There are now a wide variety of connectivity systems for flightdeck communications and transmissions. The practical application and uses of each one are examined here. Operators are having to take more consideration on how they configure their aircraft.

The applications of flightdeck connectivity systems

Flightdeck connectivity systems differ from the systems used in the aircraft cabin. The different flightdeck connectivity systems available to airlines have been examined *(see Flightdeck connectivity: the systems available, Aircraft Commerce, August/September 2013, page 16)*. The practical, in-service applications of these different systems are examined here.

Connectivity systems

There are two main categories of flightdeck connectivity systems: voice and digital data transmissions. Voice transmissions, through radio, were the only flightdeck connectivity and communication systems available to airlines until the advent of the aircraft communications addressing and reporting system (ACARS) in the late 1970s.

ACARS sends messages via various flightdeck connectivity systems, and is the main format of data messages sent while the aircraft is in the air. Data relating to aircraft position, speed and related details are transmitted by a transponder. Data can, however, be sent while the aircraft is on the ground via WiFi and cellular connectivity systems.

ACARS data transmissions

There are two standards of ACARS data transmissions.

The first is a character-oriented protocol (COP), known as plain old ACARS (POA) or 'Classic ACARS'. POA messages use all the characters on a computer keyboard, and generate a lower order ASCII file.

POA messages are sent to first-generation analogue VHF and HF radio transceivers. They can also be sent via satellite communication (Satcom).

The string of characters in a POA message is decoded to generate the viewed message. "POA was designed originally to be used with analogue transmission systems, so it is limited to a transmission rate of 2.4 kilobits per second (kps) when sent via VHF radio or HF datalink," explains Brian Cresswell, technical support manager, at ARINC Aviation Solutions.

The second ACARS standard is a bit-oriented protocol (BOP) transmission. BOP messages are a binary file, and contain a lot more information than COP ones. BOP messages therefore need a higher rate of transmission, and can only be sent by second-generation VHF digital radio (VDR), known as VDL mode 2 (VDL M2) ACARS. These are transmitted at a rate of 31.5kps. POA messages can also be sent via digital VHF radios.

"ACARS messages can be sent at higher transmission rates, although this depends on the type of connectivity system used," explains Cresswell. ACARS messages can be read either on the flightdeck printer, or on the multifunction control display unit (MCDU) on the flightdeck. The MCDU is the screen and keyboard used by the flightcrew to operate the flight management system (FMS).

There are two types of VDL M2. The main difference between them relates to how the messages are channelled through to the air navigation service providers (ANSPs), if they are being used for air traffic services (ATS) messages. "The first type has messages sent through the aeronautical telecommunications network (ATN). The ATN is an architecture that allows air-to-ground and ground-to-ground and avionic sub-networks to operate and communicate with each other using common services and protocols. The ATN is only in place in Europe and a few other regions, however," says Cresswell. "The message from the aircraft is received by a VDL M2 ground station. The ARINC and SITA networks then deliver it to the ATN, and it is then routed to the ANSPs. It is known as ATN VDL M2."

There is only one application for ATN VDL M2, used for sending controller-pilot datalink (CPDLC) ACARS messages between pilots and air traffic controllers. These are replacing voice communications between pilots and controllers at upper altitudes in certain parts of the world.

"The second type of VDL M2 messages is those that are received by the VDL M2 ground station, passed to the ARINC and SITA networks, and then to the ANSPs," continues Cresswell. "The second type therefore does not use the ATN network. It is known as ACARS via aviation VHF link control (AVLC), or AOA. AOA is used for all types of VDL M2 messages other than CPDLC."

ACARS-based messages can also be sent by other forms of connectivity, such as Satcom.

VHF radio

VHF radio is used for line-of-sight voice and data transmissions of up to 200nm at 30,000 feet. Transmissions are made at 30-400MHz between the aircraft and ground-based transceiver stations. There are large numbers of analogue transceivers in place in all regions of the world. These are used for voice and POA transmissions. The number of frequencies available for POA communications is small compared to those available for

ACARS messages are still the main method for sending and receiving data messages on the flightdeck. The number of connectivity systems that are available for making ACARS communications has increased, and transmission rates have also improved. ACARS messages are used for all types of flightdeck communications.

voice messages.

There is a smaller number of VDRs for VDL M2 worldwide. “The majority are based in Europe, and they are installed at the request of the ANSP,” says Cresswell. Their numbers are steadily increasing, however. VDL M2 transceivers only operate on a single frequency.

Radio VHF transmissions can only be used by aircraft operating over land masses where VHF radio transceivers are in range. While there are large numbers in heavily populated areas, there are few in polar regions and other sparsely populated areas such as rain forests and deserts. VHF radio transmissions are therefore unusable when flying over such areas, or more than about 200nm from coastlines.

The first generation of VHF analogue transceivers was only capable of voice and COP/POA message transmissions.

