July 3, 2018

Ali Bahrami
Associate Administrator for Aviation Safety
Federal Aviation Administration
800 Independence Ave, SW
Washington, DC 20591

Dear Ali,

The Performance Based Operations Aviation Rulemaking Committee (PARC) is pleased to submit to you the attached document, entitled *FANS 1/A over SwiftBroadband (SBB) Evaluation Results and Recommendations*. This report describes over two and a half years of operational evaluation of FANS 1/A communications over the medium of SwiftBroadband.

Based on analysis of the evaluation results and the guidance in the ICAO Performance-Based Communications and Surveillance (PBCS) Manual for determining compliance, the PARC Communications Working Group (CWG) found that the performance of FANS 1/A over SBB meets and in many cases exceeds the continuity, availability, and transaction time requirements as defined by the RCP240 and RSP180 specifications for PBCS.

Accordingly, the PARC respectfully submits the following recommendations:

Recommendation 1 – That the FAA accepts FANS 1/A over SwiftBroadband as a viable medium for FANS 1/A operations in airspace which require application of RCP240 and RSP180 for reduced aircraft separations.

Recommendation 2 – That the FAA advocates internationally that aircraft using the SBB subnetwork are eligible for operations that require compliance to RCP240 and RSP180 for reduced aircraft separations.

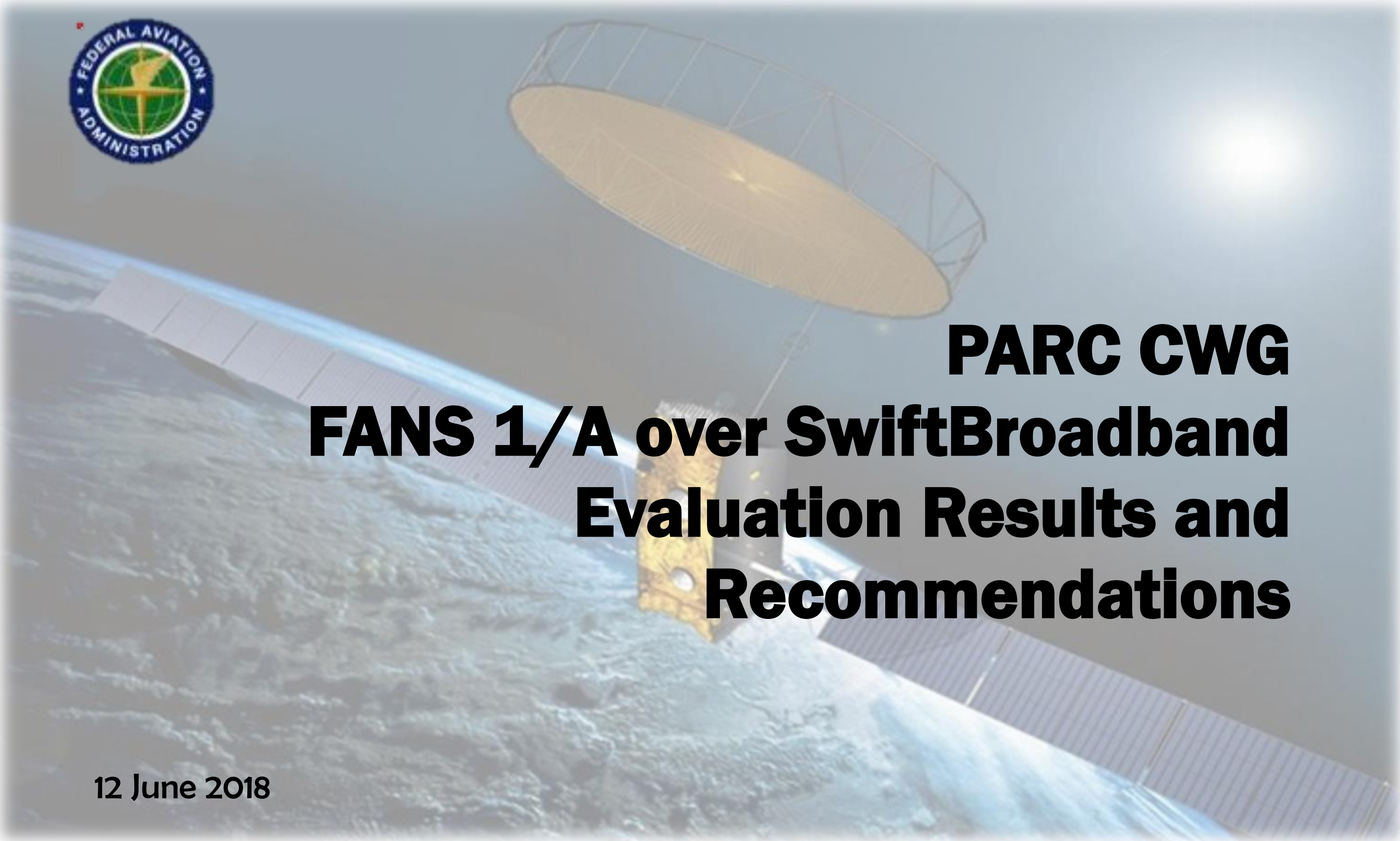
Recommendation 3 – That the FAA advocates the development of performance specifications that can make use of the superior capabilities of the SwiftBroadband technology.

The PARC appreciates your continued support of its activities and invites you to discuss any aspects of these recommendations at your convenience. The PARC also respectfully requests the FAA to provide us with a formal response to the recommendations. We thank the PARC CWG and the contributors to the FANS 1/A over SwiftBroadband evaluation led by Gary Colledge of Inmarsat for their diligence in completing the report and the PARC participants for their continued support.

Sincerely,

Mark Bradley
Chairman, PARC

Cc: Mark Steinbicker
Mike Matyas
John McCormick
Jon Pendleton
Merrill Armstrong
Jesse Wijntjes



PARC CWG FANS 1/A over SwiftBroadband Evaluation Results and Recommendations

12 June 2018

Prepared by:

Performance Based Operations
Aviation Rulemaking Committee

Communications Working Group
(PARC CWG)

Foreword

The Performance-based Operations Aviation Rulemaking Committee (PARC) is a Federal Aviation Administration (FAA) sponsored activity that operates according to the Administrator's authority under 49 USC 106(p) (5). The PARC comprises members from the FAA and the aviation community at large and provides recommendations to the FAA's Senior Management for action and implementation. The PARC has been effective since 2001 in implementing performance-based concepts initially for navigation. In 2005, the PARC established the Communications Working Group (CWG) to address a number of issues related to the implementation of aeronautical communication systems. These systems included, among others, the Future Air Navigation System (FANS 1/A), the Aeronautical Telecommunication Network (ATN), and satellite voice communications.

The PARC CWG is committed to applying the performance-based concept, which aims to leverage existing capability and maximize benefits by:

- Enabling cost-effective alternatives, using different technologies and existing capabilities, that meet business needs in a more timely manner;
- Providing performance-based criteria and evaluating aircraft equipment and capability without technological or implementation-specific constraints; and
- Enabling different levels of service in common airspace to a fleet of aircraft with varying capability and performance.

The PARC CWG develops recommendations that directly support matters that relate to the FAA's regulatory criteria and guidance material for implementation of voice and data communications within the United States (U.S.) National Airspace System (NAS). However, PARC CWG recognizes that global harmonization is crucial to the success of any State implementation initiative and, therefore, coordinates these matters to the international aviation community. As a result, the PARC CWG also contributes significantly to global solutions.

In August 2015, the PARC CWG initiated a project to evaluate Inmarsat SwiftBroadband over the Inmarsat I-4 and Alphasat satellites to be used for FANS 1/A operations in airspaces which utilize reduced separation standards. The evaluation utilises the global performance-based ATM operations framework defined in the ICAO Global Operational Data Link (GOLD) Manual and now the Performance-Based Communication and Surveillance (PBCS) Manual (published as ICAO Doc 10037 and 9869 respectively). The evaluation has been conducted against Required Surveillance Performance (RSP) 180 and Required Communication Performance (RCP) 240. This report provides project details, results of the evaluation and the consequent recommendation to the PARC.

For more information on PARC CWG activities or to comment on this report, please contact either Mike Matyas, Co-Chair (Michael.Matyas@boeing.com), Jon Pendleton, Co-Chair (Jon.Pendleton@delta.com) or John McCormick, Co-Chair (JTMcCormick@fedex.com).

The PARC CWG and its members would like to acknowledge Tom Kraft's instrumental work in the development of the GOLD and PBCS concepts, championing international adoption of a Performance-Based approach to assessment and recommendation of new Long Range Communications Systems. Also his development of methodologies for in-service performance monitoring. The aviation community owe a debt to his work.

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Executive Summary

In 2014, Inmarsat introduced its latest SwiftBroadband technology dedicated for flight deck aviation use for AOC ACARS, FANS 1/A and real-time connected EFB's. The AOC ACARS service evaluation began in June 2014, and the FANS 1/A service began its evaluation in June 2015. In airspace where reduced separation operations are in place, it was requested that in-service monitoring be applied as per Classic Aero, HFDL and Iridium services, i.e. continual evaluation against ICAO PBCS RCP240/RSP180 requirements.

At CWG33, a proposal was put forward to ANSPs to request that no operational restrictions should be imposed on the SwiftBroadband evaluation aircraft. The Pacific ANSPs agreed to this, provided that: the number of evaluation aircraft was small, the aircraft were announced and coordinated with adequate notice, and PBCS monitoring was in place in the oceanic regions. The PARC co-chair also presented information on the evaluation into ICAO NAT CNSG/12 and requested the same dispensation. This was accepted pending the availability and announcement of FANS 1/A over SwiftBroadband aircraft operating in the NAT.

Since the inception of this evaluation more than two million ACARS (FANS 1/A and AOC) messages have been transmitted and received to/from the aircraft, of which, over one and a half million were FANS 1/A messages. Eight Hawaiian Airlines Boeing 767-300ER and two Hawaiian Airlines Airbus A321neo aircraft have generated FANS 1/A data in the Pacific, and four United Airlines Boeing 767-300ER have collected FANS 1/A data across the NAT. Five additional aircraft have utilized the AOC ACARS service over the SwiftBroadband media:

- two of these aircraft are Business Aircraft flying primarily CONUS, NAT and European routes.
- the remaining three AOC aircraft are from two commercial air transport operators flying routes in the Asia-Pac and Australia regions.

The evaluation data showed compliance with the application of PBCS requirements. As a result, the PARC CWG recommends that the FAA:

- accepts FANS 1/A over SwiftBroadband as a viable medium for FANS 1/A operations in airspace which require application of RSP 180 and RCP 240 for reduced aircraft separations;
- advocates internationally, that aircraft using the SwiftBroadband sub-network are eligible for operations that require compliance to CPDLC RCP 240 and ADS-C RSP 180 specifications supporting reduced separations; and
- advocates the development of performance specifications that can make use of the superior capabilities of the SwiftBroadband technology.

1 Purpose and Scope

Inmarsat, Cobham SATCOM, Rockwell Collins Information Management Systems (RC IMS) (previously ARINC) and SITAOnAir have jointly contributed to the operational evaluation efforts in order to demonstrate that the FANS 1/A over SwiftBroadband ADS-C and CPDLC message delivery performance meet the requirements of ICAO PBCS Manual (Doc. 9869) RCP240/RSP180.

The evaluation project has been conducted with certified avionics operating FANS 1/A ADS-C and CPDLC applications in support of reduced separation operations under Supplemental Type Certification (STC). Standard Operations Approvals have been conducted referencing the published RTCA Minimum Aviation System Performance (MASPS, DO-343) and Minimum Operational Performance (MOPS, DO-262B) specifications. The ICAO Technical Manual for SwiftBroadband has now been approved and published as amendment 1 to Edition 1 of the ICAO Doc. 9925, *Manual on the Aeronautical Mobile Satellite (Route) Service*.

The use of SwiftBroadband can also provide aircraft location and tracking, broadband IP connection for Electronic Flight Bag (EFB) applications, and AOC ACARS data for crew alerting, information exchange, and flight data telemetry. At the outset of this project, evaluation of these services was outside the scope of this FANS 1/A project, but in order to guarantee as short an evaluation period as possible, ensuring the efficient use of project resources, Inmarsat requested that the PARC CWG accept inclusion of AOC data in the evaluation. In this way AOC ACARS users could assist the evaluation in loading the SwiftBroadband network and it would also be possible, in adding AOC ACARS data, to reach a statistically valid message sample size. This proposal was accepted at CWG33 and it was agreed that these additional AOC ACARS messages would also be measured within the satcom subnetwork to the applicable ICAO GOLD standards. This additional data was analyzed separately but considered as part of the network assessment.

2 Background

Inmarsat's third generation (I-3) satellite and ground network has been the main provider for satellite based Aircraft Communications Addressing and Reporting System (ACARS) and FANS 1/A datalink since the mid 1990's. The service that supports this oceanic voice and data capability is called "Classic Aero". Since its inception its use has grown exponentially, as there has been an increasing reliance on datalink. In addition, the economics of satellite systems and service operations have become increasingly more viable.

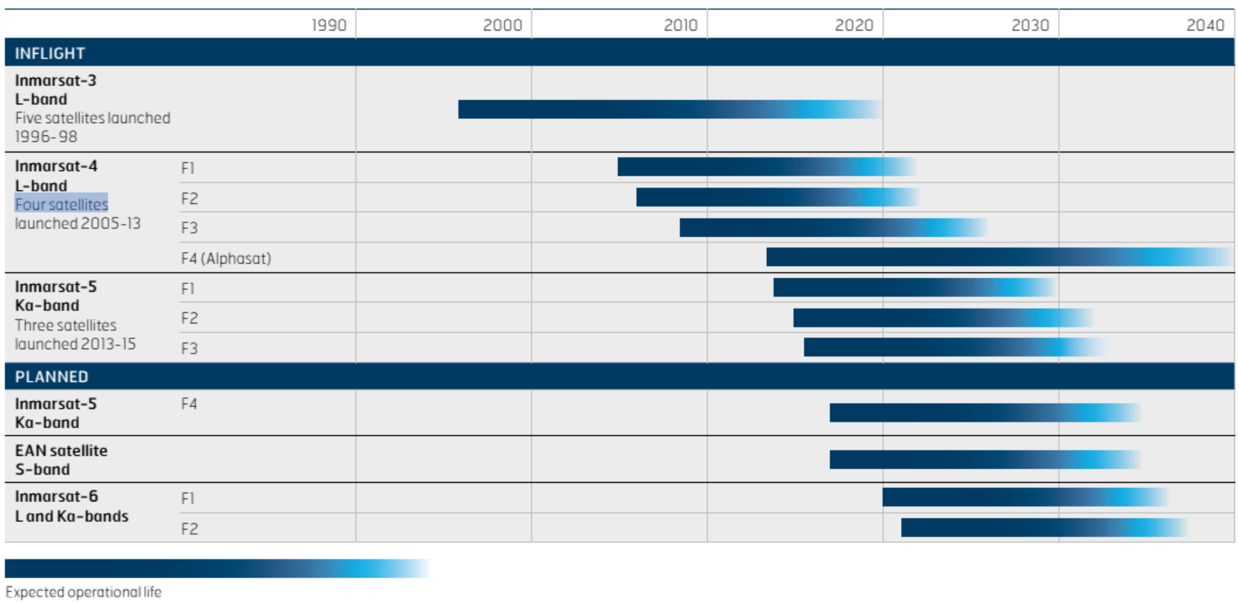

Figure 1: Inmarsat Constellation History and Estimates of Lifetime

(Extract from 'Inmarsat PLC - Annual Report and Accounts 2016'. Inmarsat 5F4 and EAN satellite now successfully launched.)

Through a continual development of their mobile communications services, starting in the mid 2000's, Inmarsat began launching and operating a more advanced satellite constellation, known as the Inmarsat-4 (I-4) constellation, which introduced a completely new sub-network, the "Broadband Global Area Network" (BGAN), which was the platform for a broadband aeronautical communications service called "SwiftBroadband". Along with the new SwiftBroadband service, the I-4 network also supports the existing Classic Aero protocols, continuing Inmarsat's commitment to FANS 1/A and ACARS for the aeronautical community.

In March 2015, Inmarsat introduced the Alphasat satellite to the I-4 network, positioning it at 25 degrees East (EMEA region). The Inmarsat I-4 satellite serving that region has been relocated, allowing a four satellite constellation (three Inmarsat-4 plus Alphasat) to provide SwiftBroadband services.

The SwiftBroadband service entered operation, supplying cabin communications, in October 2007. Following this, Inmarsat and its manufacturing partners started designing a SwiftBroadband based service that would support the existing AOC ACARS and FANS 1/A messaging in a seamless way over the new BGAN network. The existing ICAO Standards and Recommended Practices (SARPS) and Guidance Material (GOLD requirements) were used to derive design requirements.

In 2014, the necessary BGAN system enhancements were delivered, accepted and implemented in the network, and in May 2014 the first SwiftBroadband AOC ACARS STC installation was granted on an Airbus Corporate Jet (ACJ) A319, which has been flying regularly since June 2014.

In May 2015, the first commercial airliner FANS 1/A STC was granted, and the system entered performance evaluation against ICAO GOLD and PBCS specifications for RSP 180 and RCP 240.

