The demand for ever-improving cabin services and connectivity standards is driving the constant development of satcom and ATG connectivity systems. The range of cabin connectivity systems, their operators and the service providers are examined here.

Passenger cabin connectivity system & service providers

Growing demand and expectation from passengers for new generation in-flight entertainment (IFE) and connectivity are driving airlines' demand for better external and internal passenger cabin connectivity to provide internal WiFi signals to supply cabin entertainment, including live TV to seatback screens.

Airlines have to consider several factors when choosing cabin connectivity services and systems: what services are available on each route network they operate; service providers; type of contract service providers offer; external and internal hardware required for the aircraft; likely data download rates to aircraft and to each seat; type and quality of IFE services that are possible with each available service; and future developments.

Connectivity system choice

Most airlines have limited satellite communication (satcom) systems from which to choose for cabin connectivity. In most cases, airlines acquire satcom connectivity from service providers that tend to be avionics manufacturers. Service providers in turn acquire satellite capacity from satellite operators, a small number of which provide services directly to airlines.

Airlines in North America also have the option of air-to-ground (ATG) services. Airlines in Europe also have ATG services known as the European Aviation Network (EAN) as an option from Inmarsat, which is marketing the service.

Airlines in the US, Canada and Europe can use ATG cabin connectivity for IFE services. This is provided by Gogo in North America, and by Inmarsat in Europe.

The ATG service in North America is supplied from more than 250 ground transmitters located across the continent. This provides coverage across all 48 states in the main territory of the US, the main population areas of Alaska, and the southern part of Canada's main population centres.

The EAN system in Europe is provided via transmissions from 350-400 telecoms terrestrial transmitters, and is supplemented by S-band satellite service. Service coverage is over the 28 states of the European Union (EU) plus the adjacent oceanic areas.

Ku-band

Ku-band is one of two main categories of satcom service for cabin services and IFE. These are based on K-band radio waves.

Ku- (K under) band transmissions are 12-18 Giga Hertz (GHz). Ku-band transmissions were used on first generation satellites. These were primarily developed for domestic TV transmissions over several areas of the world. The main Ku-band satellite operators are Eutelsat, Intelsat, Hughes and SES. Most services provide regional rather than full global coverage.

Ku-band satellites do, however, operate in low orbits, so they provide full global coverage. Global coverage for Ku-band is mainly achieved by service providers stitching together coverage for several regions provided by different satellite operators.

The first generation Ku-band satellites were launched in the 1960s and 1970s. These were designed with a widebeam configuration, the beam from each transponder therefore covering a wide area of 7.7 million square miles. While this is optimal for domestic TV services, it provides relatively low data downlink rates to aircraft flying under the beam.

As a result, the first Ku-band systems provided downlink rates to aircraft of 1-2 mega bits per second (Mbps). These increased to 10Mbps for later examples of first generation Ku-band satellites.

In response to other satcom systems becoming available, Ku satellite operators are now in the process of launching new-generation, spotbeam high-throughput satellite (HTS) Ku-band systems. Intelsat has launched some of the first HTS Ku-band satellites in 2016. The spotbeams from each transponder on these satellites will be concentrated over a smaller area, to provide higher data download rates to each aircraft flying under the beam. HTS Ku-band satellites are expected to have downlink rates to the aircraft of 30Mbps.

