first generation Ku-band satellites were launched in the 1960s and 1970s, and were initially configured with a widebeam transmission. Each satellite therefore covers a large area, which in some cases is an entire country such as Brazil or Canada, or a continent or part of a continent such as North or South America.

The first Ku-band satellites have downlink rates of 1-2Mbps that are available to commercial aircraft. Later generation widebeam Ku-band satellites have downlink rates of 10Mbps, and an uplink rate of 1Mbps. The uplink rate is sufficient for passengers surfing the web and doing on-line shopping, as well as sending e-mails and text messages. The downlink rate is sufficient for most light activities with PEDs, plus supplying a limited number of IPTV channels.

Ka-band satellites, for use by commercial aircraft, were launched after the first Ku-band satellites. Ka-band satellites are configured with spotbeams that have transmissions in a concentrated area. This configuration therefore provides a higher concentration of bandwidth and data transmission in a given area. To combat this advantage, the latest generation of Ku-band satellites have been configured with spotbeams, and referred to as high throughput satellites (HTS). These have downlink rates of 30Mbps to the aircraft.

There are four main Ku-band satellite operators: Intelsat, Eutelsat, Hughes and SES. None of these has complete global coverage, but instead specialise in regional coverage.

Intelsat operates six widebeams over the US and Canada, one over the Caribbean, one over South Africa, one over Brazil, and one over South America.

Eutelsat, a European operator, operates a large number of Ku-band satellites in its constellation that provides coverage from 116 degrees west, which provides coverage to most of North America and all of South America; to 72 degrees east, which provides coverage for all of Europe, Africa, the Middle East, and the western half of Russia and the Commonwealth of Independent States (CIS). Each satellite provides coverage for a specific region.

Hughes has some second generation Ku-band satellites with downlink rates of 10Mbps.

SES has a constellation of more than 30 Ku-band satellites, comprising all the different generations of Ku-band satellites. The latest generation are spotbeam Ku-band satellites.

The first HTS satellites were launched in 2016 by Intelsat and SES.

Ku-band satellite operators do not deal directly with airlines, and service providers use the transmissions from several satellite operators to provide an overall global coverage if this is required. The three main Ku-band service providers are Global Eagle, Gogo, and Panasonic.

Global Eagle mainly uses satellites operated by SES, Hughes and Eutelsat. This allows Global Eagle to provide full global coverage. An example of Global Eagle's Ku-band service is Ku-band connectivity to Southwest Airlines for its IPTV service.

Global Eagle also has plans for other innovations and enhancements.

Gogo provides its own unique 2Ku-band service, which equips an aircraft with a dual, phased-array antennae. This allows one antenna to be pointed towards a satellite to receive uni-directional transmissions to the aircraft for receipt of IPTV signals. The second antenna is for bi-directional transmissions for internet connectivity. The concept of 2Ku-band to provide a high bandwidth connectivity for IPTV, while having a separate channel for other in-cabin entertainment. Gogo's 2Ku-band product complements its IPTV service called Gogo Vision.

The system currently uses SES and Intelsat satellites, which are widebeams. The downlink rate started at 70Mbps for the two antennae, but the SES satellites will go to spotbeam satellites that will provide a higher data downlink rate.

The data downlink rate has recently increased to 100Mbps, and will go up to 400Mbps with new modem capabilities.

Panasonic

Panasonic provides global Ku-band coverage, and is the major Ku-band provider for flag carriers that operate global long-haul networks. Airlines using Panasonic's global Ku-band service include Lufthansa and Singapore Airlines.

Panasonic uses satellites operated by Intelsat, Eutelsat and SES. Its Ku-band coverage can be used for a variety of services, including IPTV.

Ka-band

Ka-band satellites were the second family of K-band satellites that followed Ku-band. The essential difference between Ku- and Ka-band satellites is that Ka-band systems are configured with spotbeams. The area of the world's surface covered by a Ka-band satellite can be similar to a Ku-band widebeam satellite. Ka-band satellites generally have 75-100 spotbeams, however, so the area covered by each spotbeam will be a fraction of that covered by a Ku-band's single widebeam.

The Ka-band spotbeam may have a diameter of about 1,000nm and so covers about 785,000 square miles. This is a small fraction of the area covered by a single Ku-band widebeam. The area of the US, for example, is about 3.8 million square miles. The Ka-band spotbeam configuration therefore concentrates data transmission in a small area, meaning a higher data downlink rate to each aircraft.

Inmarsat is the only satellite operator to provide global coverage with Ka-band. It does this with its Global Xpress (GX) constellation of I5 satellites. It launched three I5 satellites that orbit around the equator, with each one covering about a third of the earth's surface longitudinally. The polar regions are the only area not covered.

The I5 satellites have 89 spotbeams, with each one having a downlink rate to each aircraft of 50Mbp. The high capacity of these spotbeams makes the system suitable for high-demand cabin activities, such as IPTV *(see The technical issues for providing live TV, Aircraft Commerce, June/July 2017, page 43)*, and live streaming for activities such as Netflix.