2.1 Satellite and Supporting Satellite Access Stations (SAS)

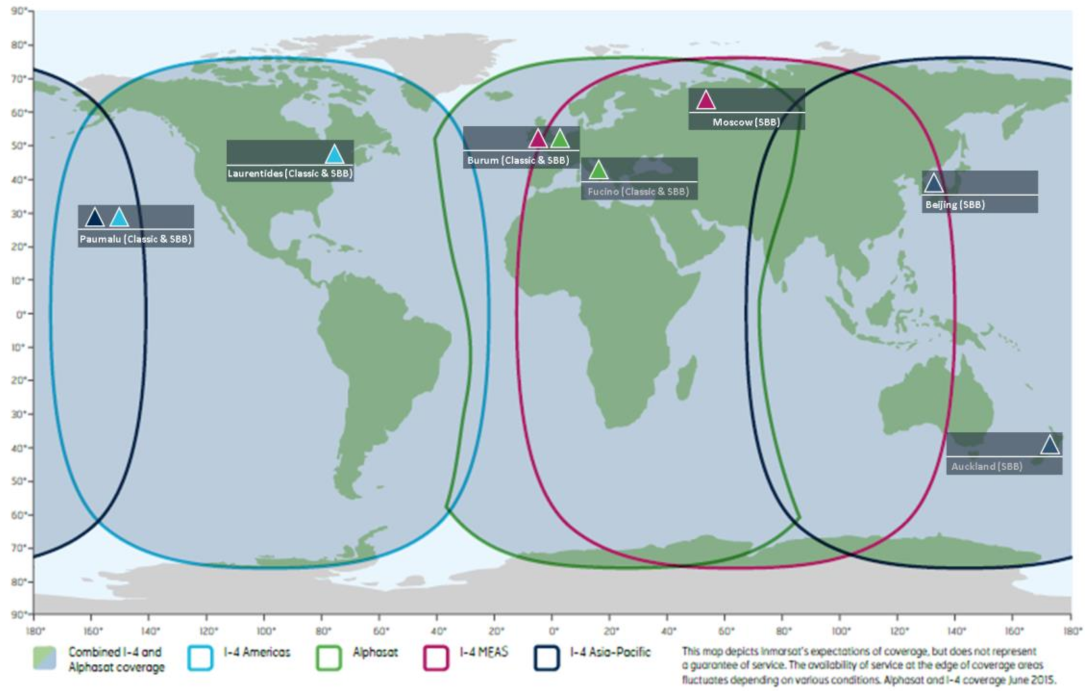

Figure 2: Inmarsat 4 & Alphasat Constellation

Four satellites, three Inmarsat I-4 and one Alphasat, provide Inmarsat's SwiftBroadband service with primary Satellite Access Stations (SAS) located at Paumalu (Hawaii), Burum (The Netherlands), Moscow (Russia) and Beijing (China). Secondary (back-up) SAS stations are located at Auckland (New Zealand), Fucino (Italy), and Laurentides (Canada).

Table 1: Inmarsat 4 and Alphasat Satellite Constellation for SwiftBroadband

Satellite	Coverage	Longitude	Launch Date	Services
I-4 F1	APAC	143.5E	Mar-05	Classic Aero & SwiftBroadband
I-4 F1A (Alphasat 'AF1')	EMEA	24.9E	Jul-13	Classic Aero & SwiftBroadband
I-4 F3	AMER	98W	Aug-08	Classic Aero & SwiftBroadband
I-4 F2	MEAS	64.4E	Nov-05	SwiftBroadband

The network and telecommunications technology is founded on a traditional 3G version of GSM mobile telephone protocols (3GPP), adapted with proprietary technology to augment the signal and propagation characteristics needed in a satellite based system. SwiftBroadband IP services are currently provided up to a data rate of 432 kbps per channel, and higher using High Data Rate (HDR) bearers. SwiftBroadband avionics can host up to four channels.

Figure 3: Inmarsat-4 Satellite

2.2 Inmarsat Gateway and Communications Service Provider (CSP) Network Infrastructure

As shown in Figure 4 and Figure 5, the I-4 SwiftBroadband sub-network processes the ACARS messaging using the ACARS Ground Gateway (AGGW) and distributes this via the Data Communications Network (DCN). From there, Distribution Partners (DPs) or 'Communications Service Providers' (CSPs) receive this information via the Meet Me Points (MMPs) at New York and Amsterdam. It is then the responsibility of the CSPs to present the ACARS messaging to the aircraft operators and the applicable

ANSPs. Each CSP has multiple interconnections into each of Inmarsat's Points Of Presence (POPs) for added redundancy.

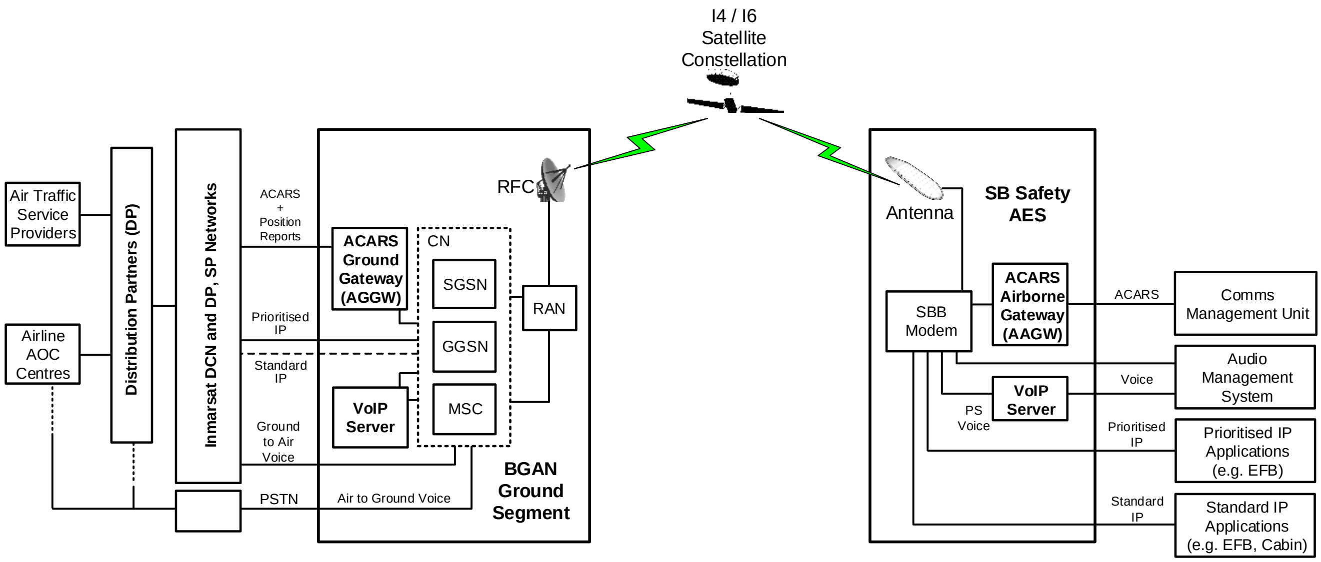

Figure 4: Inmarsat-4 Satellite and SwiftBroadband ACARS Sub-Network Architecture

The FANS 1/A over SwiftBroadband and ACARS messaging is passed over the air interface, encapsulated in IP packets, and exchanged over 3GPP PDP contexts. Standard 3G encryption is used. On the ground interface, the ACARS Ground Gateway (AGGW) uses TCP/IP to exchange ACARS data with the Distribution Partner ACARS message processors.

Figure 5 details the RC IMS (ARINC) and SITAOnAir interconnects as CSPs for AOC ACARS and FANS 1/A datalink messages

Note: Traffic in the EMEA region can be landed via the Burum SAS or the Fucino SAS, in the AMER region via the Paumalu SAS or the Laurentides SAS, in AsiaPac via the Paumalu SAS or the Auckland SAS, and in the MEAS region via the Russia SAS or the Burum SAS.

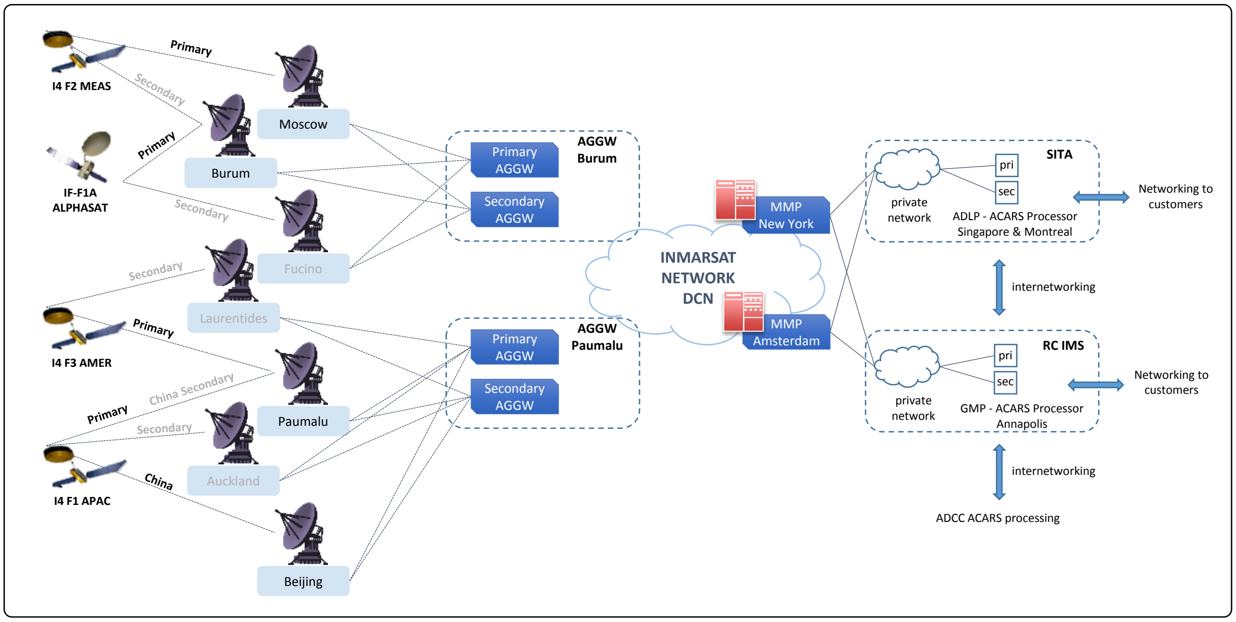

Figure 5: RC IMS (ARINC) and SITAOnAir Interconnect to Inmarsat SwiftBroadband Network

A set of SwiftBroadband Station/Gateway identifiers is used to indicate the path taken through the network for a particular satellite/region, SAS and CSP combination, as shown in Table 2.

Table 2: SwiftBroadband Station/Gateway Identifiers

SwiftBroadband Station/Gateway Identifiers			
ACARS GATEWAY LOCATIONS	SATELLITE/ REGION	SITAOnAir	ARINC
Burum, Netherlands	Inmarsat I-4 EMEA SwiftBroadband	EME9	XXB
Paumalu, Hawaii, US	Inmarsat I-4 Americas SwiftBroadband	AMR9	XXU
	Inmarsat I-4 Asia-Pacific SwiftBroadband	PAC9	XXS
Burum, Netherlands	Inmarsat I-4 Middle East and Asia Satellite	MEA9	XXM

2.3 Inmarsat BGAN SAS and ACARS Ground Gateway Uplink Message Processing

The Inmarsat ground system rapidly processes uplink messages for delivery. Once a message is delivered to the BGAN/SATCOM system for transmission over the air, if it cannot be transmitted over the air to the mobile (uplink) - or to the ground (downlink) - within 60 seconds, it will be discarded. The application layer that sits on top of the BGAN system is then responsible for retransmission and control.

If an uplink message is received for delivery to an aircraft that is not logged on, the message is discarded and an unsuccessful response is sent to the initiating DP.

All SwiftBroadband uplinks containing ACARS messages are associated with a message sequence number, containing within it a Logon Session identifier. In the unlikely event that a rogue message was transferred for an old session, then the aircraft would discard the message due to an invalid Logon Session ID.

The logon state is periodically confirmed from both the air and ground side gateways. The aircraft will poll the AGGW every 5 minutes (configurable) in the absence of other traffic. If there is no response then it will logoff and try another site. Similarly, the ground confirms the logon state of the aircraft. This is performed every 60 mins (configurable) in the absence of any traffic – if the ground gateway receives no response then the aircraft will be logged off from the gateway and a new session will be required.

3 Goal of this Project

The goal of this project is to verify that the Inmarsat I-4/Alphasat SwiftBroadband sub-network is an additional viable sub-network for aeronautical AMS(R)S services and that reduced separation operations can be applied on a reliable basis in any airspace region. This report provides the results of the evaluation to meet these goals:

- ❒ Validating Inmarsat's I-4 SwiftBroadband network integrated with the RC IMS (ARINC) and SITAOnAir ACARS networks against the PBCS Manual RCP 240 and RSP 180 specifications for reduced separation standards.

  Note: Some examples of the different separation standards where FANS 1/A provides an acceptable datalink capability for RCP 240 and RSP 180 operations are reduced separation to 50 NM longitudinal in RNP 10 or RNP 4 airspace, and 30 NM lateral / 30 NM longitudinal in RNP 4 airspace.

- ❒ Following the successful evaluation of the SwiftBroadband technology and generation of the final report, the PARC will submit the assessment to the FAA including a recommendation statement for approval.

4 Benefits for Operators

4.1 Technology and Service Evaluation

a) The PARC CWG is responsible for the evaluation of Long Range Communication Systems (LRCS), thereby expanding the utility of FANS 1/A datalink capabilities to support the use of performance-based separation minima.

b) The PARC assessment results show that ADS-C and CPDLC performance required to obtain operational approvals for RSP 180 and RCP 240 is achieved, which will enable the use of more efficient routes by the application of performance-based separation minima.

4.2 Technology Advances Increasing Performance and Functionality

a) **Speed:** SwiftBroadband utilizes an ACARS over IP infrastructure. Initial implementation of FANS/ACARS shows average message latencies of the order of 8 to 10 times less than that of

Classic Aero, with the potential to match that of VHF datalink for continental airspace use. It paves the way for RCP/RSP more stringent than RCP240/RSP180.

b) **Network Capacity**: SwiftBroadband utilizes 193 narrow spot beams with dynamically assigned channels. This provides better efficiency of resource use and higher availability that dramatically increases datalink capacity. Each channel can offer up to 432kbps and multiple channels can be assigned to a single spot beam.

c) **Prioritized IP:** SwiftBroadband has been designed to enable future safety critical applications that will require the use of a prioritized IP link.

d) **Integral Position Reporting:** In addition to supporting ADS-C and AOC based tracking, SwiftBroadband has an integral position reporting capability that is capable of providing latitude, longitude, altitude, heading and ground speed data at reporting intervals of less than 1 minute. Future SwiftBroadband avionics will also include vertical rate. *Note: This service is not currently evaluated against the ICAO RCP 240/RSP 180 requirements in this project.*

e) **Enhanced timestamping:** Satcom Data Unit (SDU) timestamping has been implemented in the terminals and this enables new, previously unavailable, analysis of message delay 'on aircraft' to be conducted. Now that SDU to AGGW timing is available, the time that a CPDLC message spends on the airframe during its uplink and downlink paths can be determined – this will allow maximum time limits for PORT to be determined.

4.3 Lightweight Small-form-factor Avionics

a) The SwiftBroadband system can be supplied in ARINC 781 2MCU format that is capable of providing all the cockpit ACARS and voice services supplied by older 6-18MCU systems, plus additional capability in the form of large bandwidth IP for EFB applications.

b) The SwiftBroadband system has the ability to use small form factor enhanced low gain antennas in cases where only lower IP throughputs are required, or where ACARS and voice services is all that is required.

5 Global Performance-based Framework

The PARC CWG is committed to applying the performance-based concept, which aims to leverage existing capability and maximize benefits by:

- Enabling cost-effective alternatives, using different technologies and existing capabilities, that meet business needs in a more timely manner;
- Providing performance-based criteria and evaluating aircraft equipment and capability without technological or implementation-specific constraints; and
- Enabling different levels of service in common airspace to a fleet of aircraft with varying capability and performance.

The PARC CWG develops recommendations that directly support matters that relate to the FAA's regulatory criteria and guidance material for implementation of voice and data communications within the United States (U.S.) National Airspace System (NAS). However, the PARC CWG recognizes that global harmonization is crucial to the success of any State implementation initiative, and it therefore coordinates these matters to the international aviation community. As a result, the PARC CWG also contributes significantly to global solutions.

In September 2010, the PARC submitted a report to the FAA entitled, *FANS 1/A over Iridium (FOI) and Performance-Based Concept Recommendations*. PARC had requested the FAA to implement a performance-based framework for Required Communication Performance (RCP) and Required Surveillance Performance (RSP). The FAA responded:

> The FAA agrees that the performance-based concept for communications and surveillance will leverage existing capability. Foremost, the FAA sees that the concept will ensure safe use of communications and surveillance capability as we increase reduced [Automatic Dependent Surveillance – Contract] ADS-C-based separations. This is important during the NextGen transition.
>
> The FAA accepts PARC's recommendation to implement a performance-based framework for Required Communication Performance (RCP) and Required Surveillance Performance (RSP) specifications for oceanic and remote operations. The FAA has already included provisions for the framework in AC 20-140A, Guidelines for Design Approval of Aircraft Datalink Communication Systems Supporting Air Traffic Services and AC 120-70B, Operational Authorization Process for Use of Datalink Communication System. The FAA recognizes more work needs to be done and will work with PARC to establish priorities and timelines to fully implement the performance-based framework.
>
> The FAA will advocate global implementation of the performance-based framework within ICAO and regional ATS coordinating groups. The ICAO Regions will need to prescribe RCP/RSP specifications in airspace requirements documents, such as ICAO Doc 7030, *Regional Supplementary Procedures*, to ensure operator eligibility and flight plan filing requirements for seamless operations, performance, interoperability and standardization.

FAA Letter (2011), p. 2

Over the years, the PARC work on the performance-based framework for RCP/RSP has progressed through the FAA's leadership within ICAO through the Operational Datalink Panel (OPLINKP), the Separation and Airspace Safety Panel (SASP), and in the ICAO regions. The ICAO Council has adopted amendments—to include a Performance-based Communication and Surveillance (PBCS) provision—to the following annexes (ICAO, 2016a – e):

a) Annex 6 — *Operation of Aircraft*

b) Annex 11 — *Air Traffic Services*

c) Annex 15 — *Aeronautical Information Services*

ICAO also approved amendments to the following procedures for air navigation services (ICAO, 2015a and b):

d) *Procedures for Air Navigation Services — Air Traffic Management* (PANS-ATM, Doc 4444)

e) *Procedures for Air Navigation Services — ICAO Abbreviations and Codes* (PANS-ABC, Doc 8400)

The ICAO PBCS provision has been applicable since November 2016 and is supported by the *PBCS Manual* (Doc 9869). The second edition, published in June 2017 is the current version. This manual was based on work in the ICAO regions since 2007 as well as within RTCA and EUROCAE. The FAA reached an agreement with its NAT and PAC international partners regarding a target date for PBCS and relevant ATM operations, and PBCS was subsequently implemented on March 29, 2018. Under PBCS, aircraft not meeting the 95% performance requirement for the RSP/RCP are permitted to operate at a less stringent performance level provided they file the appropriate performance flight plan designator. These efforts apply PBCS to support implementation of 93 km (50 NM), 55.5 km (30 NM) and 5 minute longitudinal separation minima, and a 42.6 km (23 NM) lateral separation minimum, which was formerly 55.5 km (30 NM) lateral. (ICAO, 2015a and b).