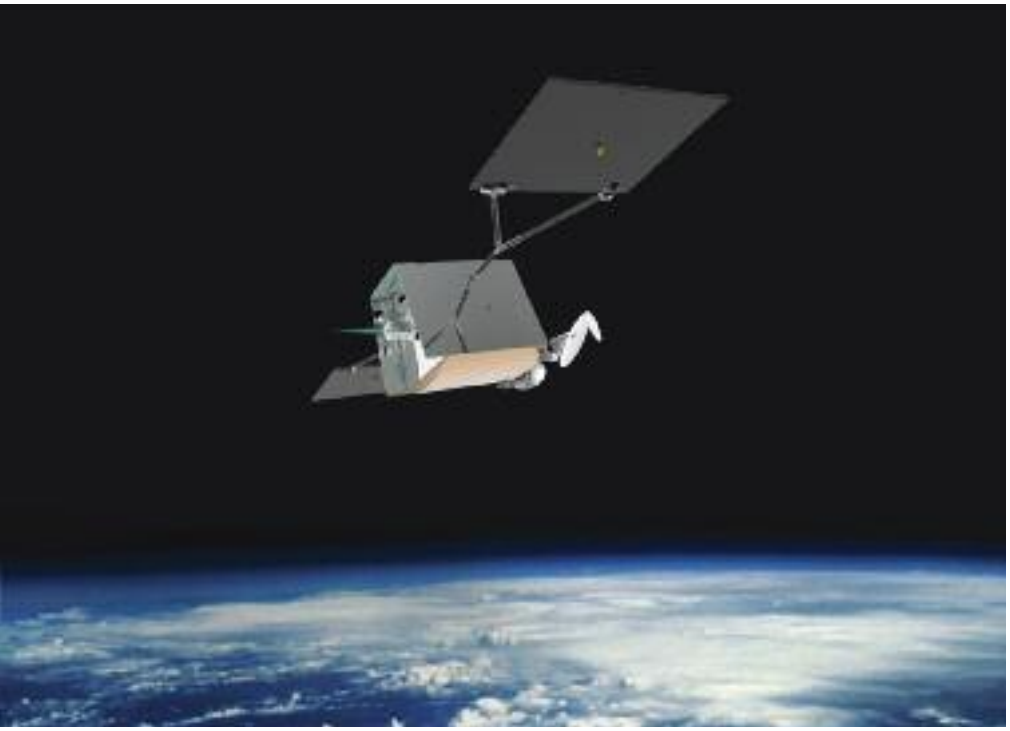
Gogo also provides an enhanced Ku-band service called 2Ku-band, which entered service in late 2015. Gogo claims it has downlink rates to the aircraft of 70Mbps. The 2Ku-band system is achieved by Gogo's two-phased array Ku-band antennae in a single radome.

Intelsat

Intelsat operates about 50 geostationary satellites, the majority of which are Ku-band. Three of the satellites are Ka-band. The constellation operates over four main regions: the Atlantic Ocean, the Americas, the Indian Ocean region, and the Pacific Ocean region.

Intelsat is deploying the next-generation (NG) HTS Ku-band satellites called Intelsat EpicNG, starting from March 2016, launching seven of these.

Intelsat 29e provides service over the



OneWeb is a new constellation of more than 600 Ku-band satellites. Each satellite is expected to have a data downlink transmission rate of 150Mbps to the aircraft.

Americas, the Caribbean and the North Atlantic air traffic routes. Intelsat 29e is an HTS spotbeam Ku-band satellite, but it is also a Ka-band wide beam satellite.

The second NG satellite is 33e, and will be launched in the third quarter of 2016, to provide services in Africa, the Asia Pacific and Europe.

The launch of Horizons 3e will be in the second half of 2018, and will complete the full global footprint of Ku-band coverage over the Pacific Ocean. There will be seven Intelsat EpicNG satellites in service by 2020.

These new satellites have been chosen by service providers Gogo and Panasonic.

The Intelsat EpicNG satellites use HTS, spotbeam technology. They have been designed with backwards compatibility with the remainder of the Intelsat Ku-band fleet. This allows Intelsat to provide the best mix of coverage based on customers' needs. The HTS spotbeams can be directed to high traffic areas and regions. The traditional widebeam satellites can be used to support wider global coverage.

The Intelsat EicNG satellites are configured with a mix of widebeams and spotbeams, to provide a total capacity of 60 gigabits per second (Gbps) per satellite, 10 times the amount of traditional Ku-band satellites. The Intelsat 29e provides 9,395 MHz of downlink capacity. Intelsat says that testing has indicated that a downlink rate to each aircraft of at least 200Mbps is possible, although actual rates will depend on the antenna and the hardware used.

Eutelsat

Eutelsat of France has a fleet of 38 Ku- and Ka-band satellites. Most are Ku-band satellites, and are early generation examples. These are in geostationary orbit. They collectively provide regional coverage from 116 degrees west to 72 degrees east.

The western-located satellites provide coverage to the western USA, and all of Central and South America. The eastern satellites provide coverage to most of the Asia Pacific and Oceania.

Hughes

Hughes is a US satellite operator that operates fleets of Ku- and Ka-band satellites. The Ku-band satellites comprise both old and new generation HTS satellites. The new-generation Ku-band satellites have transmission rates to the aircraft of up to 10Mbps.

Hughes provides capacity for service provider Global Eagle Entertainment (GEE). It is the Hughes constellation that provides Southwest Airlines with connectivity for its internet protocol (I.P.) live TV service.

SES

SES is based in Luxembourg, and operates a fleet of more than 30 Ku-band satellites. These are from five generations. A minority of the satellites, however, are Ka-band satellites.

The first-generation satellites have 16 to 24 transponders. The fleet of second-generation satellites comprises 12 Astra Ku-band satellites with 22-56 transponders. These satellites were launched from 2006 to 2014.

The third-generation satellites are NSS, and were launched from 2002 to 2009. These have 28-60 transponders.