VHF radio services are provided by ARINC and SITA, and airlines have to subscribe to at least one of these.

The second generation of VHF transceivers are used for the two types of VDL M2/BOP ACARS transmissions: ATN and AOA. The second generation of transceivers can also be used for both POA/COP messages. There are therefore three categories of ACARS messages sent via VHF: POA, ATN and AOA.

POA messages are transmitted at a rate of 2.4kps, while VDL M2, BOP, messages can be transmitted at a higher rate of 31.5kps.

HF radio

Because of VHF radio’s limitation of about 200nm, line-of-sight range, HF radio was used as the only source of long-range transmissions including on polar routes, prior to the advent of Satcom.

HF radio transmissions are made at 3,000-30,000 kHz. They bounce off the ionosphere, and therefore have a range of several thousand miles. Aircraft transmissions are picked up by ground-based transceivers, and then channelled into the various communication networks.

Like VHF radio, there are two levels of HF transmissions: the original voice transmissions, which use one set of transceivers; and HF datalink (HFDL), used for ACARS transmissions, which uses a different set of 15 digital HF radio transceiver stations. HF datalink messages suffer from fade-out and drop-out problems.

HFDL’s bandwidth is large enough for POA transmissions, due to the latency effects of the radio medium.

Satcom

There are currently three levels of Satcom system for flightdeck connectivity and communications: Inmarsat Classic, Iridium and Inmarsat Swiftbroadband (SB).

Inmarsat Classic uses 10 high-orbit satellites that are geostationary over the equator. These provide coverage for 99% of commercial flights. The remaining 1% that fly over polar regions are out of range.

Inmarsat Classic L-band radio communications are all digital. “They can therefore be used for POA ACARS transmissions,” explains David Coiley, vice president of aviation, at Inmarsat. “Although Inmarsat Classic communications are digital, its transmission rate is matched to the POA original transmission rate of 2.4kps. An ACARS message that goes at a rate of 31.5kps over VDL M2, will revert to 2.4kps over Inmarsat Classic.”

Inmarsat Classic can also be used for long-range voice transmissions as an alternative to HF radio. It is approved for safety-related ACARS transmissions for air traffic services (ATS) communications to and from the aircraft.

Iridium is the second generation of Satcom used for commercial aircraft. It uses 66 low orbiting satellites, which provide 100% long-range, global coverage.

Iridium was approved for safety-related data transmissions via POA messages in 2011. The transmission rates are limited to 2.4kps.

Inmarsat SB is provided by Inmarsat’s new-generation, higher-bandwidth satellites. These use spotbeam transmissions, and will provide similar coverage to Inmarsat Classic.

Inmarsat SB will use L-band radio transmissions more efficiently than Inmarsat Classic, and will therefore operate at transmission rates of up to 432kps. Inmarsat SB is used for sending standard or POA ACARS messages at a high transmission rate.

Unlike Inmarsat Classic, Inmarsat SB uses Internet Protocol (IP), and so cannot send ACARS messages in their original form. These have to be encapsulated in an IP packet, in a dedicated avionic unit on the aircraft, prior to being sent from the aircraft. One example of this avionic unit is Cobham’s Aviator S for Safety box. The received ACARS message is extracted when it arrives at ground stations, and is then put into the ARINC or SITA network as a POA message. The avionic unit and the receiver network together identify the message as a safety-related ATS message so that it receives transmission priority. Inmarsat SB will be approved to carry safety-related ATS messages in 2015.

Iridium will be superseded in 2015 by Iridium NEXT. This will be based on a new generation of satellites. Iridium Next will have a transmission rate of 1.5Mb per second, and so should be allow higher rates of transmission for ACARS messages in the same way that Inmarsat SB does.

Long-haul aircraft are now equipped with FANS-1/A equipment. This provides the most savings on the longest routes through more direct and optimal routeings. New-build long-haul aircraft from 2014 will also need to be equipped with VDL M2 radios for flying into upper EU airspace.

On-ground connectivity

The transmission rate of connectivity systems in the air is low, although Inmarsat SB provides a faster rate for AOC, AAC and APC messages than other systems. On-ground connectivity systems can provide higher data transmission rates.

While most on-ground communication systems are not relevant to most ATS messages, they are useful for a lot of AOC and AAC messages and communications. This includes downloading engine health monitoring (EHM) and aircraft health monitoring (AHM) data from the aircraft, and uploading the FMS database to the FMS, and load sheet and chart databases to the electronic flight bag (EFB) *(see table, page 22)*. A navigation database upload for the FMS can be 2MB or more.

Today each aircraft typically downloads 1-3 megabytes (MB) of AHM and EHM data per month via ACARS. Downloading quick access recorder (QAR) data relating to the flightdeck involves even more data: 200MB to 2 gigabytes per aircraft each month.