The ICAO PBCS provision is a globally harmonized framework that prescribes an RCP specification (i.e. performance-based criteria with less dependence on technology) to communication services and capability in specified airspace (e.g., FAA Oceanic airspace). The RCP specification provides allocations to the aircraft, ANSP, communication service provider, and aircraft operator. The PBCS provision also provides consistent methods for determining that the operational system complies with the RCP specification initially, and in continued operations, and the actions to take when non-compliances are found.

The FANS 1/A over SwiftBroadband project leverages the PBCS concept. The below documents have been identified as components that are required to be incorporated by the operator and by partners that provide the datalink service.

- ICAO Doc. 10037 GOLD
- ICAO Doc. 9925 AMS(R)S Manual Amendment 1 Inmarsat SwiftBroadband
- ICAO Doc. 9869 Performance-Based Communication and Surveillance (PBCS) Manual
- AC20-140C Guidelines for Design Approval of Aircraft Datalink Communication Systems Supporting Air Traffic Services (ATS)
- AC90-117 Datalink Communications
- Regional SUPPs

Since the start of the evaluation in 2014, a number of the documents listed above have been updated to specifically call out SwiftBroadband's use for ATS. Advisory Circular 20-140C (AC20-140C) was updated in September, 2016 to include the recognition of Inmarsat SwiftBroadband satellite communications as a viable sub-network for ATS data communications. The ICAO Manual On The Aeronautical Mobile Satellite (Route) Service Doc. 9925 has been updated to Amendment 1 which is dedicated to Inmarsat SwiftBroadband.

6 Key Stakeholders

The key participants in this evaluation are provided in the listing below.

Organization	Point of contact	email
PARC CWG Co-Chairs		
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FAA, Flight Standards, Flight Technologies and Procedures Division		
FAA, Flight Standards, Air Transportation Division		
FAA, Aircraft Certification, Avionics Systems Branch		
Air Navigation Service Providers and Airframers (involved in data reception and evaluation as of CWG34-CWG39)		
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The authors would like to thank all the stakeholders for their continued supply of data, analysis and support throughout the evaluation. A special note of thanks goes to Theresa Brewer at the FAA who has supplied the majority of the specialist end-to-end performance analysis charts.

The participating ANSPs/FIRs/CTAs are listed below:

Table 3: SwiftBroadband FANS 1/A Evaluation Participating ANSPs/FIRs/CTAs

<table>
<tr><th colspan="5">Participating ANSPs/FIRs/CTAs</th></tr>
<tr><th>FIR/CTA</th><th>Logon</th><th>Region</th><th>ANSP</th><th>Coord</th></tr>
<tr><td>Nadi</td><td>NFFF</td><td>APAC</td><td>Airports Fiji Ltd</td><td rowspan="8">ISPACG</td></tr>
<tr><td>Brisbane</td><td>YBBB</td><td rowspan="4">APAC</td><td rowspan="4">Airservices Australia</td></tr>
<tr><td>Honiara</td><td>YBBB</td></tr>
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<tr><td>Melbourne</td><td>YMMM</td></tr>
<tr><td>Auckland Oceanic</td><td>NZZO</td><td>APAC</td><td>Airways NZ</td></tr>
<tr><td>Oakland Oceanic</td><td>KZAK</td><td>APAC</td><td>FAA</td></tr>
<tr><td>Tahiti</td><td>NTTT</td><td>APAC</td><td>SEAC PF</td></tr>
<tr><td>Fukuoka</td><td>RJJJ</td><td>APAC</td><td>JCAB</td><td rowspan="3">IPACG</td></tr>
<tr><td>Anchorage Oceanic</td><td>PAZN</td><td>APAC</td><td rowspan="2">FAA</td></tr>
<tr><td>Oakland Oceanic</td><td>KZAK</td><td>APAC</td></tr>
<tr><td>New York Oceanic</td><td>KZWY</td><td>NAT</td><td>FAA</td><td rowspan="5">NAT CNSG & NAT IMG</td></tr>
<tr><td>Reykjavik</td><td>BIRD</td><td>NAT</td><td>Isavia</td></tr>
<tr><td>Gander Oceanic</td><td>CZQX</td><td>NAT</td><td>NAV CANADA</td></tr>
<tr><td>Santa Maria Oceanic</td><td>LPPO</td><td>NAT</td><td>NAV Portugal</td></tr>
<tr><td>Shanwick Oceanic</td><td>EGGX</td><td>NAT</td><td>UK NATS</td></tr>
<tr><td>New York Oceanic (S of 27° N)</td><td>KZWY</td><td>CAR</td><td>FAA</td><td>FAA</td></tr>
</table>

- Indicates FANS 1/A over SwiftBroadband flights logged

7 Flight Evaluation

Of the 22 aircraft equipped with FANS 1/A over SwiftBroadband capability, thirteen flew FANS 1/A operational flights globally within the evaluation period and five additional aircraft utilized AOC ACARS over SwiftBroadband.

The first aircraft, an Airbus ACJ, was configured for operation of AOC ACARS and started using the SwiftBroadband capability in May 2014. In the fall of 2015, and through the first quarter of 2016, an additional AOC ACARS aircraft was brought online, along with eight Boeing 767-300ER aircraft from Hawaiian Airlines. Additionally, four Boeing 767-300-ER aircraft from United Airlines and two Airbus 320s from Shenzhen Airlines came online in 2017, operating FANS 1/A and AOC ACARS respectively, and two Hawaiian Airlines Airbus A321neo aircraft contributed to the performance data collection from December 2017. The details of the aircraft implementation schedule is shown in Figure 6.

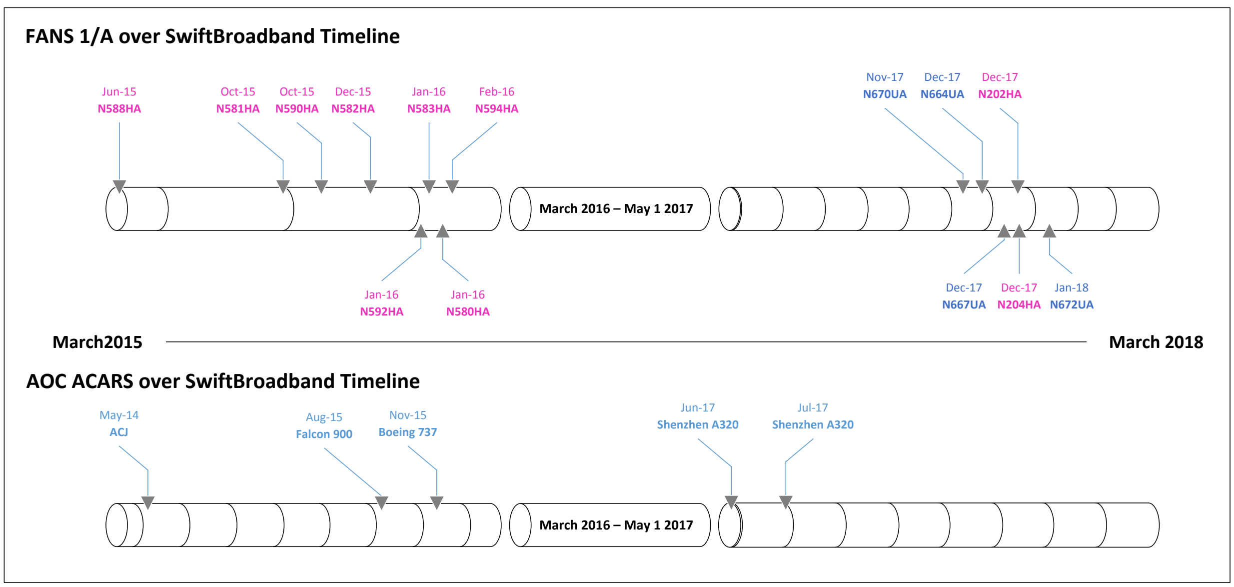

Figure 6: Evaluation Aircraft Implementation Timeline

The HAL aircraft data has been logged, analyzed and presented at PARC CWG, including data through PARC CWG/39. The AOC ACARS data has been collected and analyzed over the period from 26th June 2014 to the end of August 2017 as input to the assessment.

Performance data has been sourced from the FAA Oakland and New York centers, the Japanese Civil Aviation Bureau (JCAB), NAV Portugal, UK NATS, Airways New Zealand, Isavia, Boeing and Inmarsat. (The ACARS latency measurement and analysis has been supplied by Inmarsat.) Performance has been assessed against the PBCS RCP 240/RSP 180 performance targets for both the end-to-end and subnetwork latency measurements. The following sections describe the methodology.

7.1 Required Communication Performance and Required Surveillance Performance Assessment Requirements

Once the aircraft entered service, evaluation of their FANS 1/A CPDLC, ADS-C & AOC communication performance began. The PARC CWG has been monitoring, analyzing and reviewing the performance data at each of the PARC CWG meetings since CWG 35. For the US-based operators, the FAA offered to co-ordinate with ANSPs and aircraft OEMs. Each participating ANSP used the procedural guidance provided in the ICAO PBCS document to log, monitor, and report data performance against RCP240/RSP180. The RSP and RCP requirements and timing allocations are shown in Figure 7 and Figure 8.

Additionally, in order to build up the number of messages transmitted and logged in the evaluation, and to offer a further independent review of the performance, Boeing kindly offered to set up additional contracts with the FANS 1/A aircraft. This was conducted from their FANS ground system, the ADS-C Collection and Analysis Tool (ACAT). Two aircraft had additional 2-minute periodic contracts applied, and two aircraft had 5-minute demand contracts applied (i.e. every 5 minutes the FANS avionics was requested to deliver an ADS-C position report – this effectively emulated a CPDLC exchange). Hence during the evaluation these aircraft have supported simultaneous ANSP ADS-C, ACAT and HAL AOC reporting in addition to any background IP application communication.

The ACAT system was also programmed to wait for 30 minutes of 'pure' SwiftBroadband messaging before it began its ADS-C requests, i.e. the ACAT data samples do not include VHF-Satcom transitions. The performance is thus the closest representation of 'SwiftBroadband-only' performance. A summary of this analysis can be found in Appendix B.

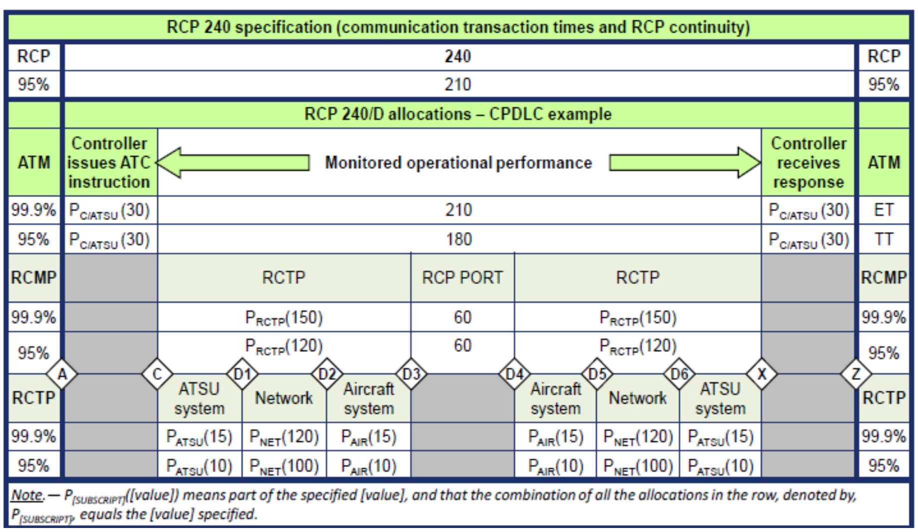

Figure 7: RCP 240 Allocations – Communication Transaction Times & Continuity (PBCS Manual Doc 9869)

Satcom Data Unit (SDU) timestamping has been implemented in the terminals under evaluation and this enables new, previously unavailable, analysis of message delay 'on aircraft' to be conducted. This significantly enhances the aviation community's ability to analyse on-aircraft delay prior to the SDU.

RSP 180 specification (surveillance data delivery times and RSP continuity)				
RSP	180			RSP
95%	90			95%
	RSP 180/D allocations – CPDLC or ADS-C example			
Time +/- 1 second at position (RNP at UTC)	Monitored operational performance			ATM (ATSU system updated)
99.9%	180			OT
95%	90			DT
RSMP/RSTP	Aircraft system	Network	ATSU system	RSMP/RSTP
99.9%	5	170	5	99.9%
95%	3	84	3	95%

Figure 8: RSP 180 Allocations – Data Delivery Times and Continuity (PBCS Manual Doc 9869)

Additionally, per the pre-implementation guidance of the PBCS Manual, Inmarsat reported on the Required Communication Technical Performance (RCTP) and the Required Surveillance Technical Performance (RSTP), providing further granularity into the performance of the satellite sub-network and avionics. The Inmarsat RSTP data provides timestamp information for segments A, D1 and D2 as defined in Figure 9. The colours red and purple are used to delineate the two different measurement points and will be seen again in the evaluation results section. As noted above, the addition of the SDU Timestamp-6, shown in Figure 9, allows for the first time the on-aircraft message delay to be accurately logged.

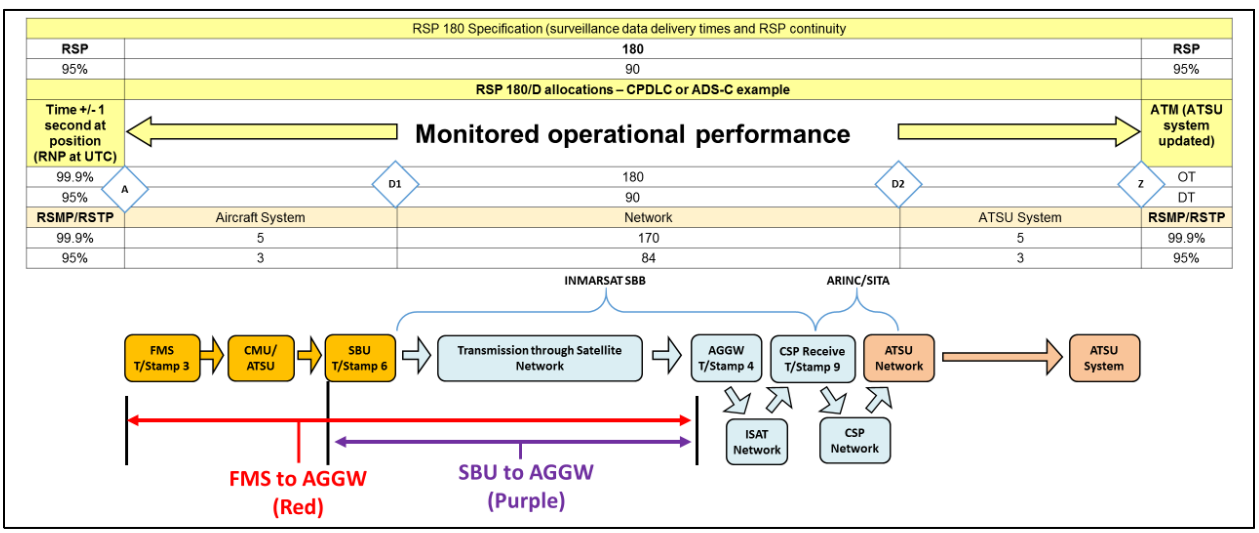

Figure 9: Inmarsat RSTP Measurement Points

7.2 Network Availability Assessment Requirements

In addition to the data delivery and continuity analysis for RSP and RCP described above, there is also a need to assess network availability. PBCS defines acceptable outage duration limits. In summary, an availability of 99.9% is required for safety and 99.99% for operational efficiency, equivalent to maximum accumulated unplanned outage time of 520 and 52 minutes for safety and efficiency respectively. Refer to PBCS Doc 9869 (Section 2.1.3) and Appendix D for complete availability criteria.

7.3 Aircraft Avionics Installations

Cobham provided the following ACARS-capable SwiftBroadband configuration for the evaluations:

- **Cobham Aviator 300D/350D:** 2 MCU Transceiver, Flange Mount Amplifier/Diplexer and Intermediate/High Gain Antenna respectively.
    - SwiftBroadband ACARS IP PDP
    - 1 Channel SwiftBroadband Circuit Switched Voice
    - IP connectivity via Ethernet for e.g. EFB connection

Figure 10: Aviator 300D & IGA

The Hawaiian Airlines (HAL), United Airlines (UAL) B767 and the AOC ACARS operators were equipped with the Aviator 300D satcom system. Figure 11 displays a block diagram of the Boeing 767-300ER aircraft configuration using the Aviator 300D satcom system. The Hawaiian Airlines aircraft use a Mark II Honeywell CMU, and the Honeywell Pegasus FMS hosts the FANS 1/A applications. The United Airlines aircraft use a Rockwell Collins CMU and Honeywell Pegasus FMS. The wired Ethernet to an EFB is unique to four of the Hawaiian B767 evaluation aircraft.

