The eXConnect Broadband Aero Service

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Panasonic Avionics Corporation (Panasonic) is the leading provider of In-flight Entertainment and Connectivity (IFEC). Panasonic recently completed the global coverage rollout of its eXConnect network which is comprised of 15 satellites, 20 satellite beams, and 10 gateways stations and covers 99.6% of all commercial aero routes. Panasonic operates the eXConnect network as a seamless, end-to-end service solely for the aero market. This allows airlines to offer continuous services such as voice, live television, and data for passengers and crew on both domestic and long haul passenger aircraft.

In addition to operating the eXConnect network, Panasonic designs and manufactures its own aero antennas and modems, obtains certifications, creates and delivers content, and partners with other providers for additional services. There are more than two hundred eXConnect-equipped aircraft flying today and Panasonic anticipates installing several hundred more aircraft by the end of 2013. Boeing and Panasonic have also recently announced that they are preparing to offer services to government customers as well.

Building a satellite network and terminals to serve the aero market poses special challenges. Panasonic must acquire capacity in virtually every corner of the world traversed by commercial airlines and integrate this network so that aircraft can seamlessly transition between different satellites and beams without interrupting their service. Aero antennas have several key limitations such as low gain, off-axis ESD limits, skew/elevation dependent gain patterns, and aircraft integration constraints.

Ever increasing demand has motivated Panasonic to add High Throughput Satellite (HTS) capacity to its network. Panasonic has partnered with Intelsat on the first Ku-band HTS satellite, Intelsat-29e, which covers North America and the North Atlantic. Panasonic is also working with Intelsat and other satellite operators to roll out HTS capacity in Europe, Asia, the Middle East and the Pacific Ocean Region. Adopting Ku-band HTS will allow existing eXConnect installed aircraft to reap the benefit of HTS satellite technologies with their existing terminals.
I. Introduction

As the leading provider of Inflight Entertainment and Connectivity (IFEC), Panasonic Avionics Corporation (Panasonic) designs, develops, manufactures, and installs entertainment and communication solutions for commercial airline customers. Inflight movies, television episodes, and games have been the primary entertainment options on long haul commercial flights using these inflight entertainment systems. As the use of laptops, tablets, and smartphones has grown, passengers now expect services on the aircraft similar to their on-ground experience with real time services such as voice, live television, and Internet access. Panasonic has expanded its in-flight entertainment business to address this growing demand for in-flight connectivity.

Panasonic is picking up where Connexion by Boeing left off. After Boeing exited the commercial in-flight connectivity market in 2006, Lufthansa Airlines, one of Boeing’s launch customers, kept their satellite terminal antenna and sought out a new network operator. Panasonic responded and launched its eXConnect network with Lufthansa using the original Connexion by Boeing antennas. Panasonic has since introduced its own antenna design, signed up 30 more leading airline customers and expanded its network to include 15 satellites, 20 satellite beams, and 10 gateway earth stations, making Panasonic the leading provider of broadband in-flight connectivity worldwide.

I. Services

The primary services being offered are eXConnect for data, eXPhone for voice, and eXTV for video.

eXConnect – Provides in-flight Internet service to passengers which is accessed through Wi-Fi. Airlines choose how to market the service to the passengers. Some airlines use a simple pay-per-use retail model, while other airlines offer the service for free to first class and premium passengers and pay Panasonic for the wholesale capacity.

eXPhone – Provides a GSM pico-cell on the aircraft that allows passengers to make phone calls and send SMS messages from their own mobile handsets. The availability of this service depends on local regulatory constraints. For example, the service is widely available in Europe but not in the US.

eXTV – Provides up to 8 channels of live TV focusing on perishable content like sports and news. This includes SPORT 24, which carries premier league and world
cup soccer, US major league sports and the Olympics, and major news networks like BBC World News.

As the service matures Panasonic expects other enterprise applications will be developed – content delivery, weather data, and airline telemetry to name just a few – that will also make use of broadband connectivity to and from the aircraft.

II. Global Network

Panasonic’s eXConnect network is the largest broadband aeronautical network in the world, covering 99.6% of all commercial aero traffic. Panasonic is aggressively expanding its network by introducing high throughput satellites (HTS) and is already planning additional advances in technology to meet the ever-increasing user demand. The result will be a tiered network that matches high capacity to areas of high traffic density and leverages the investments of our partner satellite operators.