The two main systems for on-ground data transmission are Gatelink WiFi and cellular. Gatelink WiFi is used by aircraft types that have an on-board network system. Gatelink WiFi typically works with an on-board network server unit that is part of a modern aircraft's avionic architecture. Aircraft that have this type of avionics architecture are the A380, A350, 747-8 and 787. On-board networks are also to become standard on 737 and 777 models.

Gatelink WiFi requires a WiFi antenna to be in installed on the aircraft fuselage and a corresponding WiFi infrastructure to be in place at all gates at an airport terminal. WiFi ground infrastructure is now provided at some airports by service providers. The aircraft has to be fitted with a terminal wireless lan unit (TWLU). These are supplied by Teledyne Controls, Miltope, Honeywell and Rockwell Collins. Maximum transmission rates are 11Mb or 54 Mb per second, although actual throughput rates achieved are about one-third of this or less.

Cellular signals have the advantage of requiring no additional or new ground infrastructure. The aircraft, however, needs an avionic unit that complements, or is an alternative to, the TWLU. The A350 and 787-9 are being offered with WiFi and cellular connectivity. Boeing now offers a new TWLU model for the 777 that supports both cellular and WiFi.

Teledyne Controls offers a wireless ground link unit (WGL Comm+), which has multiple cellular radios. Not only does this provide cellular communications at the airport terminal, it also has server-like capabilities that provide it with a high storage capacity, and an aircraft interface device (AID) function that allows it to work with the aircraft's avionic systems. The WGL Comm+ has theoretical maximum transmission rates of 23Mb per second for upload, and a download rate of 84Mb per second. The WGL Comm+ allows aircraft types, that do not have an on-board network system, to transmit data via broadband cellular signals.

Communication categories

Communications to and from the flightdeck can be classed into four categories: air traffic service (ATS) messages for air traffic control (ATC), classed as safety-of-flight related; airline operational communication (AOC) messages; airline administration communication (AAC) messages; and air passenger communication (APC) messages.

There are widely held views that ACARS cannot be used as a connectivity system for non-flightdeck communications. Coiley points out that there is a regulation that prevents specific ACARS frequencies being used for revenue-generating communications, because of the need to prioritise safety-related transmissions. "ATS, AOC, AAC and APC messages can be distinguished from each other because of data labels, and so can be sent via ACARS. AOA or HFDL are usually the cheapest overland," says Coiley. "Few aircraft, however, are equipped with HF datalink; and even fewer have VHF, HF and Satcom. Most aircraft with Satcom installed will also have VHF as a minimum equipment standard."

ATS messages

ATS messages account for most of the communications that have to be transmitted while the aircraft is in the air. ATS messages also have to be sent using approved connectivity systems, because of their relation to safety of flight.

All ATS messages were originally made over VHF or HF radio by voice. Many are now sent via ACARS messages, using various connectivity systems.

There are several types of ATS messages. The first of these is automatic terminal information service (ATIS) messages. These are a recorded voice message played as a repeating loop. Traditionally they were listened to by flightcrew on the ground using VHF radio, and could also be listened to in the air, using either VHF or HF radio *(see table, page 18)*.

"ATIS messages are now digital messages, so they are referred to as

DATIS," says Gary Anderson, business development director, at ARINC Aviation Solutions. "These are digital communications sent as POA or AOA messages (*see table, page 18*). These are read as messages on the MCDU screen."

The second category of ATS messages are pre-departure clearance (PDC), also known as DCL in Europe, messages. Departure clearance has traditionally been given using voice communications by VHF radio. "Flights at the gate request PDC, and are sent back an ATC clearance with a pushback time via a POA or AOA ACARS message (*see table, page 18*)," explains Anderson. "This is done by using simple text messages that are sent by the control tower by VHF radio."

Pilot & ATC communications

Pilot-controller communications have traditionally always been via VHF or HF radio. The use of VHF or HF depends on where the aircraft is operating.

A new protocol has been developed by Eurocontrol for datalink messages to be sent between pilots and controllers. This is known as controller-pilot datalink communication (CPDLC). It is a set of standard messages that are sent by ACARS, over various communication channels.

The messages are chosen by pilots from a menu on the MCDU in the case of an FMS that has been modified and upgraded to perform CPDLC, or on the keyboard of a separate and dedicated CPDLC unit on the flightdeck's centre pedestal. Messages sent by ATC to the aircraft are read on the MCDU or CPDLC unit.

CPDLC replaces voice transmissions in the cruise phase of flight above certain altitudes and FLs, and is now used in some parts of the world.

CPDLC messages can be sent via ATN ACARS when the aircraft is operating overland and in range of VDRs (*see table, page 18*). It therefore replaces voice communications made via VHF radio. This is the only application of ATN VDL M2, and currently is only in use in European Union (EU) airspace.

CPDLC communications are made as ACARS via classic Satcom when the aircraft is over oceans or sparsely populated land masses (*see table, page 18*). In particular, this is on trans-Pacific and trans-Atlantic operations. This replaces voice communications made by HF radio.