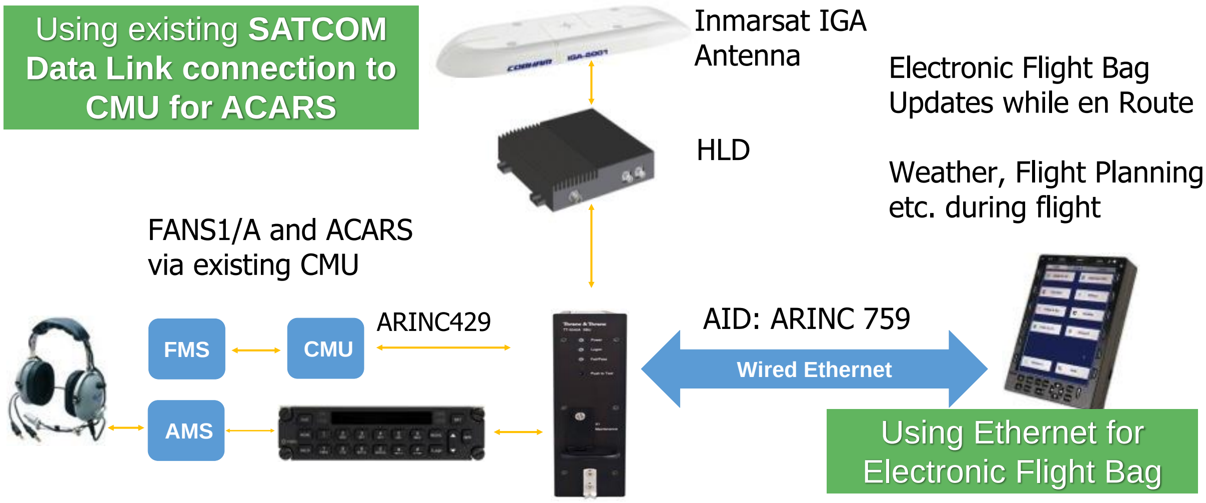

Figure 11: Block Diagram of the Boeing 767-300ER Aviator 300D FANS 1/A Installation

Figure 12 is a block diagram of the Hawaiian Airlines A321neo FANS 1/A SATCOM equipage with the Cobham HGA-7001 high gain antenna. The ACARS traffic is managed by the Air Traffic Services Unit (ATSU), serving a similar function as the CMU on the Boeing aircraft.

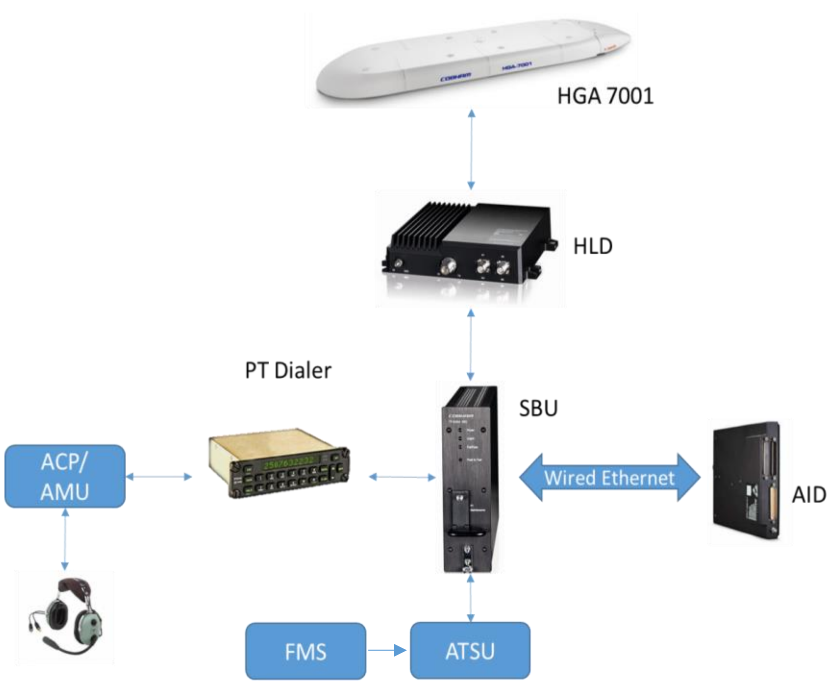

Figure 12: Block Diagram of Airbus A321neo Aviator 350D FANS 1/A Installation

7.4 Hawaiian Airline Boeing 767-300ER and Airbus A321neo Cobham Aviator 350D FANS 1/A Evaluation

Hawaiian Airlines was the first commercial air transport operator to participate in the FANS 1/A over SwiftBroadband flight evaluations with RC IMS (ARINC) as their service provider. Eight of their Boeing 767-300ER aircraft were equipped with the Cobham Aviator 300D. The Hawaiian Airlines B767 Aircraft were put in service operating FANS 1/A over SwiftBroadband starting in June 2015 with N588HA. The other seven aircraft were activated sequentially as they had maintenance downtime, with the final, eighth, aircraft re-entering service on January 26, 2016.

In December 2017, a sequence of new deliveries of A321neo aircraft began STC installation with the Cobham 350D terminal utilizing the high gain antenna. By January 2018, two of these aircraft had entered the evaluation.

7.4.1 Routes flown, FANS 1/A Data Types and ADS-C Contract Regimes

Hawaiian Airlines' operations are centered on their hub in Honolulu, Hawaii. The evaluation aircraft have been operating without ATS restrictions flying FANS 1/A routes in the Oakland, Fukuoka, and Auckland flight information regions. As of the date of this report, over 1 million CPDLC, ADS-C and ACARS messages have been collected on these aircraft. The routes flown are shown in Figure 13.

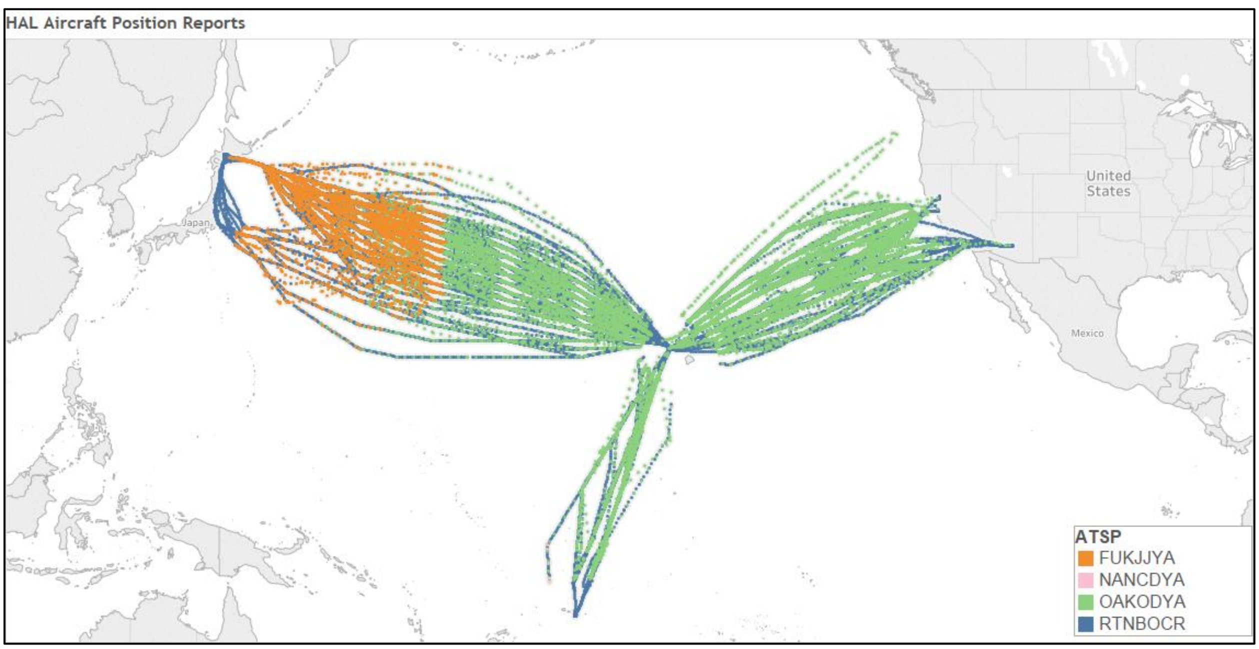

Figure 13: HAL B767 flights operating FANS 1/A over SwiftBroadband (Oct 2016 – June 2017)
(*Note: The A321neo aircraft that entered the evaluation in December 2017 fly similar routes.*)

From the start of the evaluation until June 2017, in addition to the standard operational ADS-C contracts and CPDLC messaging, four of the B767 aircraft also had ADS-C Periodic Event Report (PER) contracts and 5 min ADS-C demand requests initiated by the Boeing ACAT system. The ANSP PER contracts varied between 10 and 15 minutes depending on the FIR as defined in Table 4. For more information on the Boeing ACAT system and the performance results from that data, refer to Appendix B.

Table 4: Data Types and Contract Definitions

FIR	Types of Data Transmission	Reporting Period
Oakland (KZAK)	• ADS-C PER - 14 min • ADS-C WCE • CPDLC	June 2015 – December 2015 January 2016-June 2106 July 2016 – December 2016 January 2017 – June 2017 July 2017 – December 2017
Auckland (NZZO)	• ADS-C PER – 15 Min • ADS-C WCE • CPDLC	June 2015 – December 2015 January 2016-June 2106 July 2016 – December 2016 January 2017 – June 2017 July 2017 – December 2017
Fukuoka (RJJJ)	• ADS-C PER – 10 Min • ADS-C WCE • CPDLC	July 2015 – December 2015 January 2016-June 2106 July 2016 – December 2016 January 2017 – June 2017 July 2017 – December 2017
Boeing ACAT	• ADS-C DEM – 5 min** • ADS-C PER – 2 min**	June 2015 – December 2015 January 2016-June 2106 July 2016 – December 2016 January 2017 – June 2017 July 2017 – December 2017

**The Boeing ACAT ground system initiated 2 minute PER and 5 minute DEM (demand) contracts once SwiftBroadband transition had been establish for 30 minutes. Refer to Appendix B for more details.

In addition to the FANS 1/A and Boeing ACAT traffic, Hawaiian Airlines was also reporting additional AOC ACARS traffic at regular intervals. Further detail on the configuration of the HAL terminals, the ADS-C contract and gateway keep-alive rates, whether EFB was fitted, and the software release operating on each terminal, can be found in Appendix C.

7.5 United Airlines Boeing 767-300ER and Cobham Aviator 300D FANS 1/A Evaluation

United Airlines provided four of their Boeing 767-300ER aircraft in support of the FANS 1/A over SwiftBroadband evaluation, with SITAOnAir as their service provider. The first United Airlines Boeing 767-300ER, N670UA aircraft began FANS 1/A operations of SwiftBroadband in November 2017. This was followed by N664UA and N667UA and then N672UA. The United Airlines team supporting the project requested their flight scheduling teams to fly these aircraft across the North Atlantic to collect as much data as possible in support of the evaluation. The second and third of the four aircraft had their inaugural FANS 1/A over SwiftBroadband flights in December 2017 and the fourth aircraft N672HA had its inaugural FANS 1/A over SwiftBroadband flight in early April 2018.

7.5.1 Routes flown, ADS-C Contract Regimes and ANSP Evaluation Results

As shown in Figure 14, the United Airlines aircraft have flown regular routes in and out of the USA across the North Atlantic to Europe. There have also been a few flights from the USA to South America; however, the ADS-C data collected on those flights is minimal and statistically inconsequential for the purpose of this evaluation. All four of these aircraft have been provisioned on the SITAOnAir network in order to increase the diversity of data from different communication service providers.

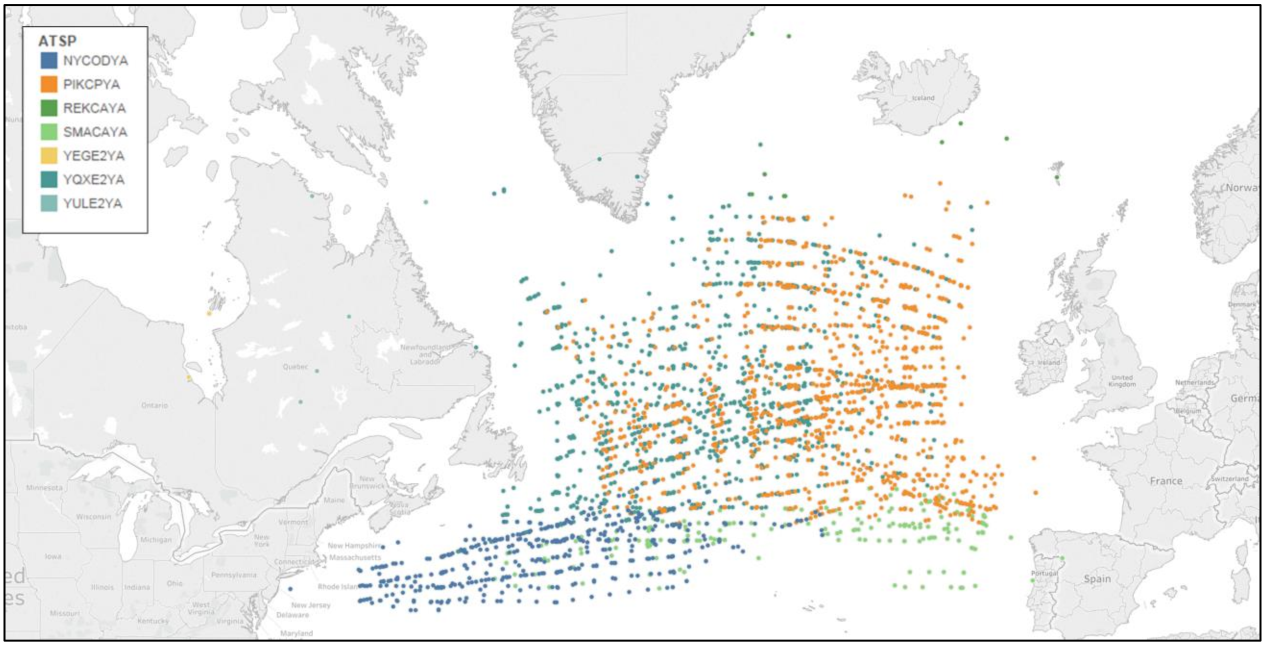

Figure 14: United Airlines B767 FANS 1/A over SwiftBroadband

7.6 ACARS AOC Evaluation

The Airbus Corporate Jet (ACJ) ACARS AOC aircraft with SITAOnAir as service provider was the first to start collecting data for this evaluation in 2014. Five different aircraft have contributed to AOC data collection in the evaluation. Two of the aircraft are business aviation aircraft, including the ACJ and a Falcon 900, again with SITAOnAir service provision. The remaining three aircraft are two commercial Shenzhen Airlines A320s (RC IMS (ARINC) service provision with partners MCN/ADCC) operating in the Asia-Pacific, and a Boeing 737-800 operating out of Australia (SITAOnAir service provision).

7.6.1 Aircraft and Routes Flown

The ACJ and Falcon 900 aircraft flight patterns as shown in Figure 15, were throughout the USA, Europe, and across the Atlantic Ocean. The Shenzhen Airlines A320 aircraft flew primarily through China. The position reports shown in Figure 15 are generated from the SwiftBroadband Integral Tracking reports – the different colours of the position reports denote the five aircraft.

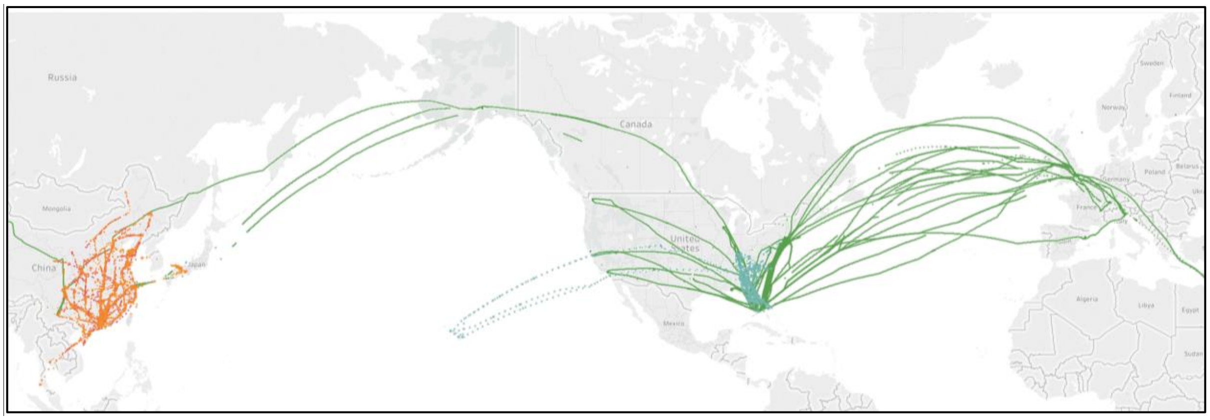

Figure 15: Aircraft Flights Operating AOC ACARS over SwiftBroadband

8 Flight Evaluation Results

The PARC CWG evaluated the performance of the FANS 1/A over SwiftBroadband aircraft over the course of five CWG meetings held over two and a half years. The performance metrics generated were analyzed by multiple parties independently over 27 months and reported at the PARC CWG meetings between CWG 35 and CWG 39. The FAA provided PBCS RSP reporting in the Pacific for the Oakland, Fukuoka, and Auckland FIRs, and RCP for the Oakland FIR, alongside VHF, Classic Aero and Iridium performance metrics. JCAB provided RSP performance, as well as RCP, for Fukuoka.

In the NAT, the FAA, NAV CANADA, NavPortugal, NATS and ISAVIA provided performance data.

Additionally, availability metrics for delivery of these services over the RC IMS (ARINC) and SITAOnAir networks are provided.

The results from these evaluations are discussed in detail in the following sub-sections.

8.1 Network Availability

Table 5 and Table 6 display the Inmarsat network availability for both RC IMS (ARINC) and SITAOnAir for the SwiftBroadband service over the years of 2016 and 2017 (the data was collected by the FAA).

The data shows that in 2016 the SwiftBroadband Service generally meets the 99.9% availability criteria for safety, with two exceptions on the EMEA satellite regions, which had outages exceeding the allocated 520 minute requirement. In 2017, the SwiftBroadband Service meets the 99.9% availability criteria for safety in all regions.

In summary, the network availability averaged over the three satellites for both SITAOnAir and RC IMS (ARINC) was thus greater than the 99.9% availability criteria for safety in all regions for 2016 and 2017.