Current Network

Panasonic’s current eXConnect network consists of leased transponder capacity on 15 satellites and 20 conventional Ku-band wide beams as shown in Figure 1. This represents the first tier of the Panasonic network. Critical regions such as North America, the North Atlantic and Europe are covered by more than one beam for both redundancy and increased capacity. All of this satellite capacity is operated using Panasonic gateway equipment installed in 10 earth stations around the world and linked together by a dedicated backbone. This network covers virtually the entire inhabited world including nearly all of the world’s commercial aviation traffic (99.6% of air traffic).

Assembling Panasonic’s own dedicated network has considerable advantages for aero customers. Panasonic has full control of its network – it is not a reseller of capacity who is held at arms length from the actual network operations. Panasonic is also a 100% aero network rather than a primarily maritime or direct to home internet network selling a small fraction of its capacity into the aero market. Direct control over our network and
an aero focus allows Panasonic to tailor its network specifically to the needs of the aero market.

**High Throughput Capacity and Future Coverage**

Technological challenges in the aero service, commitments from airline customers, and ever increasing demands for bandwidth from passengers have all encouraged Panasonic to partner with satellite operators on a new generation of high throughput satellite (HTS) payloads. Panasonic is taking full advantage of its partners’ numerous orbital slots to do this. Between 10 and 20 satellites are replaced every year in our partners’ satellite constellations. Each of these satellites represents an opportunity to customize a portion of a payload to meet the specific needs of the aero community.

Panasonic is introducing HTS payloads that use spot beams and frequency reuse to provide concentrated capacity along the world’s major air routes as shown in Figure 2. These payloads will cover more than 80% of global aero traffic by the end of 2016. This represents the second tier of the Panasonic network. HTS payloads will allow Panasonic to greatly increase its capacity and raise the data rates available to its customers in the regions with the densest aero traffic.

Panasonic is working with Intelsat to customize HTS payloads on Intelsat-29e and Intelsat-33e, which will provide coverage of North America, the North Atlantic, Europe, the Middle East and Asia. These satellites are the first two of five Epic\textsuperscript{NG} satellites that Intelsat has on order\textsuperscript{2}. The additional Epic\textsuperscript{NG} satellites will expand Intelsat’s HTS offering and provide redundancy.

Panasonic is also working with satellite operators to develop a Pacific Ocean HTS payload that will cover Asia, the North Pacific and North America. Eight satellite operators responded to Panasonic’s Request For Information (RFI) concerning such a satellite payload. Panasonic is now preparing a Request For Proposal (RFP) and anticipates contracting this payload by the fall of 2013 for service entry in 2016.
At the same time, Panasonic will continue using wide beams even after the introduction of HTS payloads and will continue to expand its wide beam coverage into previously uncovered areas. Wide beams are the most economical way to provide service in low traffic density areas such as the southern oceans, South America and Africa. Some wide beam capacity will also be retained in the areas covered by HTS payloads to provide redundancy. Finally, new coverage will be added in the Southeastern Pacific, the South Atlantic and the South Indian Ocean as demand and commercial opportunities arise.

**Beyond High Throughput**

Panasonic’s strategy of partnering with satellite providers, tailoring capacity to the aero market and buying capacity incrementally lends itself to rapid technology insertion. The next step beyond the HTS payloads under development today will be super high throughput regional systems. Very small spot beams on Ku-band payloads are a logical extension of Panasonic’s HTS payloads - using even smaller spot beams and more frequency reuse to achieve higher throughputs over a smaller area - but Panasonic is considering other technologies as well. These represent a third tier of the Panasonic network and will focus on the 50% of global aero traffic that falls within three small regions: North America, Europe and the Middle East, and East Asia. These regional overlays will allow smaller terminal sizes and higher data rates, particularly for narrow body and regional aircraft.

Actual entry into service of a super high throughput system may happen as early as 2017 but will depend on the growth of aero demand. In the meantime, Panasonic will continue to expand its HTS coverage into additional regions as demand justifies. Panasonic will continue to push the state-of-the-art in satellite technology and will roll the benefits of these technologies to its customers.