SES launched the first of its fourth-generation satellites in 2010. There are 10 of these, and they have 12-81 transponders.

The fifth-generation satellite is a Ka-band satellite called YAHSAT, which was launched in 2011, and has 23 spotbeams.

All five generations of satellite provide regional coverage in particular locations. All main land masses are covered, with the exception of the Russian Federation. The Atlantic Ocean is the only oceanic area covered.

Airlines acquire SES satellite coverage is acquired via service providers.

OneWeb

OneWeb is a relatively new satellite operator, founded by Greg Wyler in 2012. The company will launch the first satellites of its constellation in 2018.

OneWeb's constellation will be a system of low earth orbit (LEO) satellites that will provide full global coverage. The system is ideally suited to bringing broadband internet connection to rural and remote areas. It will also support applications that require low latency connections, such as cloud-based applications, voice over I.P. (VOIP) and teleconferencing.

OneWeb aims to serve three main market segments: corporate broadband, domestic broadband, and the global mobility and transport sector that includes aviation and maritime.

With the launch of the first satellites in 2018, OneWeb will start rolling out the first services to selected parts of the world in 2019. OneWeb has partnered with Rockwell Collins to develop the global aviation network for high-speed broadband service. The initial satellite constellation is projected to reach 648 satellites by 2020. The project is expected to eventually launch up to 900 satellites.

In addition to a large number of satellites, the main strength of OneWeb's project is that the constellation is expected to have downlink transmission rates of up to 150Mbps to the aircraft. This is comparable with ViaSat's ViaSat-1 Ka-band satellite.

Ka-band

Ka- (above) band transmissions are 17-40GHz. These are later-generation satellites compared to the first Ku-band

Viasat operates very high capacity Ka-band satellites. Its Viasat-1 satellite operates over North America, and has a total capacity of 140Gbps. It will launch ViaSat-2 in 2017, and will have a total capacity of 300Gps. This will be followed by three Viasat-3 satellites in 2019 and 2020, and each one will have a total capacity of 1,000Gbps.

satellites. There are fewer Ka-band satellite operators compared to Ku-band, but the number is increasing.

Ka-band satellites have always had a spotbeam configuration. Each satellite has a number of transponders that operate simultaneously, and there is a spotbeam for each transponder.

Inmarsat

Inmarsat is the only Ka-band satellite operator to provide global coverage.

The first Inmarsat satellites to use spotbeam technology were Inmarsat-3s, which were launched in 1996-1998. Four of them are still in active service. These provide L-band transmissions that are certified for safety transmissions from the flightdeck.

Inmarsat has launched three high-speed Inmarsat-5 (I5) satellites that form the backbone of its Global Express (GX) constellation. These three satellites are in geostationary orbit, and are located at intervals of 120 degrees of latitude, so they provide coverage all around the Equator. Their positioning means that they can provide almost full global coverage, with the exception of the polar regions.

The first I5 satellite serves Europe, the Middle East, Africa and Asia. The second I5 satellite serves the Americas and the Atlantic Ocean, while the third serves the Pacific Ocean. Between them these three satellites provide seamless global coverage.

A fourth I5 satellite will be launched in late 2016, to provide additional GX capacity for North America and Europe, which are regions of high demand.

Inmarsat's sixth generation of satellites will provide a combination of L-band and Ka-band transmissions.

The I5 satellites use spotbeam technology. Each satellite can generate up to 89 spotbeams, of which 72 can be used simultaneously. There are also six steerable beams, which can be directed to areas of high demand.

The satellite has a transponder for each spotbeam, and the transponder has a set amount of frequency through each spotbeam. The spotbeam configuration of Ka-band satellites means that each beam covers an area of 770,000 square miles, which is one-tenth of the area covered by widebeam Ku-band satellites.

The downlink rate of each spotbeam is about 50 Gbps. This means that the 72 spotbeams will generate a total capacity of 3.6-4.0Gbps when they are being used simultaneously. The six steerable spotbeams will take this total up to about 5.0Gbps.

Viasat

ViaSat is a US operator of Ka-band satellites that are configured to provide high throughputs.

ViaSat has three first-generation satellites that provide coverage over North America: Anik-F2, WildBlue-1 and ViaSat-1. Anik-F2 and WildBlue-1 have a total combined capacity of 9Gbps, while ViaSat-1 has a much larger capacity of 140Gbps. The three therefore have a total capacity of about 149Gbps.

ViaSat will launch its second-generation Ka-band satellite, called ViaSat-2, in 2017 and will launch the third-generation ViaSat-3 satellites in 2019.