Table 5: 2016 FAA Measured Network Availability by Path

2016 Network Availability Monitoring Report						
PBCS Criteria – Maximum Values						
Safety 99.9%				48	520	99.90%
Reliability 99.99%				4	52	99.99%
				Colour Key		
				Meets Safety and Reliability Criteria	Meets Safety Criteria only	Does not meet Safety or Reliability Criteria
Satellite	**Region**	**DSP**	**Path ID**	**# unplanned outages affecting path > 10 min**	**Sum of unplanned outages affecting path > 10 min (min)**	**Estimated availability for path**
Inmarsat I-4 and Alphasat	EMEA	SBB SITA	EME9	6	736	99.86%
		SBB ARINC	XXB	6	733	99.86%
	AMERICAS	SBB SITA	AMR9	5	354	99.93%
		SBB ARINC	XXU	6	480	99.91%
	Asia-Pac	SBB SITA	PAC9	3	160	99.97%
		SBB ARINC	XXS	5	248	99.95%
	MEAS	SBB SITA	MEA9	only test data available		
		SBB ARINC	XXM			
	Global	SBB SITA	n/a	n/a	n/a	99.92%
		SBB ARINC	n/a	n/a	n/a	99.91%

Table 6: 2017 FAA Measured Network Availability by Path

2017 Network Availability Monitoring Report						
PBCS Criteria – Maximum Values						
Safety 99.9%				48	520	99.90%
Reliability 99.99%				4	52	99.99%
				Colour Key		
				Meets Safety and Reliability Criteria	Meets Safety Criteria only	Does not meet Safety or Reliability Criteria
Satellite	**Region**	**DSP**	**Path ID**	**# unplanned outages affecting path > 10 min**	**Sum of unplanned outages affecting path > 10 min (min)**	**Estimated availability for path**
Inmarsat I-4 and Alphasat	EMEA	SBB SITA	EME9	3	268	99.95%
		SBB ARINC	XXB	3	314	99.94%
	AMERICAS	SBB SITA	AMR9	2	300	99.94%
		SBB ARINC	XXU	3	390	99.93%
	Asia-Pac	SBB SITA	PAC9	3	350	99.93%
		SBB ARINC	XXS	3	390	99.93%
	MEAS	SBB SITA	MEA9	only test data available		
		SBB ARINC	XXM			
	Global	SBB SITA	n/a	n/a	n/a	99.94%
		SBB ARINC	n/a	n/a	n/a	99.93%

8.2 Hawaiian Airlines Boeing 767-300ER Compliance Against RCP240 & RSP180

The Actual Communications Performance (ACP) from these aircraft was reported by the FAA for Oakland (KZAK), by JCAB for Fukuoka (RJJJ), and by Airways New Zealand for Auckland (NZZO) for the period July 2015 through December 2017.

Table 7 provides a tabulated report of ACP and Actual Communications Technical Performance (ACTP) during the reporting period as per PBCS Manual, ICAO Doc. 9869 Guidance for measuring against RCP 240. Figure 16 provides a collated view of the Oakland (KZAK) performance charts produced over the reporting period to CWG 38.

Table 7: HAL B767/RC IMS (ARINC) PBCS RCP Monitoring report

PBCS Monitoring Report						
Region →	Pacific		**Period →**	Multiple		
RCP						
Specification →	RCP 240		**Application →**	CPDLC		
Colour Key		**Transaction Counts (WILCO Received)**	**95% RCP 240 benchmark**		**99.9% RCP 240 benchmark**	
Meets Criteria →	(green)		**ACP**	**ACTP**	**ACP**	**ACTP**
Under Criteria but above 99.0% →	(yellow)		**<=180 sec**	**<=120 sec**	**<=210 sec**	**<=150 sec**
Under Criteria →	(red)		**End-to-End**	**Network**	**End-to-End**	**Network**
ANSP/Control area (CTA) - July to December 2015						
FAA OAK (KZAK) Jul-Dec 2015		447	99.82%	99.82%	99.82%	99.82%
JCAB Fukuoka (RJJJ) Jul-Dec 2015		68	98.55%	97.10%	98.55%	100%
FAA Auckland (NZZO) Jul-Dec 2015		34	100%	100%	100%	100%
ANSP/Control area (CTA) - January to June 2016						
FAA OAK (KZAK) Jan-Jun 2016		1,901	99.74%	99.95%	99.89%	100%
JCAB Fukuoka (RJJJ) Jan-Jun 2016		211	99.53%	100%	99.53%	100%
FAA Auckland (NZZO) Jan-Jun 2016		97	96.9%	98.96%	100%	100%
ANSP/Control area (CTA) - July to December 2016						
FAA OAK (KZAK) Jul-Dec 2016		2,170	99.63%	99.77%	99.72%	99.86%
JCAB Fukuoka (RJJJ) Jul-Dec 2016		199	100%	100%	100%	100%
FAA Auckland (NZZO) Jul-Dec 2016		110	100%	100%	100%	100%
ANSP/Control area (CTA) - January to June 2017						
FAA OAK (KZAK) Jan-Jun 2017		2,235	99.73%	99.87%	99.87%	99.96%
JCAB Fukuoka (RJJJ) Jan-Jun 2017		188	98.94%	99.47%	99.47%	100%
FAA Auckland (NZZO) Jan-Jun 2017		91	98.9%	100%	100%	100%
ANSP/Control area (CTA) - July to December 2017						
FAA OAK (KZAK) Jul-Dec 2017		2,274	99.78%	99.78%	99.82%	99.82%
JCAB Fukuoka (RJJJ) Jul-Dec 2017		175	98.86%	100%	99.43%	100%
FAA Auckland (NZZO) Jul-Dec 2017		102	100%	100%	100%	100%

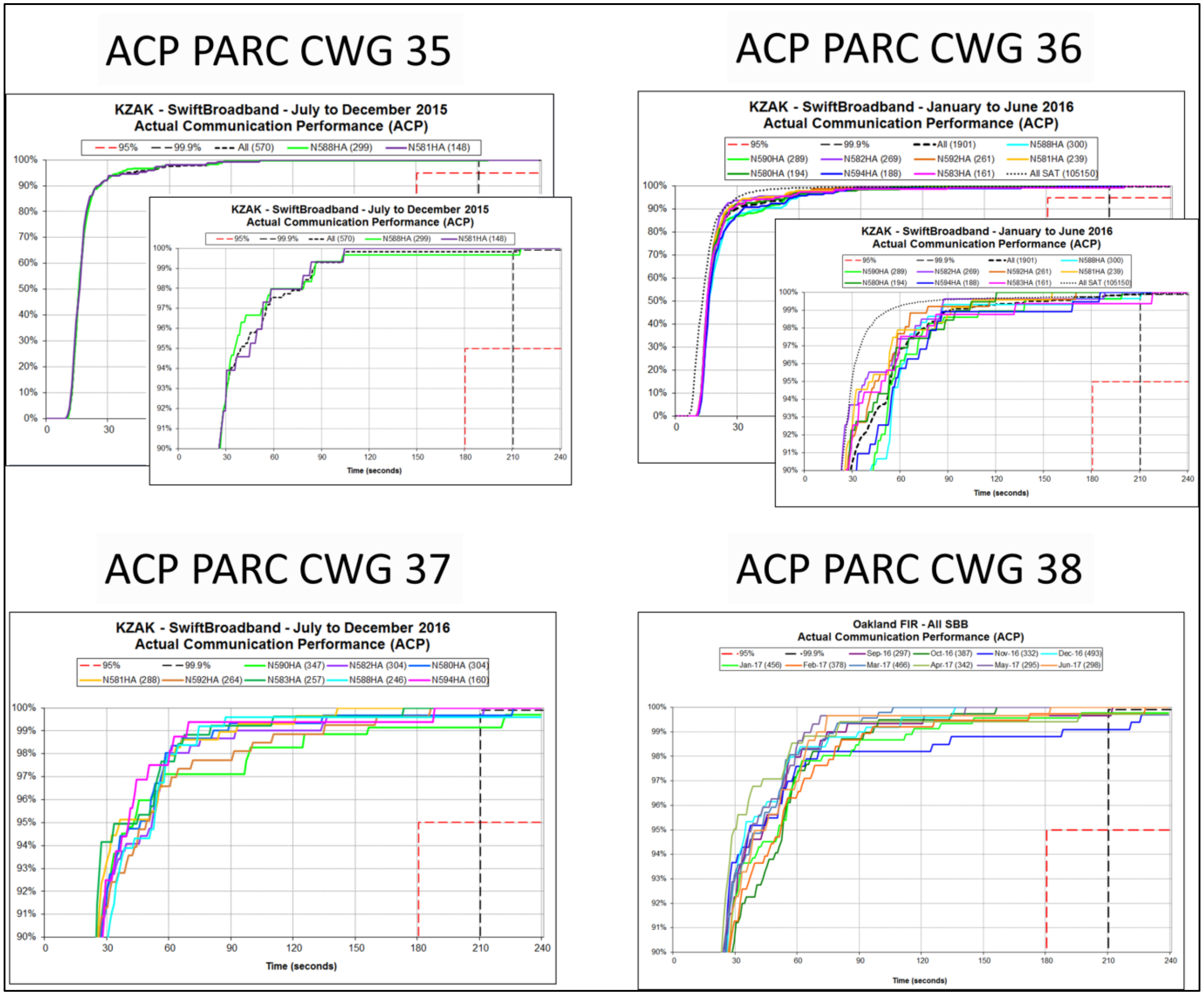

Figure 16: HAL B767/ RC IMS (ARINC) ACP Oakland Oceanic as Reported by FAA

The Actual Surveillance Performance (ASP) performance of these aircraft was reported by the FAA for Oakland (KZAK), by JCAB for Fukuoka (RJJJ), and by Airways New Zealand for Auckland (NZZO) for the period July 2015 through December 2017. Table 8 provides a detailed monitoring report separated by FIR over the four reporting periods. Figure 17 provides a collated view of the Oakland (KZAK) performance charts produced over the reporting period to CWG 38.

During three of the periods described in Table 8, the ASP recorded by Oakland Oceanic was below the 99.0% level (the rule-of-thumb acceptable level for the current operational environment) at the 99.9% RSP 180 benchmark. Analysis of the SDU-to-ACARS Ground Gateway (AGGW) message delivery times showed no differences in downlink delays to any other ATSP, however. Additionally, further investigation of the ADS-C timestamp-to-AGGW message delivery times led to the conclusion that the delays occurred on the aircraft, not in the SwiftBroadband subnetwork.

More specifically, that investigation revealed that the delays were primarily caused by relatively time-consuming transitions between VHF and SATCOM (especially from VHF to SATCOM) when aircraft exited land-based VHF coverage from the US west coast and Hawaii. (Notably, because Oakland Oceanic's airspace encompasses both the US west coast and Hawaii it recorded more transitions than other ATSPs.) In other words, these delays did not occur within the SwiftBroadband subnetwork itself, but rather as a result of ACARS network router (CMU) subnetwork routing logic. Please refer to Section 9 for further analysis of this and related factors; in particular, Figure 28 clearly shows the effects of the transitions as well as 'pure' SwiftBroadband performance unaffected by transitions.

Table 8: HAL B767/RC IMS (ARINC) PBCS Pacific Region RSP Monitoring Report

Regional PBCS Monitoring Report - RSP				
Region →	Pacific		**Period →**	Multiple
RSP				
Specification →	RSP 180		**Application →**	ADS-C
Colur Key		**Report Counts**	**95% RSP 180 benchmark**	**99.9% RSP 180 benchmark**
Meets Criteria →			**ASP**	**ASP**
Under Criteria but above 99.0% →			**<=90 sec**	**<=180 sec**
Under Criteria →			**End-to-End**	**End-to-End**
ANSP/FIR - July to December 2015 (CWG 35)				
FAA OAK (KZAK)		9467	97.0%	99.0%
FAA Auckland (NZZO)		325	>98.0%	>99.0%
FAA Boeing (ACAT)		26543	>99.0%	>99.0%
FAA Fukuoka (RJJJ)		1134	>99.0%	100.0%
ANSP/FIR - January to June 2016 (CWG 36)				
FAA OAK (KZAK)		32830	>97.0%	>99.0%
FAA Auckland (NZZO)		711	>98.0%	>99.0%
FAA Boeing (ACAT)		76288	>99.0%	>99.0%
FAA Fukuoka (RJJJ)		4842	99.52%	99.65%
ANSP/FIR - July to December 2016 (CWG 37)				
FAA OAK (KZAK)		53226	>96.0%	>98.0%
FAA Auckland (NZZO)		990	>97.0%	>99.0%
FAA Boeing (ACAT)		78866	>99.0%	>99.0%
FAA Fukuoka (RJJJ)		4961	99.27%	99.72%
ANSP/FIR - January to June 2017 (CWG 38)				
FAA OAK (KZAK)		60062	>96.0%	>98.0%
FAA Auckland (NZZO		966	98.44%	99.37%
FAA Boeing (ACAT)		N/A	N/A	N/A
FAA Fukuoka (RJJJ)		4472	99.49%	99.82%
ANSP/FIR - July to December 2017 (CWG 39)				
FAA OAK (KZAK)		70881	96.79%	98.79%
FAA Auckland (NZZO)		1056	97.53%	99.43%
FAA Boeing (ACAT)		N/A	N/A	N/A
FAA Fukuoka (RJJJ)		4295	99.58%	99.84%

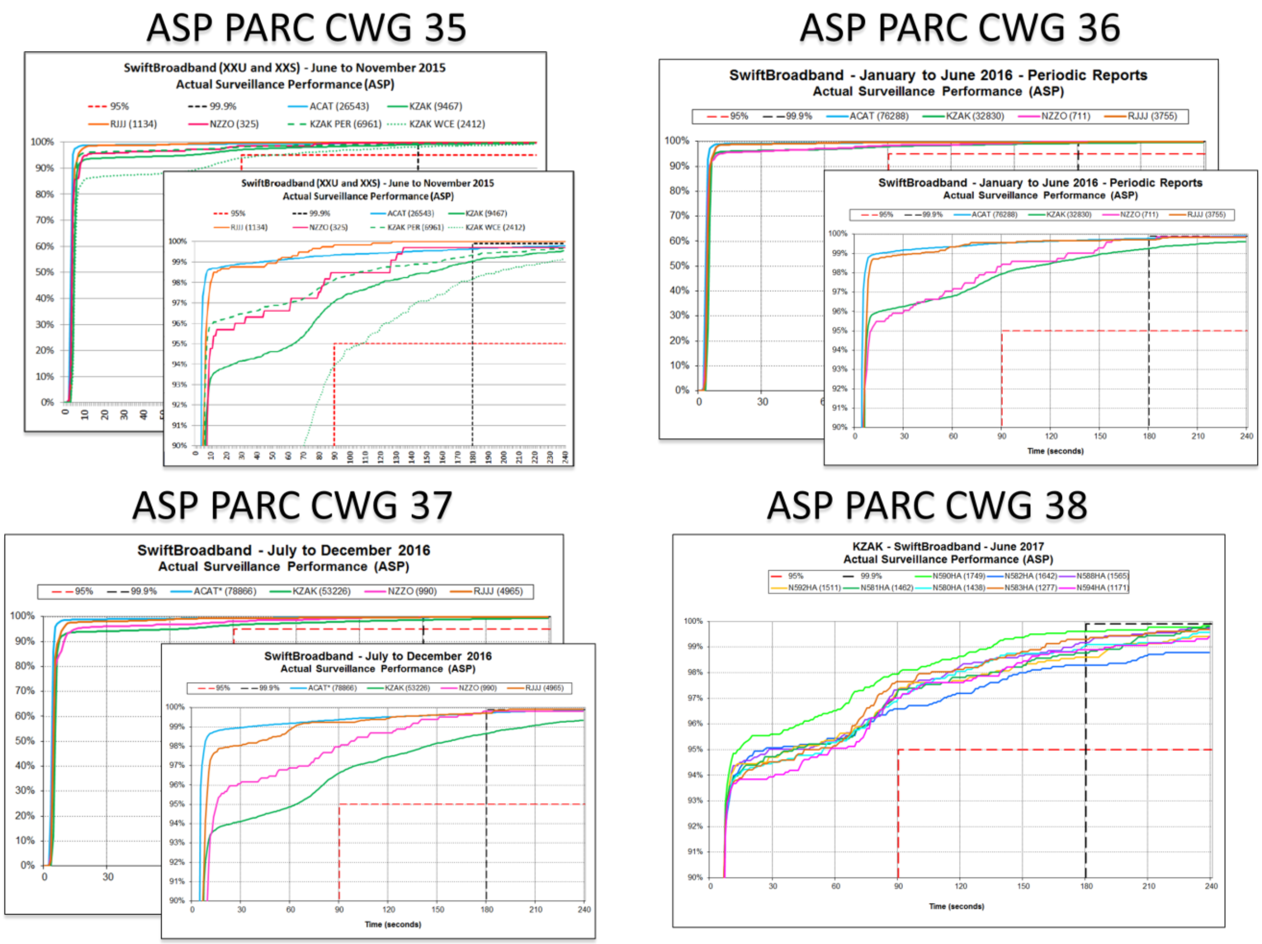

Figure 17: HAL B767/RC IMS (ARINC) Pacific ASP by FIR as Reported by FAA

Note: For CWG 38, the FAA did not present an ASP figure summarizing the fleet performance over the three FIRs. ASP in Oakland coloured by tail is provided instead.

8.3 Hawaiian Airlines Airbus A321neo Compliance Against RCP240 & RSP180

In late 2017, initial performance data began to be collected from the A321neo aircraft evaluation. The ASP for KZAK was provided by the FAA for December 2017, and for January and February 2018. Table 9 provides a detailed monitoring report for the data collected in the Oakland Oceanic FIR. The sample size was relatively small at the time of finalization of this report, but it is noted, with the aircraft flying exactly the same Oakland airspace routes as the B767 aircraft, that the ASP performance does not appear to be affected to the same extent by the on-aircraft message delays that affected the B767 aircraft. The ASP was greater than 98.9% at the 95% RSP 180 performance allocation and 100% at the 99.9% performance allocation. Figure 18 shows the excellent HAL A321neo/RC IMS (ARINC) ASP performance.