There are several advantages to using CPDLC, including: fewer mistakes by pilots and controllers; increased airspace capacity; and allowing ATC controllers to have voice communications with fewer aircraft, which contributes to increased airspace capacity.

Flightplan changes

Either before departure or shortly after, aircraft on long-haul, trans-oceanic missions need to receive oceanic clearance from ANSPs or ACARS. "This is to receive clearance by ACARS for either the particular trans-oceanic track and FL at the time and speed requested in the flight plan, or an alternative," says Anderson. "These are sent via POA or AOA messages (*see table, page 18*)."

Once in the air, aircraft can also request or be sent FL and track changes to the original flight plan while in the air. Traditionally this has been via voice communications using VHF or HF radio.

There are now three methods for aircraft and ATC to make these communications, depending on which part of the world the aircraft is operating.

These changes have traditionally been requested by flightcrew by communicating with ATC via VHF or HF radio, or Satcom radio. This is still the case in certain parts of the world.

In some cases the instructions relating to FL and track changes, and other ATC communications, are sent as ACARS messages. This will be via POA or AOA over VHF, HF datalink, or via Satcom (*see table, page 18*). In the US, FL and track changes are sent as POA or AOA ACARS messages.

FL, track and other flight plan changes are requested by CPDLC where CPDLC is in use. This includes some trans-oceanic regions, especially the Pacific and the Atlantic, and increasingly in parts of European airspace.

Aircraft surveillance

Aircraft surveillance traditionally used radar over land masses and within a few hundred nm of coastlines, and provided regular position reports by voice using HF radio on long-range operations or where there was no radar coverage. This system of surveillance has been replaced, or will eventually be replaced, with automatic dependent surveillance (ADS).

ADS is the process by which an aircraft determines its own position, using an on-board global navigation satellite system (GNSS), and then transmits this at regular intervals either by radio or via Classic Satcom to the

FLIGHTDECK CONNECTIVITY TABLE - ATS COMMUNICATIONS

Connectivity System	Message Category	Message Type
VHF radio-voice	ATS	Short-range ATC comms
	ATS	Recorded ATIS messages
	ATS	Pre-dep clearance
	ATS	FL & track changes
VHF-POA	ATS	Recorded DATIS messages
	ATS	Pre-dep clearance
	ATS	Trans-oceanic clearances
	ATS	FL & track changes
VDL M2-ATN ACARS, for CPDLC	ATS	Short-range CPDLC messages
	ATS	Short-range FANS-2/B+ posn reports in EU airspace via CPDLC
VDL M2 - AOA ACARS	ATS	Recorded DATIS messages
	ATS	Pre-dep clearance
	ATS	Trans-oceanic clearances
	ATS	FL & track changes
HF radio-voice	ATS	Long-range ATC comms
	ATS	Recorded ATIS messages
	ATS	FL & track changes
HF datalink (HFDL) - POA ACARS	ATS	Trans-oceanic clearances
	ATS	FL & track changes
ADS-C	ATS	Trans ocean/long-range posn reports & related info
ADS-B	ATS	Overland/short-range posn reports & related info
Inmarsat Classic - voice	ATS	Short- & long-range ATC comms
	ATS	FL & track changes
Iridium (Classic) voice	ATS	Short- & long-range ATC comms
	ATS	FL& track changes
Inmarsat Classic - POA ACARS	ATS	Short- & long-range CPDLC messages
	ATS	FL & track changes via POA
	ATS	FL & track changes via CPDLC
	ATS	Long-range FANS-1/A posn reports via CPDLC
Iridium (Classic) - POA ACARS	ATS	Short- & long-range CPDLC messages
	ATS	FL & track changes via POA
	ATS	FL & track changes via CPDLC
	ATS	Long-range FANS-1/A posn reports via CPDLC
Inmarsat SB - POA ACARS at high speed	ATS	Short- & long range ATC voice comms from 2015
	ATS	Short- & long-range CPDLC messages from 2015
	ATS	FL & track changes via CPDLC from 2015
	ATS	FANS-1/A posn reports VIA CPDLC from 2015

ANSPs.

ADS will be mandatory in EU airspace from 2017, and in the US from 2020. The objective of ADS is to improve aircraft surveillance, reduce aircraft separation and increase airspace capacity.

There are two levels of ADS: ADS Broadcast (ADS-B), and ADS Contract (ADS-C).

ADS-B is a system used overland, and where aircraft position and other data are continuously broadcast (*see table, this page*). The information can be received by anyone.

ADS-B is sub-divided into two sets of functions: ADS-B 'Out', which transmits information relating to aircraft position to ATC, altitude and speed; and ADS-B 'In', which receives information on weather and terrain to be displayed on the navigation displays.