There will be one ViaSat-2 satellite, and it will have a total capacity of 300Gbps, almost twice that of the three first-generation ViaSat satellites. ViaSat-2 will provide coverage to the eastern half of North America, the Caribbean, the northern part of South America, and part of the North Atlantic between North America and Europe.

Early generation Ka-band satellites are configured with 36 spotbeams, while ViaSat-1 and ViaSat-2 satellites have 100-200 spotbeams.

The ViaSat-3 satellite constellation of three geostationary satellites, to be launched in 2019, will have the highest capacity of any satellite network in the world. ViaSat claims that the capacity of each satellite will be 1,000Gbps, or 1.0 Terabits per second.

ViaSat also claims that the ViaSat-3 constellation will provide more capacity than all of the other telecommunications spacecraft in the world. This includes all of the HTS satellites currently under construction.

The first satellite, to be launched in 2019, will provide coverage over the Americas; the second, to be launched in 2020, will cover Europe, the Middle East and Africa; and the third will cover the Asia Pacific.

ViaSat's Ka-band -1 and -2 satellites have been built mainly to provide domestic internet connectivity, and only a fraction of their capacity is used by airlines and commercial aircraft.

Eutelsat - Ka-band

In addition to Ku-band satellites, Eutelsat also operates a single Ka-band satellite called KaSAT. This provides coverage over Europe.

KaSAT was launched in 2010, and has a total capacity of 90Gbps. The satellite is thought to have 80 spotbeams.

ViaSat has partnered with Eutelsat to provide Ka-band coverage over an extended area. The two companies together will provide coverage for all of North America, the Atlantic Ocean and Europe.

Intelsat - Ka-band

Intelsat's fleet of Ka-band satellites is small compared to its Ku-band satellite constellation. There are three Ka-band satellites: the Intelsat 29e satellite covering the Atlantic Ocean area; and Intelsat 20 and Intelsat 33e covering the Indian Ocean area.

Hughes - Ka-band

Hughes, based in the US, operates Space 3 and Jupiter Ka-band satellites. They were launched to provide broadband connectivity over North America. The Jupiter satellite has a multiple spotbeam architecture, and a data downlink rate of 100Mbps. The Spaceway 3 satellite has an overall capacity of 10Gbps.

Telenor

Telenor operates a small fleet of satellites, and the youngest in its constellation is the THOR 7 Ka-band satellite. This was launched in late 2015. It provides mobility services for maritime and aviation applications, in an area from the East and North Atlantic Ocean that covers part of Greenland and all of Iceland, to most of Europe, the Mediterranean, the Baltic states, the Black Sea, and the Persian Gulf.

THOR 7 provides seamless spotbeam handover, and offers a variety of service packages that provides up to 24Mbps.

ATG services

As described, the main operator of ATG services has been Gogo over the North American continent.

Gogo has an exclusive licence for a 3Mhz bandwidth of cellular transmissions over North America, transmitted from 250 towers.

There are two levels of ATG: the original ATG1 launched in 2008; and the enhanced ATG4 launched in 2012. The towers emit the same transmissions, and it is the equipment on board the aircraft that determines whether ATG1 or ATG4 is available.

ATG1 has a downlink rate to the aircraft of about 3Mbps. About 1,400 aircraft have been equipped with the system. US airlines charge passengers that use it to gain access to e-mails and the internet.

A high number of aircraft using ATG1 led to the launch of ATG4. This provides a higher-capacity downlink rate to the aircraft of up to 9.8Mbps. So far about 1,100 jetliners have been equipped with ATG4 in North America.

Combined S-band & ATG

As an alternative to Ku- and Ka-band satcom systems, a combination of S-band satellite and ATG transmissions will be provided in the terrestrial area of the 28 EU countries, the Mediterranean, North Sea and Bay of Biscay from 2017.

This service is called the European Aviation Network (EAN) and has been launched by Inmarsat.

The ATG system is provided via 350-400 terrestrial transmitters operated by Deutsche Telekom. Each of these provides transmissions in a cell 160km in diameter. Each cell is divided into three segments, and the transmissions for each tower generate a transmission uplink rate to the aircraft of about 70Mbps.

A small number of transmission towers transmit signals in a smaller diameter, and are placed close to major airports and areas of high traffic density.

The S-band satellite is operated by Europasat, and Inmarsat has been allocated a frequency spectrum. This satellite service supplements the ATG towers over the oceanic areas of Europe. The S-band satcom service can also be supplemented by Inmarsat's GX Ka-band service.

Inmarsat controls the EAN network that is being offered to airlines from 2017.