Table 9: HAL A321neo/RC IMS (ARINC) PBCS Pacific Region RSP Monitoring Report

Regional PBCS Monitoring Report - RSP				
Region →	Pacific		**Period →**	Multiple
RSP				
Specification →	RSP 180		**Application →**	ADS-C
Colur Key		**Report Counts**	**95% RSP 180 benchmark**	**99.9% RSP 180 benchmark**
Meets Criteria →	(green)		**ASP**	**ASP**
Under Criteria but above 99.0% →	(yellow)		**<=90 sec**	**<=180 sec**
Under Criteria →	(red)		**End-to-End**	**End-to-End**
ANSP/FIR - December 2017 to February 2018				
FAA OAK (KZAK)		5,425	>98.9%	100.0%
ANSP/FIR - March 2018				
Not provided				
ANSP/FIR - April 2018				
FAA OAK (KZAK)		4,444	99.0%	100.0%

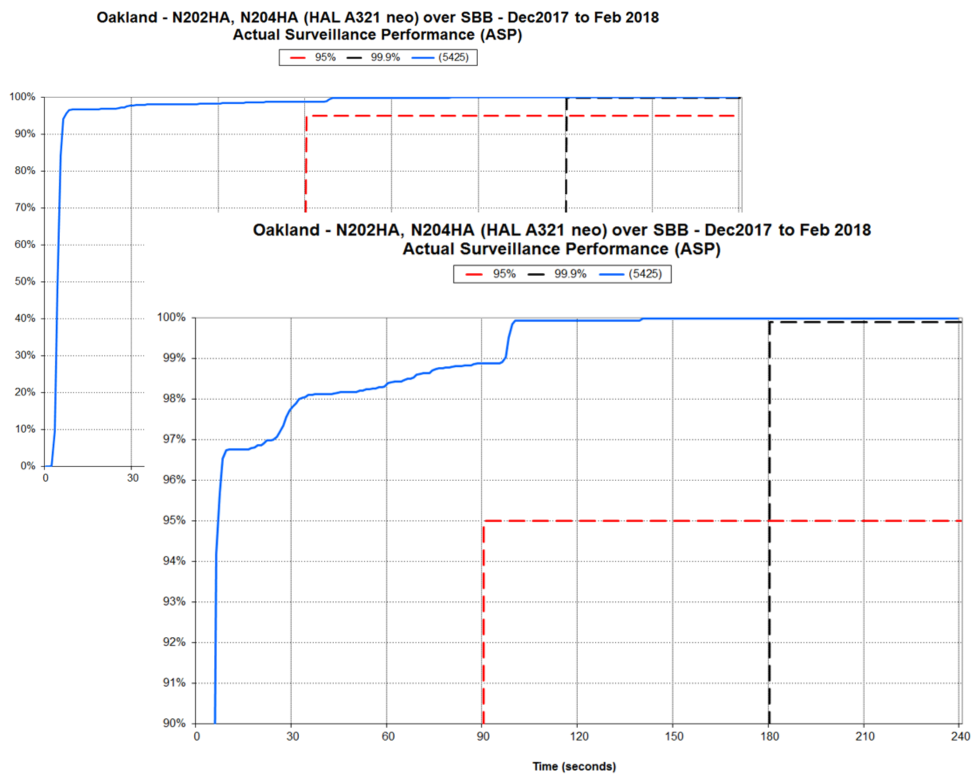

Figure 18: HAL A321neo/RC IMS (ARINC) ASP Performance

8.4 United Airlines Boeing 767-300ER Compliance Against RCP240 & RSP180

The ADS-C Latency data for Actual Surveillance Performance (ASP) performance of these aircraft was provided by the FAA, NAV CANADA, Nav Portugal, Iceland and NATS, and processed by Inmarsat. The Iceland data was not included in the ASP reports as there was only a very small sample and the data provided was in raw ACARS format. Table 10 provides a detailed monitoring report separated by ANSP. The ASP met the 95.0% and 99.9% RSP 180 requirement in the four FIRs for which data was provided.

Table 10: UAL B767/SitaOnAir PBCS NAT Region ATSP Monitoring Report

Regional PBCS Monitoring Report – RSP			
Region →	NAT	**Period →**	November 2017 - December 2017
RSP			
Specification →	RSP 180	**Application →**	ADS-C
Colur Key	**Report Counts**	**95% RSP 180 benchmark**	**99.9% RSP 180 benchmark**
Meets Criteria →		**ASP**	**ASP**
Under Criteria but above 99.0% →		**<=90 sec**	**<=180 sec**
Under Criteria →		**End-to-End**	**End-to-End**
ANSP Contracts - November to December 2017			
FAA, New York	77	>98.7	100.0%
NATS, Prestwick	247	>99.6%	100.0%
Nav Portugal, Santa Maria	258	>95.0%	100.0%
NAV CANADA, Gander	338	100.0%	100.0%

Figure 19 shows the RSP 180 performance curves for both ASP and ASTP. The ASTP is measured between the FMS timestamp and the AGGW timestamp, as explained in Section 7.1

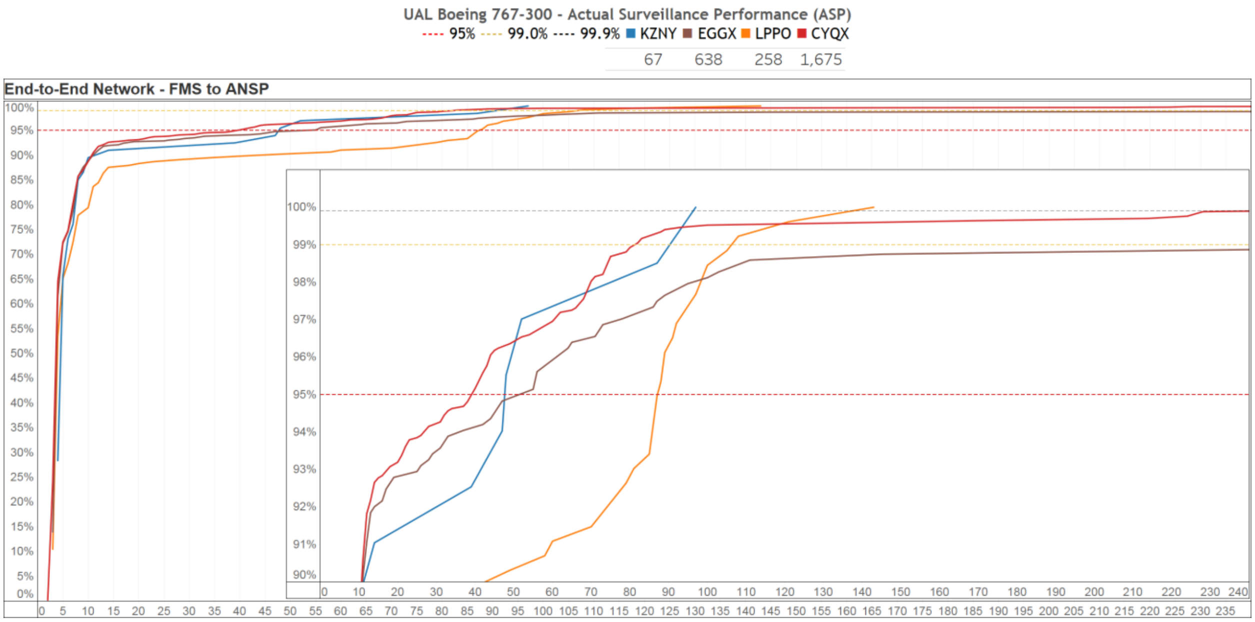

Figure 19: UAL B767/SITAOnAir NAT ASP coloured by ANSP

Note: Santa Maria (LPPO) airspace routes are subject to VHF transitions in-bound and out-bound similar to the Honolulu/West Coast USA routes. These transition events cause additional end-to-end message delay that is included in the satcom data.

8.5 Comparison of Airframe Performance Against RSP180

8.5.1 FMS to ACARS Ground Gateway ADS-C Message Delay

Figure 20 below compares the performance of the different airframes over the course of the evaluation. Referring to section 7.1, this chart presents the difference between timing points 4 and 3. It can be viewed as the time taken for an ADS-C message time-stamped at the FMS source to transit to the Inmarsat AGGW.

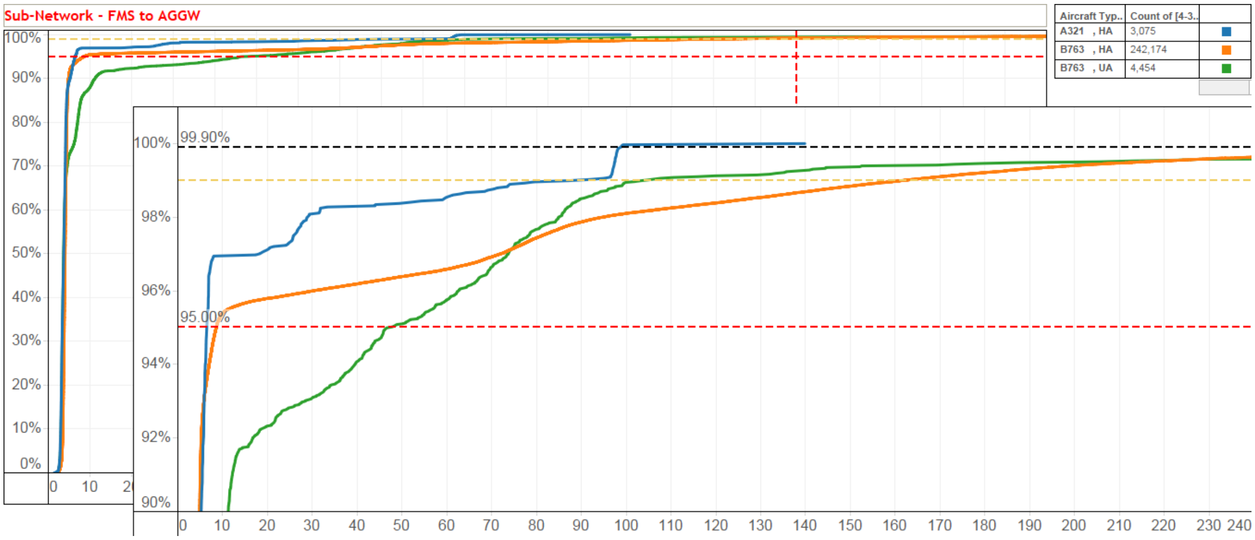

Figure 20: FMS to AGGW ADS-C Cumulative Message Delay Distribution by Operator/Aircraft Type

8.5.2 SDU to ACARS Ground Gateway ADS-C Message Delay

Figure 21 below compares the performance of the different airframes over the course of the evaluation. Referring to section 7.1, this chart presents the difference between timing points 4 and 6. It can be viewed as the time taken to deliver the ADS-C message from the SDU to the Inmarsat AGGW.

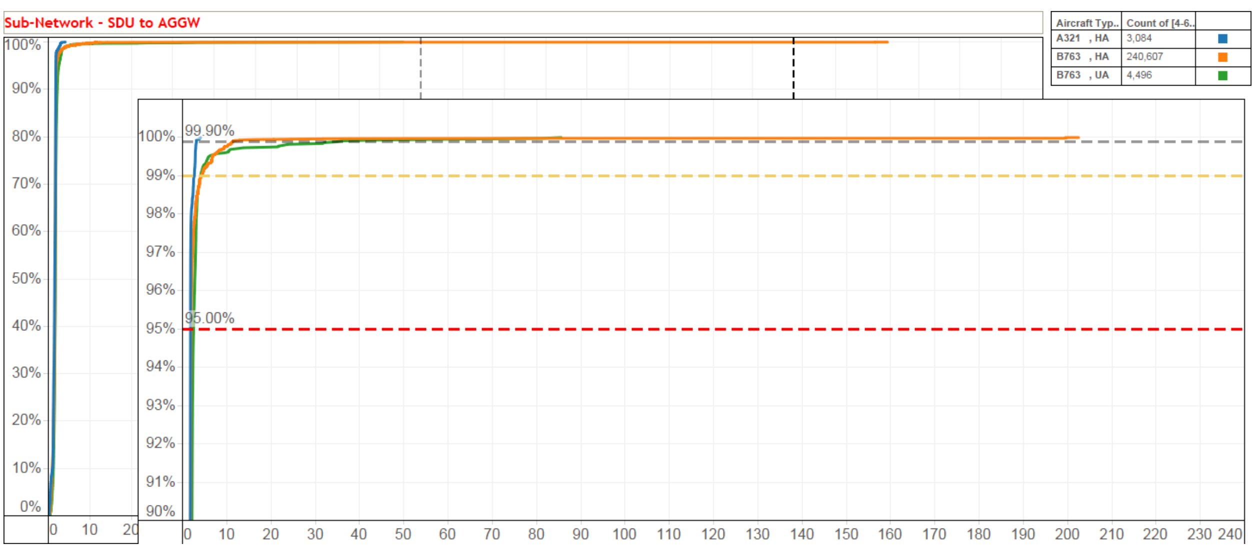

Figure 21: SDU to AGGW ADS-C Cumulative Message Delay Distribution by Operator/Aircraft Type

Since the message latency between the AGGW and ANSP via the CSP is negligible in the air to ground direction it can be seen that the majority of the additional delay is occurring within the aircraft avionics.

8.6 AOC ACARS Evaluation

8.6.1 ACARS Counts

Over the course of the evaluation period (which began in June 2014 for the first AOC ACARS over SwiftBroadband aircraft), over 2 million ACARS messages were transmitted across the four Inmarsat-4 satellites. Figure 22 provides a detailed breakdown of AOC ACARS message counts by ocean region, CSP, and aircraft, during the period June 2014 through July 2017.

Figure 22: AOC ACARS Message Counts (June 2014 to July 2017)

Note: The 'ACARS' category represents AOC ACARS messages only.

9 Explanation of Issues and Ongoing Work

During the evaluation, the major factors contributing to delayed end-to end messaging were analysed and explained. This section is divided into four subsections:

- Occasional 'log-tail' or delayed messages, software issues in the satcom system and mitigation;
- Oakland ADS-C WCE performance and how WCE downlinks have unique delay characteristics, and why these effects are more noticeable in the Oakland FIR;
- Media transitions, and their effect on satcom measured performance;
- Media advisories, analysis and expert opinion.

9.1 Long-tail Messages

In the analysis of the occasional long-tail messages seen, two areas were identified and evaluated which required mitigation:

- How the Cobham software handles a loss of resource indication;
- Session IDs losing synchronization.

These conditions and their mitigation are described below.

9.1.1 Cobham Software Updates

In normal operations, it is possible for the terminal to lose radio resources (ACARS PDP). This could be caused by a signal disturbance from the aircraft or its surroundings. In the Cobham 2.0.1 software, the terminal will send a list of expected resources to the Inmarsat RAN when the terminal believes it has lost radio resource. The RAN then compares what is sent by the terminal against what is currently known. The time that this process takes can contribute to long-tails.

In order to improve the latency performance, in March 2016 Cobham developed, tested and certified a software update for all the evaluation terminals. In this updated software release, upon experiencing what the terminal believes is a loss of radio resource, it will immediately request a new resource (ACARS PDP). This software became available in August 2016 and took the revision from 2.0.1 to 2.0.2. Hawaiian Airlines has implemented this revision as a Service Bulletin upgrade on three of the eight aircraft in November 2016, and in June 2017 HAL took the decision to roll it out on the remaining five aircraft included in the evaluation.

9.1.2 AGGW Software Upgrades

During CWG 35 it was reported that there were six short outage events which required further investigation of their root cause. Analysis conducted by SED (the AGGW supplier) determined that the cause was due to the AGGW and AAGW session IDs becoming out of sync. This caused uplinks to be discarded by the AAGW. An interim process was put in place to mitigate the occurrence of this issue by increasing the NAK alarm sensitivity, which would then invoke an operator action to manage the traffic appropriately. As part of the long-term mitigation plan, SED produced and delivered a software update for the ground gateway which mitigated this issue. Both AGGW sites were updated to this latest software in May 2015. No “excessive AAP NAK messages received” alarms have been logged in the AGGW since the software upgrade.

It should be noted that the software upgrade does not have an effect on FANS 1/A over SwiftBroadband latency performance. The purpose of the upgrade was to improve the system availability.

In addition to the software enhancement described above, Inmarsat and SED introduced new monitoring capabilities into the ground gateway enabling expansion of the Tableau tool-set for message latency monitoring.

9.2 Oakland WCE Performance

The FAA has provided PBCS monitoring reports of the FANS 1/A ACP and ASP performance from PARC CWG 35 to PARC CWG 38, and additional data to the end of December 2017. In each of these reported periods, it was noted that the ASP in the Oakland Oceanic airspace is the worst of the three FIRs in which data is collected. The green plot in Figure 23, shows the Oakland performance relative to the other four regions where data has been collected. All four regions are able to achieve the 95% RSP 180 benchmark in

90 seconds. However, at PARC CWG 37, the Oakland ASP performance at 180 seconds fell below 99.0% for that reporting period.

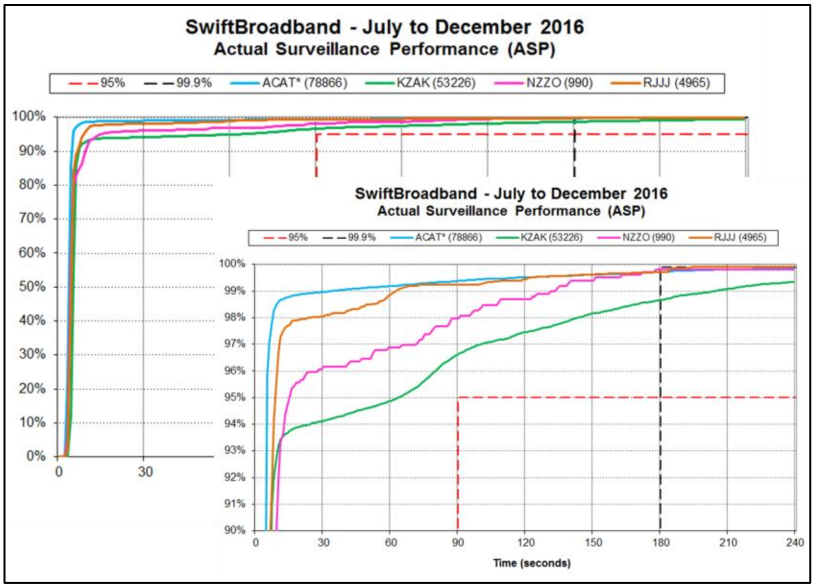

Figure 23: HAL B767/RC IMS(ARINC) FANS 1/A over SwiftBroadband Actual Surveillance Performance (ASP) July to December 2016

This trend was a concern to the PARC CWG when compared with the ASP of Classic Aero in the Oakland airspace. Figure 24, displays both the ASP of the Hawaiian Airlines B767 for Oakland as well as the ASP for all aircraft types/models using Classic Aero in the Oakland airspace.