ADS-B makes aircraft visible to ATC and other aircraft that have ADS-B equipment. The information is transmitted from the aircraft via a mode S transponder. This is a modified Mode S transponder used in the traditional secondary radar surveillance system. It is therefore a piece of hardware required on the aircraft. It provides short-range transmission, similar to VHF radio, but uses an L-band radio signal that is received by ground-based receivers. It is therefore used for trans-continental and overland operations.

ADS-C provides the same information and capability as ADS-B. ADS-C is used for contact between an airline and various ANSPs, and gives aircraft the capability to transmit and receive all data relevant to ADS via Classic Satcom at a pre-agreed frequency. "This is usually every 10 degrees of latitude," says Coiley. "The objective is to send position information more frequently in order to reduce separation between aircraft."

Classic Satcom provides the aircraft with the ability to transmit position information and data over long distances. ADS-C is therefore used for trans-oceanic operations, as well as flights over deserts and sparsely populated areas (*see table, this page*).

The hardware required for ADS-C is a GNSS and FMS. Unlike ADS-B, a separate transponder is not required. Instead the FMS is upgraded to provide the aircraft with the capability of transmitting and receiving all the relevant data and information.

FANS

The future air navigation system (FANS) was conceived in the late 1980s. The concept was to provide an ATC and air navigation system that did not use the traditional radar surveillance, inertial navigation and ATC communication systems for long-distance, trans-oceanic

While many may regard FANS-1/A equipment as only being appropriate for widebody, long-haul aircraft, more A320 and 737 family aircraft are being used on medium- and long-haul routes in more remote parts of the world. These aircraft would benefit from having FANS-1/A equipment installed.

operations. The new system would use a digital system for communication, navigation and surveillance.

The first FANS system was based on the combined use of a GNSS, Classic Satcom and ADS-C capability. This allowed aircraft to send periodic position reports using ADS, and flightcrew to send FL and track change requests to ATC and receive appropriate instructions back via CPDLC. The CPDLC transmissions are ACARS messages via Satcom. Inmarsat Classic was the first Satcom system approved for FANS-1/A, but Iridium was also approved for FANS-1/A in 2011 (*see table, page 18*).

Canadian avionics manufacturer FLYHT provides its AFIRS 228S unit, which has two Iridium channels. AFIRS 228 is certified for ATS communications via Iridium. One Iridium channel is used for FANS-1/A and the related CPDLC messages. The second Iridium channel can be used for voice communications via Satcom.

FANS-1/A replaced ATC communications and position reports all made by voice using HF radio in the trans-ocean and cruise phase of the flight. The aircraft must also, however, have either a Satcom or HF radio as a back-up in the event of the FANS system failing.

The first generation of FANS for long-haul aircraft was developed by Boeing in 1990, and was called FANS-1. Airbus developed a similar system for the A330/340 called FANS-A. Since the two systems achieve the same, they are called FANS-1/A.

Captain Michael Bryan, principal at Closed Loop Consulting explains that FANS-1/A is primarily used on trans-Atlantic and trans-Pacific operations. It is also, however, now used over the Indian Ocean, and increasingly on trans-Siberian routes. "It is also used across Australia, but using ADS-B," explains Bryan. "It is also available across the North Sea."

FANS-1/A is most beneficial on the longest routes across the Pacific and other Oceanic areas. FANS-1/A allows more optimal and direct routeing for aircraft. It also has dynamic re-routeing, compared to the rigid traditional track system. Overall FANS-1/A is more flexible in terms of aircraft being able to switch routes and tracks. It therefore produces flight time and fuel savings.

FANS-1/A equipment is also becoming increasingly useful for short- and medium-range aircraft operating in more remote areas. These either have old ATC equipment, or a limited number of VHF transceivers. The use of FANS-1/A equipment in areas of the world such as Siberia, or many parts of Africa, makes operation of all types of aircraft easier.

Reduced aircraft separation minima and increased airspace capacity are also possible because of the improvement in aircraft surveillance, navigation accuracy and communication times.

A second level of FANS was developed for aircraft operating over land masses, and able to send ACARS messages via VDL M2, rather than by Satcom. This is known as FANS-2 for Boeing, and -B for Airbus aircraft.

The GNSS equipment used on the aircraft for FANS-2/B is the same as for FANS-1/A. For FANS-2/B the aircraft also requires VDL M2 capability, and an ADS-B transponder. Position reports are broadcast by ADS-B, and CPDLC messages for FL and track changes are all sent as ATN VDL M2 messages (*see table, page 18*).

A later version called FANS-B+ was developed, and this provides a security layer for CPDLC messages so that they cannot be interfered with.

Link 2000/2000+

As part of an upgrade to European ATC practices, freeflight, a new concept of ATC and navigation is being introduced. Freeflight will ultimately replace the use of radar surveillance, voice communications at some altitudes, and navigation of aircraft at set altitudes and operating down airways and standard departure and arrival routeings.