Connectivity services

As described, airlines acquire their cabin connectivity services via service providers, rather than directly from the majority of satellite operators. There are several models of service contracts.

Airlines will first be interested in the level of in-flight service they want to provide, and each level will require a different data transmission rate to the aircraft and to each seat.

The simplest services are e-mail, text messaging and phone calls. These require downlink rates to the aircraft of 1-2Mbps. Gogo's ATG1 is an example of an external connectivity system for these services.

Internet browsing and shopping combined with live credit card transactions require higher transmission rates of about 3Mbps to the aircraft.

Streaming live audio and content and viewing live TV require higher downlink rates to the aircraft. Live TV requires a downlink rate of 1Mbps per channel. JetBlue in the US has 50 live channels available. In many cases, however, only a small number of TV channels, such as sport and news, need to be live. The number of different languages catered for will depend on the area of aircraft operation, and so may require live transmission on several channels.

Other TV channels can be pre-loaded and transmitted internally from servers wirelessly to passengers' devices, or via hardwire connections to seatback screens.

The downlink rate required for live TV is influenced by the type of TV provided. This can either be broadcast TV or I.P. TV. Broadcast TV comes from broadcast Ku-band satellites, including those provided by Direct TV and DISH TV in the US, Bell Express View in Canada and Sky Brazil in Brazil. In several cases, broadcast TV from these satellite operators is only possible with an aircraft with hardwired seatback screens, not with wireless IFE systems to passengers' personal electronic devices (PEDs).

IPTV is delivered to the aircraft in I.P. format, and PEDs operate with I.P. packets. Broadcast Ku-band satellites do not deliver to the aircraft in I.P. format, but IPTV can be delivered with a Ku-band, Ka-band or EAN system. The number of programmes delivered to the aircraft depends on the I.P. stream

downlink rate.

Gogo launched its own IPTV service called Live TV in 2016. This will provide live TV viewing on PEDs, and it requires Gogo's 2Ku-band connectivity service.

Airlines have a growing choice of external connectivity systems. Ku-band was the only choice for many years, but Inmarsat's GX has provided an alternative. Ka-band has spurred the introduction of new-generation Ku-band HTS. In terms of satcom, airlines operating in most global regions can therefore access high throughput of downlink rate Ku- and Ka-band services. Some airlines have even opted for a combination of both, or have a dual channel of the same type to enhance service delivery.

Airlines operating over North America have the additional choice of Gogo's ATG system, while EAN has recently become available for airlines operating over Europe.

Airlines require a service level agreement (SLA) when acquiring cabin connectivity. This guarantees a minimum rate per seat and/or to the aircraft. Additional criteria may stipulate different rates per seat for different percentages of the time. The downlink rate to the whole aircraft is less than the downlink rate per seat multiplied by the number of seats. This is first because the take-up rate will be less than 100%, and second because not all passengers that are connected will be downloading webpages or other content simultaneously.

The minimum downlink rates needed by an airline will clearly depend on what cabin services it wants to make available to passengers. Rates are generally trending upwards as passenger expectations increase. The rate that can be delivered will not only depend on the type of connectivity system and vintage or generation of the satcom system, but also on the number of airlines operating in the area.

Airlines have the choice of going direct to the system operator in the case of some connectivity systems. This includes Gogo for ATG1 and ATG4, or to ViaSat for Ka-band in North America, and Inmarsat for EAN.

The other option is to acquire cabin connectivity from a group of service providers. These include GEE, Gogo, Honeywell, Panasonic, Rockwell Collins, SITA OnAir, and Thales. These provide Ku- and Ka-band connectivity.

Service providers have several options for acquiring capacity from satellite operators. These will include leasing a transponder or a fraction of a transponder for a period of time. Alternatives are to buy a volume of bandwidth, and therefore capacity, over a particular period or to acquire satellite capacity on a pay-as-you-go basis.

The details of the agreement will also stipulate the geographical area of connectivity provision. Service providers will have to group or 'stitch' together capacity from several satellite operators to provide global Ku-band capability.

Ku-band services

There are four main service providers of Ku-band connectivity: GEE, Gogo, Panasonic, and Thales.

GEE

GEE provides airlines with Ku-band and KU HTS satellite services, using transmissions from satellite operators Hughes, SES, Intelsat, Eutelsat and a variety of smaller operators.

GEE uses these different operators to provide global coverage of Ku-band and Ku HTS. GEE uses a combination of acquisition methods that include the leasing of transponder capacity, capacity volume and bandwidth.

GEE states that while it does provide airlines with SLAs, they are limited by the economics of the different business models with customers rather than technology or capability.