Inmarsat launched a fourth I5 satellite in 2016, and will launch two more in 2021 and 2022 to boost regional coverage as demand increases.

With the configuration of its I5 satellites, Inmarsat provides airlines with service level agreements (SLAs) that guarantee a data rate to the aircraft of 12Mbps.

Inmarsat does not market the GX product directly to airlines. It has four distribution partners which sell the service. These are Honeywell, Rockwell Collins, SITA ONAIR, and Thales.

Rockwell Collins is one of several distribution partners for the Inmarsat GX system. It confirms that is offers a data downlink rate of 50Mbps per beam, and a total satellite capacity of 4-5Gbps.

The tiered service rates to the aircraft are stated at 1-12Mbps.

Together with the supply of IFE services and hardware, Thales is another distribution partner for Inmarsat's GX which complements the IFE services.

Honeywell works with cabin IFE and connectivity hardware manufacturers to provide a total cabin system service. As well as being a GX distribution partner for Inmarsat, Honeywell is also the exclusive provider of Ka-band to the business aviation market.

The EAN system, a hybrid of satcom and ATG external cabin connectivity, has now been deployed across the EU28 countries and adjacent oceanic areas. First customer is British Airways, which has equipped its A320 family fleet with the system.

Viasat

Viasat is a US Ka-band spotbeam satellite operator. It has three satellites over the US. The first two are Anik-F2 and WildBlue-1, with a combined capacity of 9Gbps. The third is Viasat-1, with a total capacity of 140Gbps. These three satellites provide coverage to the US.

A fourth satellite is Viasat-2, with a total capacity of about 280Gbps. This covers the eastern half of North America, the Caribbean, the northern part of South America, and the area of the North Atlantic between North America and Europe.

Viasat partnered with Eutelsat to provide extended geographical coverage. Eutelsat, a European Ka-band spotbeam satellite operator, has its KaSAT satellite that provides coverage over Europe. This has about 80 spotbeams and a total capacity of 90Gbps. The overall network of these satellites provides a system with a downlink rate of 1,200-1,500Mbps per beam. Viasat can provide airlines with an SLA of a minimum of 12Mbps per seat.

The high data downlink rates of the current Viasat constellation make it suitable for the higher demands from passenger activities. This system is used by several carriers in the US to provide all levels of internet surfing, including live streaming. It is also used by airlines in conjunction with broadcast TV Ku-band to provide on-board DBS TV services.

Viasat will launch three satellites in 2019 and 2020. These will provide global coverage in a similar way to the first three I5 Inmarsat satellites. Each Viasat-3 satellite will have a capacity of 1,000Gbps, or 1 terabit per second (Tbps). Viasat claims the constellation of three satellites will provide the highest data rate coverage in the world. The first satellite will provide coverage for the Americas, the second for Europe, the Middle East and Africa, and the third for the Asia Pacific.

Viasat also claims that the constellation will negate any need for embedded IFE systems in the future, since the high data rate will mean all types of passenger entertainment are possible with wireless IFE systems.

In addition to Inmarsat's GX and Viasat's combined system with Eutelsat, Intelsat and Hughes operate a small number of Ka-band satellites to provide some regional coverage.

New satcom systems

The constantly increasing demands of passengers for better in-flight services has led to the development of new satcom constellations.

OneWeb

OneWeb is a new constellation of Ku-band satellites that will start launches in 2018, and go operational in 2021. This will be a large constellation of 700 satellites, and will increase to about 900. These will be low orbit vehicles, and will provide 100% geographical coverage.

The large number will provide a high downlink rate of about 150Mbps, similar to that provided by the Viasat-1 satellite.

The high downlink rate will support all levels of cabin IFE services, Cloud-based apps, voice over I.P. (VOIP) communications, and teleconferencing.

OneWeb has partnered with Rockwell Collins to develop a high-speed broadband satcom network for aviation.

Thales

Thales is due to launch a new constellation of satellites in 2020. These will be a hybrid of 200 Ka-band spotbeams that will provide coverage over North, Central and South America, and the North Atlantic. The area covered by 200 spotbeams will be covered by one large widebeam Ku-band satellite.

The satellites are SES17 machines, and will have geostationary orbits. Thales says it already has a US carrier as its first commercial airline customer, and it will use the system for passenger cabin services.

Hybrid ATG & satcom

As described, the EAN system for Europe is the first hybrid ATG and satcom connectivity system available for passenger cabin activities.

The system is a hybrid of 350-400 ATG towers across Europe and operated by Deutsche Telekom, and Inmarsat's satcom system called Europasat. The two integrated systems form an S-band system.

Each ATG tower transmits in a cell with a diameter of about 160 kilometres (96 miles), and then each cell is split into three zones. The data rate to the aircraft is about 75Mbps in each zone; about 65Mbps more than Gogo's ATG4 in North America.

The system's data rate is sufficient for all types of cabin activity, including IPTV and individual live streaming. This makes it the first ATG system that can be used for live TV.

The EAN system was launched earlier in 2017 by British Airways with its A320 family fleet. - *CHW* AC