![Figure 3 Panasonic global aero network (After 2016)](image-url)
III. Network Architecture

The eXConnect network operates a hub-and-spoke network within each beam as shown in Figure 4. All communications from the aircraft terminal are routed via the satellite to a central gateway earth station in each beam. A given gateway may serve multiple satellite beams. All of the gateways are linked together with a dedicated Internet backbone and managed by a single Mission Control Center (MCC) in Lake Forest, California.

Outbound Link

The outbound link is a DVB-S2 carrier, usually occupying a full transponder. The heavy traffic regions such as North America and the Atlantic require multiple transponders to meet the bandwidth demand. The transponders on a conventional Ku-band wide beam satellite range from 27 MHz to 72 MHz wide and may carry up to 40 Mbps of traffic, while HTS transponders may carry up to 160 Mbps of traffic.

DVB-S2 with Adaptive Coding Modulation (ACM) allows the link to operate efficiently over a wide range of satellite EIRP values from peak-of-beam to edge-of-beam. More efficient modulation and coding (MODCODs) are used to deliver higher throughputs in favorable portions of the beam, while less efficient MODCODs are used to maintain the link near the edge of beam. This is critical to maintaining the overall
efficiency of the link for small aero terminals throughout the full coverage area of a satellite beam.

In addition to broadband connectivity, the outbound link also delivers a multicast stream for live television service that can be received throughout the full beam coverage area.

Inbound Link

The inbound link is an iDirect Deterministic TDMA (D-TDMA) link. Multiple inbound links are used in each beam, and typically run at ≈500 kbps. High throughput inbound links will run at 1 to 4 Mbps. Inbound link adaptation will be added in a forthcoming version of iDirect software.

The inbound link is heavily constrained by regulatory off-axis EIRP Spectral Density limits. Carrier size and transmission characteristics must be planned considering the edge of the coverage and regulatory limits. Low G/T wide beam transponders often require the use of spread spectrum carriers. However, the transition to high G/T HTS spot beams and inbound link adaptation will largely alleviate this constraint.

IV. Aero Terminal

Panasonic’s aeronautical terminal consists of a Ku-band transmit/receive antenna along with a broadband controller. Panasonic’s Ku-band antenna, the AURA LE, is a dual panel phased array antenna that is mechanically steered and has been designed and manufactured by Panasonic. The MELCO antenna, which was originally designed for Connexion by Boeing, is still supported as well. Figure 5 shows the AURA LE antenna after installation and ready for commissioning on an aircraft. The AURA LE antenna system coherently combines the two panels to form one large elliptical narrow beam allowing elevation angles between 0° to 90° and azimuth angles between 0° to 360°. A dual panel antenna has significant advantage over other antennas because it creates a larger effective area for the same volume. The antenna system’s ARINC 429 receive bus provides information to the antenna for pointing.

Figure 5 Antenna mounted on the fuselage of aircraft
The broadband controller consists of an iDirect-licensed modem that is manufactured by Panasonic along with a file server. The iDirect modem contains a DVB-S2 receiver and a D-TDMA transmitter based on iDirect’s Evolution® modem. The broadband controller also hosts a map server that allows the terminal to autonomously select the best beam as the aircraft flies through the various beams. When multiple overlapping beams are available, the terminal makes its beam selection based on the best “quality” beam as indicated in the coverage map.

Panasonic is expert in certifying equipment for installation on aircraft and has obtained type certification for its eXConnect terminal for more aircraft models than any other aeronautical connectivity provider. The eXConnect terminal is also now available for in-line factory installation on multiple Boeing and Airbus models.

V. Conclusion
Connectivity in the commercial aviation market is growing rapidly and Panasonic is at the forefront of this market. It is expected that several thousand aircraft will be equipped with connectivity within the next few years. Satellite based connectivity is the only feasible solution that can easily be extended to near global coverage enabling homogeneous service for both long haul and domestic flights. More airline passengers than ever before will want to stay connected while in flight and high throughput satellites will offer higher data rates and better economics. As a leading provider of IFEC, Panasonic Avionics has committed to offer global coverage with high throughput satellites to commercial airline customers.

References