In addition to making internet access, email and gaming possible, GEE also provides capability for live TV. GEE provides Southwest Airlines with two Ku-band connections. One is used to provide I.P.TV and allows the airline to offer 25 live channels. This Ku-band channel is sponsored. The second Ku-band channel is used to provide e-mail, text messaging, social media and internet browsing. Southwest charges passengers for this service, while another of GEE's customers, Norwegian, provides the same service for free.

GEE also offers airlines IFE and other cabin products, including digital mobile products for devices, seatback applications, and analytics for monitoring cabin services activity. Overall, GEE provides an end-to-end connectivity system. This includes configuration management for the IFE and cabin connectivity systems.

Gogo

Gogo provides a unique Ku-band service called 2Ku-band. This provides the aircraft with a downlink rate of up to 70Mbps. This is made possible by installation of a phased-array antenna in a single radome provided by Gogo. Coverage is almost fully global.

The two main satellite operators for this service are SES and Intelsat. Gogo is also contracted with HTS satellite providers and will use OneWeb, HTS and LEO satellites in the future as the technology comes available. The new technology will allow Gogo to provide improved services over the next decade. The satellites Gogo uses for 2Ku-band are thus both broadbeam and spotbeam.

While coverage by the middle of 2016 will be almost fully global, areas of the world not currently covered are a small part of the Atlantic Ocean, northeast of Venezuela and Guyana, most of the Indian Ocean and Madagascar, a section of the Pacific Ocean west of Mexico and the whole of Central and South America, the extreme northerly regions of Canada

Thales says it feels that an adequate cost of data capacity is one cent per Megabyte (MB), equal to 8 million bits. A passenger's consumption will average about 200MB, and so would equal a cost to the airline of $2.

and Siberia, the northern part of Greenland, and both polar regions.

In addition to the antenna, Gogo provides all other required equipment for the system. Gogo's customers for 2Ku-band include Aer Lingus, Air Canada, American Airlines, British Airways, Delta Air Lines, Japan Airlines, Iberia, United Airlines, and Virgin Atlantic. Gogo has 14 airlines contracted for 2Ku-band, and these will equip more than 1,200 aircraft with the system.

The 2Ku-band system is being used for a variety of services. The increased bandwidth allows passengers to stream video content. It also allows Gogo to offer its own live TV service Gogo TV, which passengers can use on their PEDs.

Panasonic

Panasonic provides Ku-band services through widebeam and Ku HTS satellites. Panasonic says that it is the only service provider that offers a global network capable of covering 99.6% of all global air routes. The only areas not covered are the polar regions and the southern oceans.

Panasonic partners with all satellite operators. Its most recent partnerships are with Intelsat for its IS-29e and IS-33 satellites; with Telesat for its TV-12 satellite; with SES for its SES-14 and SES-15 satellites; and Eutelsat for coverage on its 172A and 172B satellites.

Panasonic is mainly confined to first-generation widebeam satellites, while the second-generation HTS network of satellites is currently being deployed. Panasonic has been involved in designing these new-generation satellites, including the Intelsat IS-29E satellite. This satellite has a spotbeam configuration, and a broad beam overlay that allows Panasonic to provide live news and sports TV channels on seatback screens or PEDs to airlines that have selected its global live TV service, eXTV.

eXTV uses a global Ku-band service provided by Panasonic. Panasonic includes advertising in eXTV, which allows airlines to generate revenue from the service.

The remainder of the HTS satellite constellation will have been implemented by the end of 2017. Panasonic will also start using HTS+ satellites: the SES -14 and -15 satellites. These will increase available output up to 80Mbps to the aircraft for about 80% of commercial flight hours.

In the future, Panasonic's network will exclusively feature Extreme Throughput Satellites (XTS). OmniAccess will participate with Panasonic in the development of these satellites. This generation of satellites will feature even narrower spotbeams, and so have a downlink rate to the aircraft of up to 250Mbps. The XTS constellation will cover about 50% of commercial flight hours. The smaller area spotbeams will provide concentrated capacity over high traffic density regions of the world that include North America, Europe and the Asia Pacific.

Panasonic leases capacity from satellite operators for up to five years, and buys a volume of about 5GHz of capacity for all industries that it services.

The maximum downlink rate that Panasonic specifies in its SLAs is about 80Mbps to the aircraft. Panasonic says that airlines want to provide passengers with similar experiences to on-ground internet connectivity at home. This is not economically possible, but the company is working to reduce the cost of providing this in the future.

Panasonic is introducing the megabyte (MB) model. This plan offers passengers the choice either of buying large volumes of data, or of using data at a slower rate to reduce cost. This allows passengers to take control of their own in-flight experience.