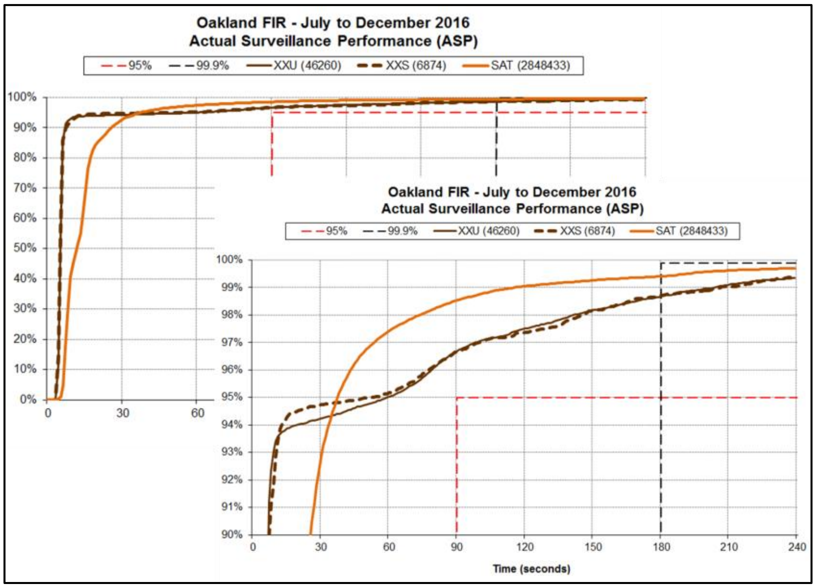

Figure 24: HAL B767/RC IMS (ARINC) SwiftBroadbandFANS 1/A over SwiftBroadband & 'All Oakland' Classic Aero (SAT) Actual Surveillance Performance (ASP) July to December 2016

The FAA analyzed the ASP performance further by separating the ADS-C message types and identified that the Waypoint Change Event (WCE) message type was the driving factor of the poor performance. WCE messages are 40% of the total Oakland ADS-C messaging. Figure 25 shows the WCE messaging performance per FIR, and, if this is compared with the overall ADS-C performance (Figure 23) over the same period, the lower overall performance is confirmed.

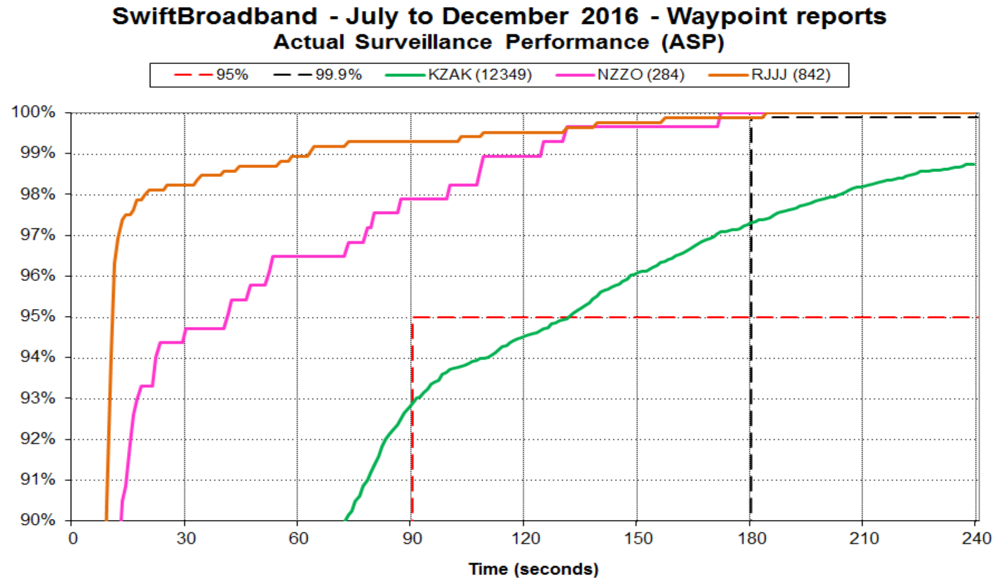

Figure 25: Comparison of HAL B767/RC IMS (ARINC) Waypoint Change Event Performance in Oakland, Auckland and Fukuoka Airspace July to December 2016

Inmarsat took this analysis further by comparing the Classic Aero performance of all 767 aircraft in the Oakland airspace against that of the Hawaiian Airlines Aircraft. Figure 26 compares the Inmarsat sub-network ASP of Classic Aero B767 aircraft with the sub-network ASP of the FANS 1/A over SwiftBroadband Hawaiian Airlines B767 aircraft on the RC IMS (ARINC network).

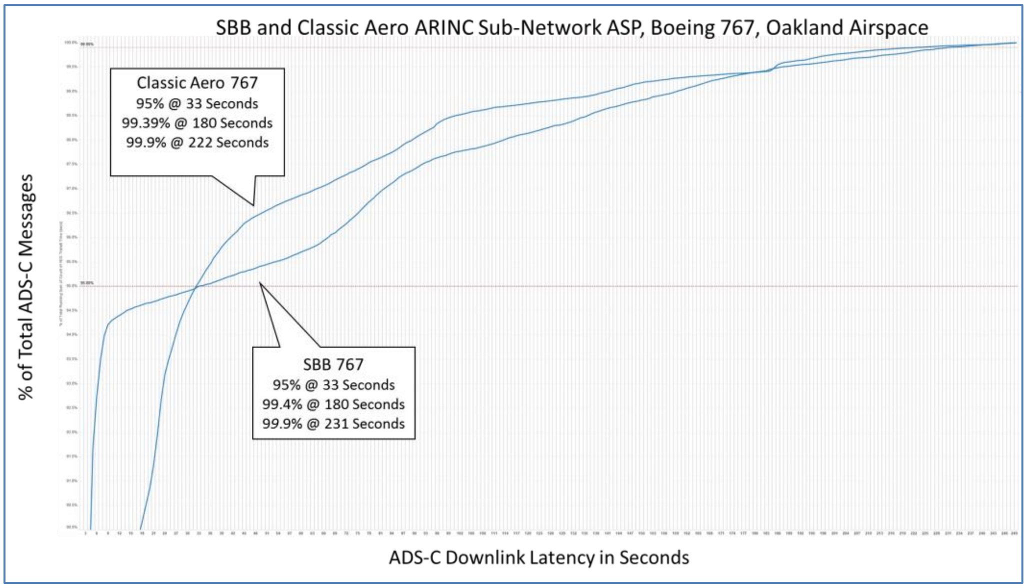

Figure 26: FANS 1/A over SwiftBroadband and Classic Aero Sub-Network ASP, ARINC, B767, Oakland

The relationship seen between the Classic Aero and FANS 1/A over SwiftBroadband sub-network performance on the Boeing 767 airframe suggested that the poor performance seen in Oakland is not unique to SwiftBroadband.

At CWG/39, Ann Heinke gave a presentation overviewing ADS-C design criteria. This raised five key conclusions that supported the evidence that ADS-C reports, like other FMS messages, can be delayed in their production and release from the FMS:

1. As intended, the ADS-C timestamp is "position-sensed" time, not "message sent" time (which is impossible to generate anyway);
2. For the ADS-C reports used in this evaluation, the FMS processing allowance is up to 5 seconds;
3. ADS-C messages are given lower priority than CPDLC messages;
4. The FMS's ADS-C application may have an internal backlog (queue of messages), just like its other datalink applications;
5. ADS-C messages may experience delays from the FMS-CMU bus, just like other FMS messages.

9.3 Media Transitions

In the Communications Management Unit (CMU), the use of VHF datalink is prioritized above satcom datalink. As aircraft approach the edge of VHF coverage, the avionics continues to attempt to use the VHF media for some time according to the defined ACARS protocols, before giving up and switching to satcom. An overview of the CMU message retry sequence is shown in Appendix D. The consequent effect is that the SwiftBroadband message delivery latency is artificially extended as a result of the CMU media routing logic. This affects the satcom ADS-C message latencies, negatively impacting the performance against the 95% and 99.9% benchmarks. During the PARC CWG 35 meeting, the FAA reported on the performance of ADS-C latency events that occur when transitioning between communication mediums. Figure 27 separates the VHF to SwiftBroadband and SwiftBroadband to VHF transitions. It can be seen that the above theory is supported by the fact that the orange line, (the performance specifically related to VHF to SwiftBroadband transitions) is well below both the 95% and 99.9% benchmark criteria, whereas the transitions from SwiftBroadband to VHF are at or above the allocations.

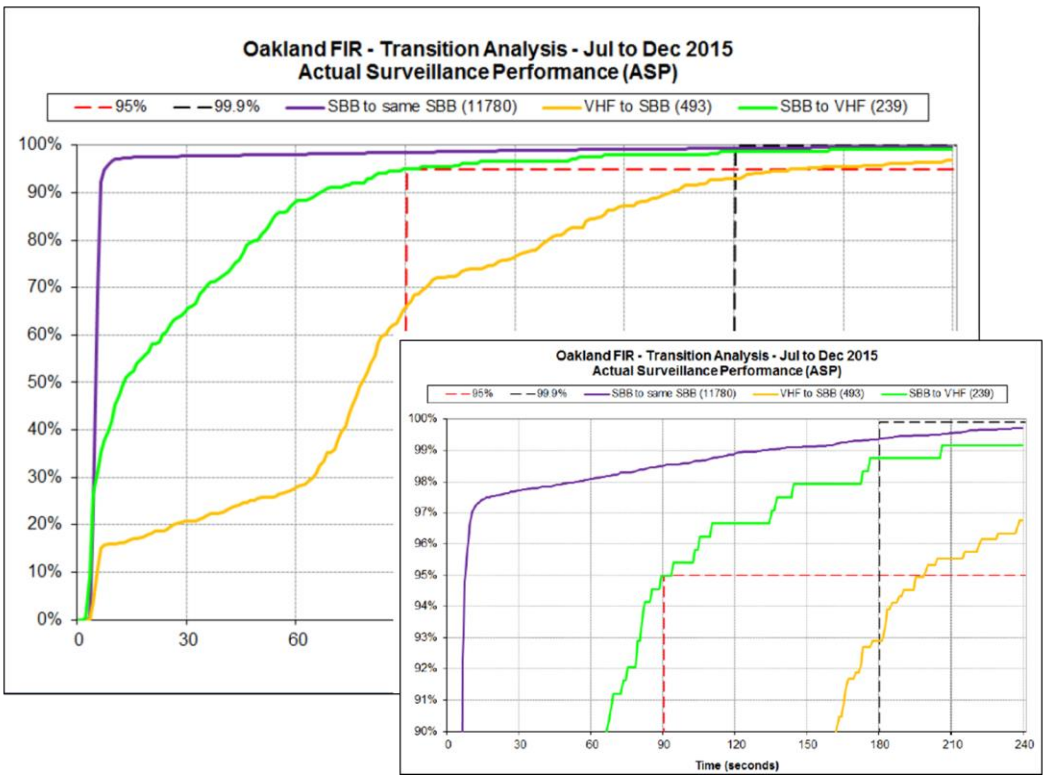

Figure 27: ASP of Media Transition Events (July to Dec 2015)

This behaviour was re-assessed towards the end of the evaluation period. Inmarsat analysed different airframes equipped with Classic Aero, flying different Pacific FIRs outside the Honolulu to West Coast USA airspace, and showed that for flights transitioning from VHF to satcom the message latency was markedly worse than transitions from satcom to VHF, i.e. comparable to the SwiftBroadband behavior. These results were presented at CWG/38.

The FAA supplied updated Oakland airspace ADS-C Media Transition Event charts for the HAL B767 aircraft for the period Jul to Dec 2017 (see Figure 28), which confirmed this effect. It was noted that in the Honolulu to West Coast USA airspace, all flights encounter two transitions, one from VHF to satcom and one from satcom to VHF compounding the latency effect.

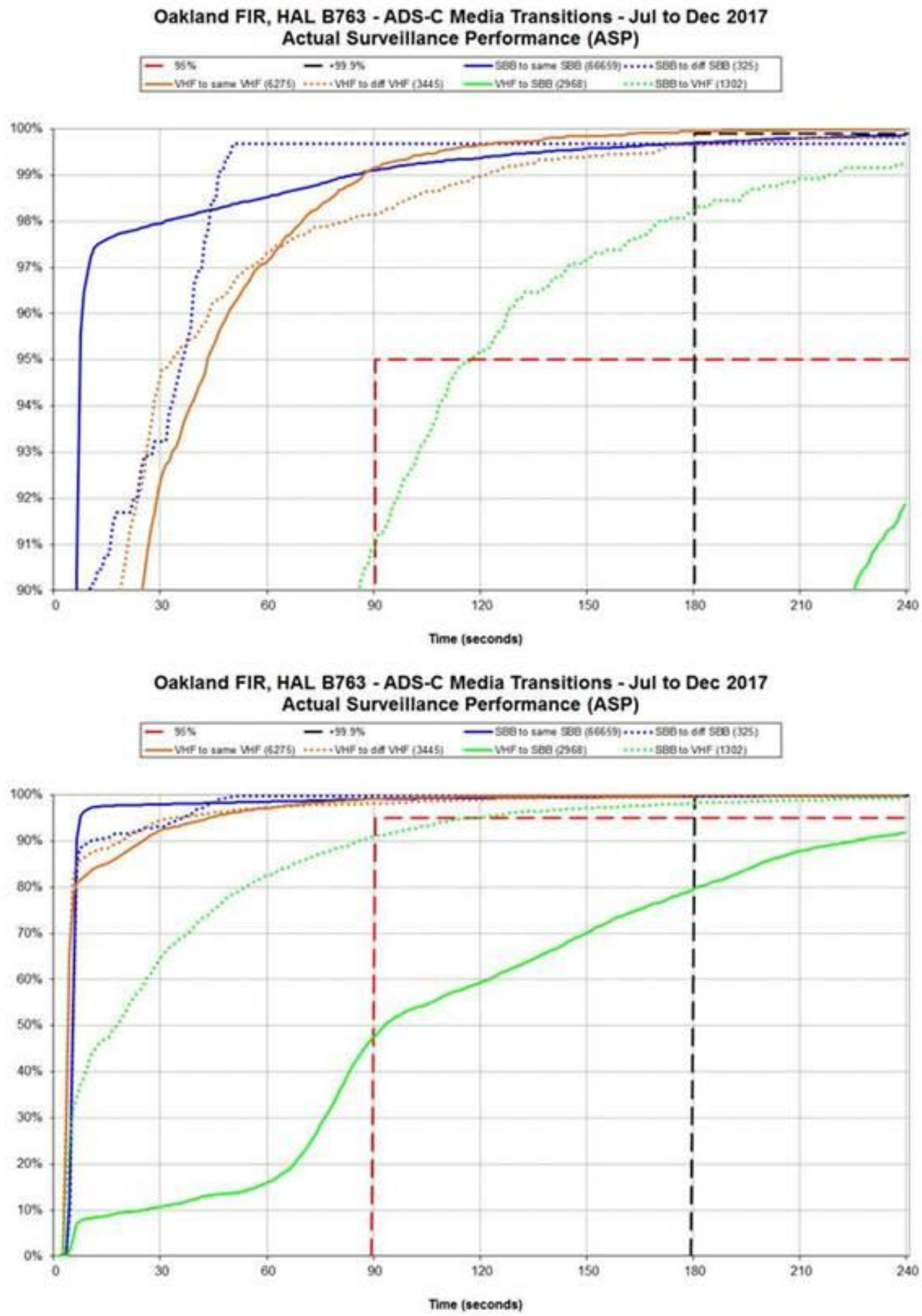

Figure 28: ASP of Media Transition Events for HAL B767 (July to Dec 2017)

The FAA also supplied media transition analysis for the HAL A321 flights from Dec 2017 to Feb 2018, as shown in Figure 29 below. The data shows a marked improvement in message latency performance during both VHF to SwiftBroadband and SwiftBroadband to VHF transitions, with the former almost meeting the 95% allocation of 90s and the latter exceeding it (>99% at 90s).