Freeflight will allow each aircraft to determine its optimum flight track, speed and altitude profile using its GNSS and FMS.

ADS-B will replace the surveillance of aircraft by radar. Voice communications in ANSPs operating airspace in the EU above flight level 285 (altitude of 28,500 feet) will be replaced by CPDLC communications between aircraft and ATC. As with FANS, the objective of this system is to reduce ATC controllers' workload, improve surveillance and increase airspace capacity.

Traditional voice communications below this altitude will still be used, because of the problem of latency in the CPDLC system.

The original deadline for airlines and ANSPs complying with this was 2000. This was not met so the project was re-named Link 2000+. "Link 2000+ is the mandate specifying that all short-haul aircraft operating in EU airspace, or operating trans-European routes, have a deadline of 1st February 2015 to ensure that aircraft are equipped for CPDLC operations," explains Ian Gilbert, representative for Spectralux Avionics. "About 1,000 short-haul European aircraft, however, are probably not yet equipped to meet the mandate, while only four out of nine European ANSPs are equipped. France, for example, has said it will not be ready for CPDLC messaging until 2018. Moreover, despite the Link 2000+ mandate, aircraft and ANSPs will still be free to communicate with each other via voice transmissions at higher

Aircraft operating trans-European routes, above FL 285 in EU airspace are required to have CPDLC equipment installed by February 2015. CPDLC equipment allows aircraft and ATC controllers to communicate via datalink messages.

altitudes."

The CPDLC messages will use ATN VDL M2 ACARS messages, in the same way that FANS-2/B does (*see table, page 18*). The standard set of CPDLC messages for use by Eurocontrol in Europe, however, is larger than the set of standard CPDLC messages used in FANS-1/A.

As described, CPDLC messages can either be selected, sent and read on the MCDU of a modified FMS, or on a dedicated CPDLC unit. Spectralux provides a Dlink+ box that is a multifunction avionics unit with CPDLC capability to meet Link 2000+ standards. Gilbert stresses that the unit does not have CPDLC capability for FANS.

"The Spectralux equipment could be adapted for the NextGen programme in the US, although it is not year clear what exactly this will be," says Gilbert. "Our Dlink+ box sends CPDLC protected-mode messages by ACARS over the ATN in Europe, and for this it has a built-in VDL M2 radio. It also has additional capability for POA messaging, and sending on, off, on and in (OOOI) times, fuel and crew information, PDC and ATIS/DATIS requests, and a variety of other messages that would be classed as AOC and AAC messages."

Installing this type of box means no other devices or modifications are needed to comply with the Link 2000+ mandate. An alternative is to upgrade the FMS to allow its MCDU to provide and display and CPDLC messages. Other ATC messages are shown on the centre flightdeck displays.

The Link 2000+ mandate specifies that aircraft that are FANs-2B+-equipped satisfy the mandate's requirement, since they can make communications with ATC via CPDLC messages.

Long-haul aircraft in Europe

The requirement to operate with CPDLC in upper EU airspace not only applies to European-based short-haul aircraft, but also to long-haul aircraft entering EU airspace.

Long-haul aircraft equipped with FANS-1/A equipment will not be able to operate to the same standards as European short-haul aircraft that comply with Link 2000+, however. "The standard set of CPDLC messages in the FMSs of FANS-1/A-equipped aircraft is smaller than the standard set of messages used on short-haul aircraft that have the Link 2000+ equipment," explains Bryan. "Most long-haul aircraft types with a FANS-1/A message set can, however, use the portion of Link 2000+ messages that are common to both. This means that ATC of European ANSPs can only send limited messages to a FANS-1/A-equipped long-haul aircraft, since it only uses a smaller message set. The 787 is the first aircraft to be equipped with both sets of messages." It is also possible that other long-haul types could be retrofitted with FMSs that have both sets of messages.

The message set in FANS-2/B+ equipment is sufficient to meet the Link 2000+ mandate.

In addition to the small FANS-1/A message set used by long-haul aircraft, there is also their ability to send CPDLC messages via ATN VDL M2. That is, FANS-1/A equips them to send ACARS messages, but only by Satcom.

"These aircraft have an exemption under the Link 2000+ mandate, whereby they can make CPDLC communications with Eurocontrol using FANS-1/A equipment, ACARS via Satcom, or use voice communications via VHF," says Gilbert. "From January 2014, new-build long-haul aircraft need to be equipped with both FANS-1/A Satcom and VDL M2 radios. There is a chance, however, that at least some long-haul aircraft will already have VDL M2 capability, to allow them to receive DATIS and PDC messages when on the ground."

US NextGen

The US has plans for its own system of freeflight in its airspace by 2020. "US NextGen will use a system of freeflight and CPDLC messages for upper altitudes, but it is not clear how they will be sent," says Gilbert. "It could send the messages by Satcom."