In addition to cabin connectivity services, Panasonic provides a satellite antenna, a broadband controller and wireless access points (WAPS). Its system is one of the few that is available as a line fit on most commercial aircraft types. It can also be quickly retrofitted.

Thales

Thales has mainly been a connectivity provider for Ka-band, but has recently started offering Ku-band. Although it expects Ka-band to overtake Ku-band, it is building the antenna, modem and other hardware on the aircraft for Ku-band connectivity. It will offer Ku-band over the Americas and the Asia Pacific.

Thales explains that there is a large increase in bandwidth coming. It says more satellites will be developed and their area of coverage will be stitched together to provide a global coverage service.

Thales says that it leases satellite capacity in terms of a number of gigabytes per month, and provides a bandwidth per month per aircraft. Thales does not lease a transponder or fraction of a transponder, and does not acquire capacity on a pay-as-you-go basis.

Thales says that it can provide about 12Mbps to the aircraft, although it will be 10Mbps per aircraft over North America. Thales says that as Ku satellites move to HTS configuration with spotbeams, airlines will have to buy a fixed quantity of data. It adds that satellite operators are already moving to a managed service, where they are selling fixed quantities of GB or TB instead of access to a particular bandwidth in terms of MHz.

Ka-band

Inmarsat is the only satellite operator that provides full global coverage of Ka-band. There are four distribution partners that are service providers for Inmarsat's GX Ka-band product: Honeywell,

Rockwell Collins, SITA OnAir and Thales.

In addition to Inmarsat's GX product, there are also regional Ka-band satellite operations from ViaSat and Eutelsat. ViaSat distributes its Ka-band service directly to airlines, and does have service providers.

GX Ka-band: Honeywell

Honeywell provides a combination of hardware and GX Ka-band service provision. It combines its JetWave high-speed satellite communications hardware with Inmarsat's GX to provide on-board Ka-band cabin connectivity. This is complete global coverage.

Honeywell has a variety of service plans and SLAs for airlines to choose from. The service plan pricing remains constant throughout the contract to provide the airline with simple budget management.

Honeywell offers multi-channel satellite (MCS) terminals. These are designed to provide a consistent high-speed in-flight service. The MCS terminals share the same RF and antenna controller, modem and router with two MCS-8000 antennae, and an MCS-8200 for larger transport aircraft. Honeywell also provides configuration management and a complete management service.

GX Ka-band: Rockwell Collins

Rockwell Collins is an Inmarsat GX service provider, as well as a service provider for Inmarsat's swiftbroadband (SBB) L-band high-speed flightdeck connectivity service. The GX service is naturally global.

In terms of SLAs for airlines, Rockwell Collins provides a tiered selection. This provides the customer with a variety of choices for service levels. The airline can thus pay for the service on the basis of bandwidth, data throughput or a SLA. It is intended to give an airline a choice of what is most flexible for their needs and budget. This allows the right amount of committed data rates to the aircraft, while still having the flexibility to adjust as data rates increase or decline.

Rockwell Collins says it can provide downlink rates that vary from the minimum required to allow simple e-mail, text messaging and VOIP phone calls, to higher rates that allow the streaming of audio and visual content such as Netflix and other types.

Like Honeywell, Rockwell Collins provides the 8200MSC GX Jetwave system to receive the GX transmissions. It also provides the PAVES cabin wireless system. This is a multifunctional headend server and control panel. It also offers configuration management to airlines.

Rockwell Collins says it will be able to offer greater bandwidth in the future for GX following the launch of the I6 satellite and other Ka-band satellites, such as Telenor's THOR Ka-band satellite.

Rockwell Collins will also be able to operate a new electronically steerable array antenna with massive Mbps throughput. A steerable or phased array antenna is electrically aligned, so it is designed to concentrate its radiation. This provides a more efficient link with greater bandwidth, and higher Mbps rates.

An electronically steerable phased array antenna can adjust the radiation patterns to electronically aim in different directions, and even remain focused on an aircraft while it is moving.

GX Ka-band: SITAONAIR

SITAONAIR provides a suite of cabin connectivity and in-cabin products. One element is being a service provider for Inmarsat's GX Ka-band. It is also a distribution partner for Inmarsat's SBB L-band system. Inmarsat's I5 GX satellites mean that SITA OnAir is able to provide global coverage for Ka-band.

SITAONAIR states that the GX Aviation network allows data transfer speeds of up to 50Mbps from satellite to the aircraft. It further states that this is sufficient to satisfy passengers' needs for

Data transmission rates to the aircraft are set to increase over the next few years as the OneWeb constellation of high capacity Ku-band satellites and further high capacity Ka-band satellites are launched.

connectivity and entertainment, as well as future needs.

SITAONAIR also states that the GX Aviation network is flexible enough to offer upgradable bandwidth that allows airlines to flexibly adapt to changing connectivity requirements.

Airlines can choose the bandwidth they want to allocate to each of their aircraft out of a selection of packages that offers various data downlink and uplink rates.

Each bandwidth selection comes with a committed information rate. This is a guaranteed data transmission speed that aircraft will benefit from while in flight. It also provides a maximum information rate in the possibility that there is some available bandwidth that can be shared.

SITAONAIR provides the entire equipment and hardware package to provide GX Ka-band cabin connectivity on the aircraft.

GX Ka-band: Thales

Thales is the fifth service provider partner for Inmarsat's GX Ka-band system. This service is provided globally.

Thales is also a service provider for ViaSat's and Eutelsat's Ka-band services that provide coverage over North America, the North Atlantic, and Europe. Thales adds that SES also has plans to launch Ka-band satellites, and therefore add to availability for airlines.

Thales follows a variety of models for acquiring capacity from the different satellite operators. One way is for Thales to provide a particular amount of bandwidth per aircraft, by buying a volume of bandwidth from a satellite operator for a specified period. It does not lease whole transponders or a fraction of a transponder, or have pay-as-you-go contracts with satellite operators.

In terms of downlink and data transmission rates, Thales says it is possible to provide passengers with the same experience in the air that they have on the ground, because not all passengers on an aircraft are using bandwidth simultaneously. It further adds that Ka-band is affordable.

The main issue is to target a reduction in the cost of bandwidth charged to the airline. Thales feels that an adequate rate is 1 cent per MB. One byte is equal to eight megabits, so 1MB is the same as 8 million bits, or 8 megabits. Users will consume 50-100MB per hour, equal to 400-800 megabits per hour. Consumption on a typical short-haul flight will be about 200MB, or 1,600 megabits, for each passenger. If the cost of data is one cent per MB, then the cost per passenger for the 200MB used is $2. This is why most of jetBlue's passengers take the free standard internet connection service, which jetBlue can offer because of the low cost of acquiring data download.

ViaSat

ViaSat is one of the few satellite operators to provide services direct to airlines. It has three satellites in operation providing coverage over North America, with a combined capacity of about 149 Gbps, including 140Gbps for the ViaSat-1 satellite. In 2017 the ViaSat-2 satellites will each have a transmission rate of 300Gbps, and in 2019 the ViaSat-3 satellites will each have a transmission rate of 1,000Gbps.

Each beam of the ViaSat-1 satellite has a data transmission rate of 1,200-1,500Gbps. The satellite's capacity can therefore be sold to multiple users. ViaSat-1's high total capacity means that ViaSat can provide SLAs to airlines with a data downlink rate per passenger or device of 12 megabits per second (Mbps). It can typically offer 10Mbps per seat 50% of the time, and a lower data rate of 3Mbps 90% of the time. These rates can be offered to airlines at an economic cost because ViaSat is selling capacity from its own high-capacity satellites, rather than leasing it at a fixed price. ViaSat says that many airlines are reporting actual data downlink rates of 12-20Mbps.

One of ViaSat's main airline customers in the US is jetBlue. jetBlue uses a dual Ku- and Ka-band cabin connectivity channel. Thales sells Ku-band to jetBlue, and other airlines, for live TV on board the aircraft. The Ku-band is sourced from specialised TV satellite operators in the US called DISH TV and Direct TV.

jetBlue uses ViaSat's Ka-band from its ViaSat-1 satellite for in-cabin WiFi and internet acess for use by passenger PEDs. ViaSat's product for high-speed internet access is called Exede, and is provided free by jetBlue. Moreover, ViaSat has also deployed a new hybrid Ku- and Ka-band aircraft antenna, allowing aircraft to access high data transmission downlink rates all over the world.

United Airlines and Virgin America also have dual Ku- and Ka-band cabin connectivity channels.

Virgin America primarily operates over the domestic US, but also to Hawaii and Mexico. It uses Ka-band provided by ViaSat for high-speed internet access when operating over the US mainland. It uses Ku-band to provide internet access when operating outside of the US, and to provide live TV in seatback screens. Ku-band is sourced from DISH TV.

United Airlines sources Ku-band from Panasonic, and uses it to provide in-flight connectivity on its long-haul fleet, and live TV on its domestic fleet. Ku-band is sourced from Direct TV for this purpose. The Ka-band is sourced from ViaSat via Thales, and is used to provide a paid-for WiFi service for PEDs on its domestic fleet. AC