ARINC, however, has been investing in upgrading the VDL M2 infrastructure, so there is a strong likelihood that NextGen in the US will use ACARS over ATN VDL M2 and Satcom for CPDLC.

AOC messages

AOC messages are not safety-related, but instead relate to aircraft and airline operations. Many do not need to be sent by approved connectivity systems, although the evolution in how these messages are sent means that a large number of AOC message types are sent via ACARS. It can either be POA and AOA via radio, or via Satcom (*see table, page 22*).

There are a large number of categories of AOC messages. The first is OOOI time messages sent via ACARS from the aircraft to the operator's flight operations department (*see table, page 22*).

A second category of AOC message involves sending flight plans to aircraft.

"Flight plans can be sent and uplinked to the aircraft via ACARS to the FMS," says Cresswell. "Flight plans include tracks and waypoints, altitudes and flight levels (FLs), and speeds. They

FLIGHTDECK CONNECTIVITY TABLE - AOC/AAC/APC COMMUNICATIONS

Connectivity System	Message Category	Message Type
VHF-POA	AOC	OOOI times
	AOC	Flight plans
	AOC	EHM & AHM data
	AOC	Crew messages
	AOC	CMC fault codes
	AOC	Non-CMC fault codes, from ETLs
	AOC	Graphical text weather services
	AOC	EFB uploads & downloads
	AAC	Crew manifests & rosters, medical & airport requests, chart and loadsheet database uploads
VDL M2 - AOA ACARS	AOC	OOOI times
	AOC	Flight plans
	AOC	EHM & AHM data
	AOC	Crew messages
	AOC	CMC fault codes
	AOC	Non-CMC fault codes, from ETLs
	AOC	Graphical text weather services
	AOC	EFB uploads & downloads
	AAC	Crew manifests & rosters, medical & airport requests, chart and loadsheet database uploads
HF datalink (HFDL) - POA ACARS	AOC	EHM & AHM data
	AOC	Crew messages
	AOC	CMC fault codes
	AOC	Non-CMC fault codes, from ETLs
	AOC	Graphical text weather services
	AOC	EFB uploads & downloads
	AAC	Crew manifests & rosters, medical & airport requests, chart and loadsheet database uploads
Inmarsat Classic - POA ACARS	AOC	OOOI times
	AOC	EHM & AHM data
	AOC	Crew messages
	AOC	CMC fault codes
	AOC	Non-CMC fault codes, from ETLs
	AOC	Graphical text weather services
	AOC	EFB uploads & downloads
	AAC	Crew manifests & rosters, medical & airport requests, chart and loadsheet database uploads
	APC	News & other items of interest to passengers
Iridium (Classic) - POA ACARS	AOC	OOOI times
	AOC	EHM & AHM data
	AOC	Crew messages
	AOC	CMC fault codes
	AOC	Non-CMC fault codes, from ETLs
	AOC	Graphical text weather services
	AOC	EFB uploads & downloads
	AAC	Crew manifests & rosters, medical & airport requests, chart and loadsheet database uploads
	APC	News & other items of interest to passengers
Inmarsat SB - POA ACARS at high speed	AOC	OOOI times
	AOC	EHM & AHM data
	AOC	Crew messages
	AOC	CMC fault codes
	AOC	Non-CMC fault codes, from ETLs
	AOC	Graphical text weather services
	AOC	EFB uploads & downloads
	AAC	Crew manifests & rosters, medical & airport requests, chart and loadsheet database uploads
	APC	News & other items of interest to passengers
GATELINK WiFi	AOC	EHM, AHM, FMS database, uploads to EFB
Cellular	AOC	EHM, AHM, FMS database, uploads to EFB

are sent to the aircraft by POA or AOA messages (*see table, this page*). The flightplan can be reviewed by the crew on the MCDU on older aircraft types. The waypoint and other data then have to be manually keyed into the FMS. On more advanced aircraft types with integrated avionics, the information is validated by the flightcrew before being auto-loaded into the FMS. This has to be sent to the ANSP prior to PDC/DCL."

The third category is AHM and EHM data. Both of these are sent while the aircraft is in the air, and sent using ACARS (*see table, this page*). There is some debate as to whether sending the data in real-time is necessary. The increased volumes of EHM and AHM data have raised airline costs, and it is felt that since the data do not relate to emergency situations they can be transmitted using a WiFi or cellular connectivity system when the aircraft is on the ground (*see table, this page*).

Another AOC category is crew and operational messages to maintenance control. These can be sent via ACARS over radio or Satcom (*see table, this page*).

Graphical text weather services (GTWS) can also be sent to the aircraft using POA or AOA (*see table, this page*). This is a text-based weather report sent direct to the MCDU on the flightdeck. The graphical content can also be integrated with an EFB, depending on how it has been installed and certified. Other types of AOC messages that can be sent from the aircraft are non-mandatory position and fuel usage data reports."

The next main category of AOC messages are central maintenance computer (CMC) fault codes. These are sent via ACARS, either by VHF or HF radio, or by one of the Satcom variants *(see table, this page)*. These fault codes indicate problems with aircraft systems and components, and are sent to inform the airline flight operations, maintenance control, and line maintenance departments of faults and problems as soon as they have developed in-flight. This allows preparations to be made to fix them while the aircraft is in the air, so that work can commence shortly after the aircraft lands.

There are several examples of avionic products that provide connectivity for multiple AOC communications. One is FLYHT's AFIRS 228B avionic product. This is not certified for ATS communications, but uses Iridium for a range of AOC transmissions. These include voice communications to airline operations departments, position reporting to airline departments via FANS-1/A, connectivity for EFBs, the transmissions of fuel management data, sending avionic and engine performance trend data, and a two-way transmission

Class 3 EFBs are integrated with the aircraft's avionics. Operational communications to and from these devices is with POA or AOA via radio, or ACARS via Satcom. Uploads for EFB databases is with Gatelink WiFi and cellular on-ground connectivity systems.

of aircraft health and system data.

"The aircraft health functionality system is an alternative to ACARS messages that send AHM and EHM data relating to exceedences," says Matt Bradley, vice president of business development, at FLYHT Aerospace Solutions Ltd. "AHM and EHM data sent by ACARS lacks context, and is really just a simple message. Our unit provides the ability to add context associated with a AHM or EHM data transmission. The same system also allows the line mechanics and engineers on the ground to have a two-way conversation with the AHM and EHM units on the aircraft. Ground staff can therefore ask for more detailed data and information."

EFBs & ETLs

There are technical problems and faults that are not monitored or reported by the CMC. These non-CMC faults have to be either reported by voice or as an ACARS message keyed in on the MCDU by the flightcrew, or reported manually from the aircraft's technical log by the flightcrew after the aircraft lands.

In recent years electronic technical log (ETL) software has been developed by several vendors. ETL software is used on EFB hardware. ETLs are used by a small number of airlines on some of their fleet.

One of the main functions of an ETL is to replace the paper log. Non-CMC faults and defects can be recorded, using standard report selections from a standard menu on the ETL.

One particular supplier is Ultramain. Ultramain has supplied ETL software to KLM for use on its 777-300ERs. Ultramain will equip all of Cathay Pacific's fleet with ETLs.

Non-CMC faults and flight defects can be transmitted to the ground, so that the airline's maintenance control department can start preparing to fix them in addition to CMC faults. The ETL therefore makes it possible for all types of faults to be reported to airline departments while the aircraft is in the air. The use of an ETL to make these in-flight reports is only possible if connectivity is established for the EFB.

"There are several types of communications to and from the EFB," says Anderson. "Some of these are AOC messages, while others are AAC. The first type of AOC communication to and from EFBs is weather updates from the ground. A second type is sending load sheets that have been completed by the crew using an application on the EFB, to the relevant department. A third category of AOC messages are revised flight plans. Sending them to the EFB is one method, and other routeings are possible."

Connectivity for the EFB is an important issue. Some modern generation aircraft have Class 3 EFBs, which are integrated with the aircraft's avionics. Class 3 devices use POA or AOA via radio, or ACARS via Satcom for communication with the ground (*see table, page 22*).

Class 2 devices are standalone pieces of equipment which operate on IPs. They therefore need to be interfaced with the aircraft's avionics for them to be able to send and receive via ACARS. The most popular method is an aircraft interface device (AID). It should be appreciated that Class 2 EFB devices can read data of the aircraft databus, but some Class 2 EFBs cannot send data into the aircraft's avionics. They can still, however, transmit data to the ground via ACARS (*see table, page 22*).

AAC messages

There are relatively few types of AAC messages. These relate to the administration processes that have to be performed to make operations possible. This includes managing libraries and databases.

"AAC messages tend to relate to crew manifests, connecting gates for passengers on the flight, and the request of medical or special assistance when the aircraft lands," says Cresswell. "These messages can be sent using ACARS via VHF and HF radio, and Satcom (*see table, page 22*)."

There are several AAC messages sent by various airline departments to the EFB.

These include sending updates for Jeppesen and other navigational charts to the EFB. Updating and revising the library of charts is an administrative function.

Another example is the updates and revisions to the load sheet database, so that the flightcrew are able to make loadsheet calculations using correct and up-to-date information.

Another type of AAC message sent to the EFB is crew rosters from the an airline's operations department.

APC messages

There are few types of APC message, and the distinction between them and AAC messages is not clear. APC messages are considered to be those related to passenger interests, rather than administrative issues such as gate information or requests for medical assistance. Examples of APC messages include sending news items or sports results that can be relayed to the cabin while the aircraft is in flight. APC messages can be received or requested using ACARS via Satcom, but not via ACARS using VHF and HF radio (*see table, page 22*). AC