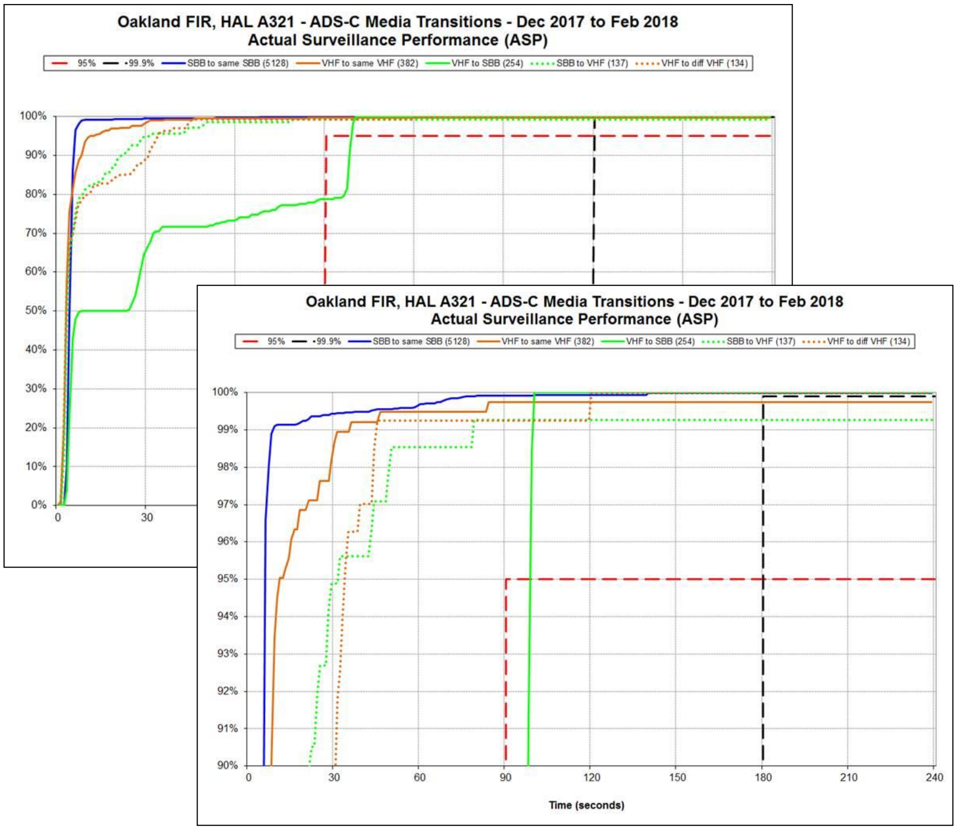

Figure 29: ASP of Media Transition Events for HAL A321s (Dec 2017 to Feb 2018)

Furthermore, when evaluating the RSTP at the GPS, SBU and AGGW timestamps (4-6 timestamps), it can be seen that the majority of the ADS-C latency is occurring on the aircraft. This suggests that there may be a correlation with the routing logic related to choosing the appropriate communication link off the aircraft. Appendix D gives an overview of the CMU logic for media re-transmission and switch-over.

The following section examines the use of the Media Advisories on the HAL B767 aircraft.

9.4 On-aircraft Handling of Media Advisories

RC IMS (ARINC) and Honeywell have conducted a co-ordinated assessment of the handling of Media Advisories on the Hawaiian Airlines Boeing 767 aircraft N588HA. As a reminder, the aircraft is equipped with a Honeywell Mark-II Communications Management Unit.

Ordinarily, and as a requirement for FANS operations, the ACARS CMU is required to send downlink messages referred to as (SA-labelled) Media Advisory Reports or MEDs, each time the CMU detects the establishment or the loss of a communications media (such as VHF, SATCOM, or HFDL). These Media Advisory Reports are delivered to airlines and the FANS gateways to allow the real-time tracking of the DSPs and available communications pathways to the aircraft. Each avionics communications sub-system, such as the SDU and the HF Data Radio, must send real-time status words regarding their Log On / Off status to the CMU, via the 429-bus. The CMU uses this information to determine when a Media Advisory

Report must be sent. The CMU also uses the 429-bus Log On/Off status words for the timely delivery of FANS Downlink messages. When the CMU has an ATS downlink to deliver, it prepares a delivery table based on the media that are currently available. In this manner, at all times, the CMU knows the most effective communications media available for the timely delivery of high-priority ATS messages.

During the course of the early FANS 1/A over SwiftBroadband trials, a potential problem was noted: In a number of instances, the RC IMS (ARINC) GLOBALink Message Processor or GMP was advised by the Inmarsat gateway equipment (AGGW) that the aircraft had logged off or had logged on to the SwiftBroadband Ground Station; however, there was no corresponding Media Advisory Report or MED confirming the event from an aircraft perspective.

Rockwell-Collins IMS (ARINC) reported their observations and data to HAL, Inmarsat, Cobham and Honeywell, and individual investigations were conducted. It was confirmed that the Cobham 300D SDU was accurately reporting the LogOn status to the CMU. Honeywell provided further details regarding their proprietary handling of LogOn/Off events and the creation of Media Advisory Reports. In an attempt to reduce the number of superfluous Media Advisory downlinks, the MK-II CMU will often not send a Media Advisory downlink after the loss or the establishment of a SwiftBroadband Satellite connection with the same SAS. This feature was introduced based on feedback from operators and tested by RC IMS (ARINC) AQP, SITAOnAir VAQ and Boeing AEIT more than 10 years ago. The information from Honeywell provided a satisfactory explanation for the observed condition and the investigation was ended.

With a better understanding of the root cause, an assessment can be made on the predicted impact of the missing media advisories for this FANS 1/A over SwiftBroadband fleet. First, it is RC IMS's (ARINC's) assessment that the implementation of the Media Advisory function in this older release of the Honeywell MK-II CMU does not meet the requirements called out in AEEC Standard 618, however this version of CMU software passed Boeing AEIT testing and RC IMS (ARINC) AQP testing over 10 years ago, which is one reason it is still installed on the aircraft. This version of CMU software has been installed on many FANS 1/A aircraft for many years (over 10) without comment. Generally, the MED function and reports are optional for AOC applications, but required for FANS operations. Since the Cobham 300D is providing accurate log on/off status to the CMU, this condition should not have an impact on the CMU media selection and the timely delivery of FANS downlinks. The MK-II implementation may have some impact on the timely delivery of ANSP FANS Uplinks.

One of the primary users of the aircraft-generated Media Advisory Reports are the RC IMS (ARINC) and SITAOnAir FANS internetworking gateways. ANSPs typically address all FANS Uplinks to one of the gateways. It is the responsibility of the gateways to develop an ordered delivery algorithm that chooses the best DSP (RC IMS (ARINC), SITAOnAir, AVICOM, ADCC…) for the timeliest delivery of the FANS uplink. The gateways rely on the Media Advisory Reports to dynamically track the media and connection paths available for delivery of the FANS uplink. Therefore missing Media Advisories may affect the gateways' ability to choose the best path for FANS uplinks.

The HAL FANS 1/A over SwiftBroadband fleet uses the services of one DSP. This should simplify the function of the FANS Gateway in DSP selection; therefore, the impact of the inaccurate or missing Media Advisories is expected to be minor.

10 Committed Future Development

The AEEC has standardized an enhanced FANS 1/A over SwiftBroadband capability, introducing VPN security over the air interface, supported by corresponding ground security gateways in the Inmarsat FANS 1/A over SwiftBroadband network. Figure 30 shows the system architecture, including the security gateway and the introduction of PS voice.

Compliant products will be supplied by Cobham, as the Light Cockpit Satcom (LCS) system for Airbus, and by Honeywell:

Cobham Aviator 200S and 700S avionics cover the single aisle and long range aircraft families:

- For the A320, A330, A340, A350, the 200S – Enhanced Low Gain Antenna, Class 4
- For the A320, A330, A340, the 700S – High Gain Antenna, Class 6

Honeywell Aspire 400 avionics will be supplied in the following configurations:

- Aspire 400 HG – High Gain Antenna, Class 6, single or multi-channel
- Aspire 400 IG – Intermediate Gain antenna, Class 7, single or multi-channel
- Aspire 400 LG – Enhanced Low Gain Antenna, Class 4, single-channel.

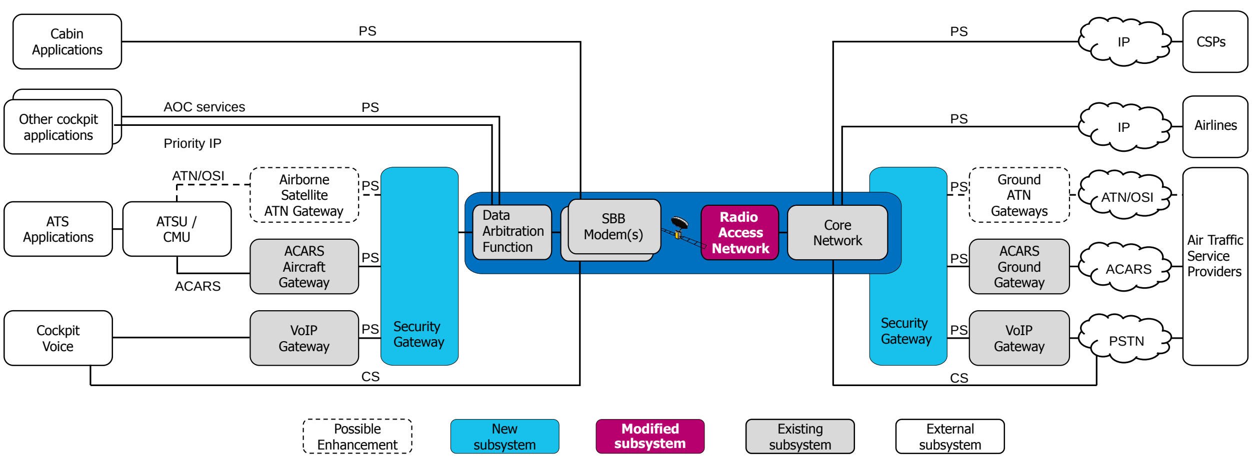

Figure 30: Enhanced FANS 1/A over SwiftBroadband Architecture Supporting LCS

11 Evaluation Conclusions

The ACP in both Oakland and Fukuoka FIR achieved the 95% RCP at 120 seconds during all reporting intervals. Performance above 99.0% was achieved in both FIRs during all reporting periods for RCP at 210 seconds.

The Pacific ADS-C ASP charts for the HAL B767s show compliance with the 95 percentile allocation for all FIRs. The ASP performance at the 99.9 percentile is very similar to the Classic Aero 99.9 percentile performance. The 99.9% latency requirement of 180 seconds was generally achieved at or above 99.0%.

There were two reporting periods over the two-year assessment period where ASP fell below 99.0% in Oakland (KZAK). It was identified that the perceived performance difference at the 99.9 percentile in Oakland (KZAK) is due to the specific route structure of the HAL aircraft, which fly primarily between West Coast USA and Hawaii, never leaving the Oakland airspace, and hence are affected by VHF to SATCOM transitions in both flight directions. The data shows that all of the FIRs are equally affected by VHF to SATCOM transitions; however, the performance degradation does not show up in the aggregate data of the other FIRs, as the flights traveling into the airspace of these other areas are not affected by VHF to SATCOM transitions. The A321neo aircraft were purchased brand new from the Airbus production line in 2017, which provided the evaluation with an aircraft configuration that had much newer avionics than the Boeing 767-300ER aircraft. The A321neo data shows that the VHF to SwiftBroadband transitions on these aircraft had less of a negative impact on the ASP.

The data collected from the United Airlines Boeing 767 aircraft demonstrated equally good performance over the SITAOnAir sub-network across the NAT airspace. The data provided similar results to that seen from the Hawaiian Aircraft flying in the Pacific.

In addition to the normal ADS-C and ACAT reporting, Hawaiian Airlines has also utilized AOC reporting and other IP communications whilst simultaneously maintaining compliance with the FANS PBCS RCP240 and RSP180 message latency requirements. The added capabilities of SwiftBroadband now offer the opportunity for the industry to evolve ATS operations by utilizing the expanded capabilities of this system.

12 Recommendations

The recommendations are based on the findings from the PARC CWG project to investigate the viability of SwiftBroadband against RCP and RSP allocations. The PARC CWG evaluation was made against the ICAO PBCS RSP 180 and RCP 240 requirements for surveillance data delivery and operational CPDLC communication.

Based on the analysis and the guidance provided for determining compliance in the PBCS Manual, the PARC CWG found that the performance of FANS 1/A over SwiftBroadband meets, and in many cases exceeds, the continuity, availability and transaction time requirements as defined by the PBCS RCP240 and RSP180 specifications. Relative to Classic Aero ADS-C performance, SwiftBroadband has shown a reduction in sub-network latency on the order of 30-40 seconds for greater than 90% of transmitted messages. The PARC CWG will continue to monitor the SwiftBroadband performance on all aircraft which install and operate FANS 1/A over SwiftBroadband as per the normal PBCS reporting practices for long range communication systems, and this will be reported at ICAO regional groups and at each PARC CWG. The PARC CWG and ICAO regional groups will put in place any necessary mitigations or investigations in order to maintain and/or improve the performance.

Recommendation 1 – That the FAA accepts FANS 1/A over SwiftBroadband as a viable medium for FANS 1/A operations in airspace which require application of RSP 180 and RCP 240 for reduced aircraft separations.

Note 1: FANS 1/A over SwiftBroadband is considered "approved" based on appropriate aircraft installation approval, operational authorization as appropriate, by the State of the Operator or State of Registry, and approval of ANSP service provisions by the appropriate ATS authority.

Note 2: Per RTCA DO-306/EUROCAE ED-122, the GOLD RCP 240 and RSP 180 specifications are intended for CPDLC and ADS-C required for 50 NM and 30 NM longitudinal and 30 NM lateral separation minima. Per the North Atlantic (NAT) Performance Based Communication and Surveillance Implementation Plan, RCP 240 and RSP 180 are the candidate specifications for Reduced Longitudinal Separation of 5 minutes between ADS-C equipped aircraft (RLongSM) and Reduced Lateral Separation of 25 Nautical Miles (NM) (RLatSM) separation minima, pending further operational evaluation and safety assessment.

Recommendation 2 – That the FAA advocates internationally, that aircraft using the SwiftBroadband sub-network are eligible for operations that require compliance to CPDLC RCP 240 and ADS-C RSP 180 specifications supporting reduced separations.

Recommendation 3 – That the FAA advocates the development of performance specifications that can make use of the superior capabilities of the SwiftBroadband technology.

13 References

Reference No	Title	Document Number	Applicable Issue
1	ICAO Global Operational Datalink Document "GOLD"	ICAO Doc. 10037	1st ed.
2	ICAO Performance Based Communications and Surveillance	ICAO Doc. 9869	2nd ed.
3	AMS(R)S Manual (including amendment for SwiftBroadband)	ICAO Doc. 9925	Edition 1 , amendment 1
4	Aeronautical Circular - Datalink	FAA AC20-140	B
5	Aeronautical Circular - Datalink Ops Procedure	FAA AC120-70	C
6	Minimum Aviation System Performance Standard for AMS(R)S Data and Voice Communications Supporting Required Communications Performance (RCP) and Required Surveillance Performance (RSP) in Procedural Airspace	RTCA DO-343	A
7	Minimum Operational Performance Specifications for Avionics Supporting Next Generation Satellite Systems (NGSS)	RTCA DO-262	C

14 Appendix A - Laboratory Testing

Prior to beginning a flight evaluation campaign, technical certification of the equipment against the RTCA MOPS [Ref. 7] was conducted for the Cobham's Aviator 300D system in the laboratory in 2014, along with validation of the ACARS capability using ARINC's AQP (ARINC Qualification Process) and SITAOnAir's VAQ (Validation, Assessment & Qualification) test criteria for AOC ACARS & FANS 1/A messaging. Additionally, Boeing has undertaken the AEIT testing and has been completed.

14.1.1 Test Program/Activities

Inmarsat, Cobham, RC IMS (ARINC), SITAOnAir, Boeing, and Dassault have all contributed to test programs of the Aviator 300 and 700 avionics & antenna system. Additionally, an Airbus Corporate Jet participated in ground and flight tests as part of the STC project for AOC Datalink.

The following outlines additional test programs and achievements for this program:

ACJ operator/ASG AOC ACARS STC (A320)	Completed Q2 2014
RC IMS (ARINC) AQP:	Completed Q2 2014
SITAOnAir VAQ:	Completed Q2 2014
Boeing AEIT:	Completed Q2 2014
Cobham EMI/EME/Black Label/PMA:	Completed Q3 2014
Inmarsat Alpha/Beta Type Approvals:	Completed Q3 2014
STC Ground/Flight Test AOC ACARS (ACJ):	Completed Q3 2014
Dassault FANS 1/A Bench Tests:	Completed Q4 2014
HAL/L2 Aviation FANS 1/A ACARS STC (B767):	Completed Q2 2015
The CAT Airline FANS 1/A STC (B767):	Completed Q1 2018

15 Appendix B – Boeing ADS-C Collection and Analysis Tool (ACAT)

Boeing participated in the evaluation by simulating an ATSU by way of the Boeing ADS-C Collection and Analysis Tool (ACAT). The ACAT system collects FANS 1/A over SwiftBroadband ASP data by establishing ADS-C contracts with aircraft in normal operation. Short interval periodic contracts and repetitive demand contracts support expeditious data collection. The ACAT system also measures the Actual Communications Technical Performance.

The ACAT collected data from four Hawaiian Airlines B767-300 aircraft, which were brought online between June and December 2015, as shown in Table 11. The performance data was collected and reported on at CWG 35-37. All four aircraft were operating on the RC IMS (ARINC) CSP network and transferred data over the Inmarsat-4 Americas and Asia-Pac satellites. The ACAT contracting was terminated in June 2017.

Table 11: ACAT Contract Regime (Brewer CWG-37)

Airframe	ACAT Contract
N581HA	Nov 2015 (5-min demand)
N582HA	Dec 2015 (5-min demand)
N588HA	Jul 2015 (2-min periodic)
N590HA	Dec 2015 (2-min periodic)

15.1 Actual Surveillance Performance

The logic in the ACAT system eliminates VHF transition latencies by delaying the ADS-C contracting until the aircraft is in a location where only the SwiftBroadband media is available for communication. This is achieved as follows:

When the ACAT receives an "OFF" OOOI event report, a 30 minute periodic contract request is sent following a 30 minute wait. If any of the first six 30-minute periodic contract reports are received via the SwiftBroadband, then a new request is sent for 2-minute periodic reports to replace the 30-minute periodic contract. If no reports are received over SwiftBroadband, the 30 minute periodic contract will terminate after 6 reports (or 3 hours). Furthermore, the 2-minute periodic contract is terminated when a non-SwiftBroadband path is reported or the ACAT system receives an "ON" OOOI event report. The ADS-C messages counts and aggregate totals over the three reporting periods are shown in Table 12.

Table 12: ACAT ADS-C Counts

Collection Period	N588HA	N590HA	N581HA	N582HA	Total ADS-C
July 14, 2015 - Feb 1, 2016*	32356	8731	6163	3595	51359
January to June 2016	27902	24952	10715	12719	76288
July to December 2016	22894	32548	12019	11405	78866
Totals	**83152**	**66231**	**28897**	**27719**	**206513**

*** ADS-C counts from Boeing presentation. Dates overlap with FAA reporting dates which explains the message count difference in the figure from CWG 35.*

Figure 31 to Figure 33 show the ASP reported by the FAA during PARC CWG 35-37 respectively. The performance over the year and a half period appears to remain consistent.

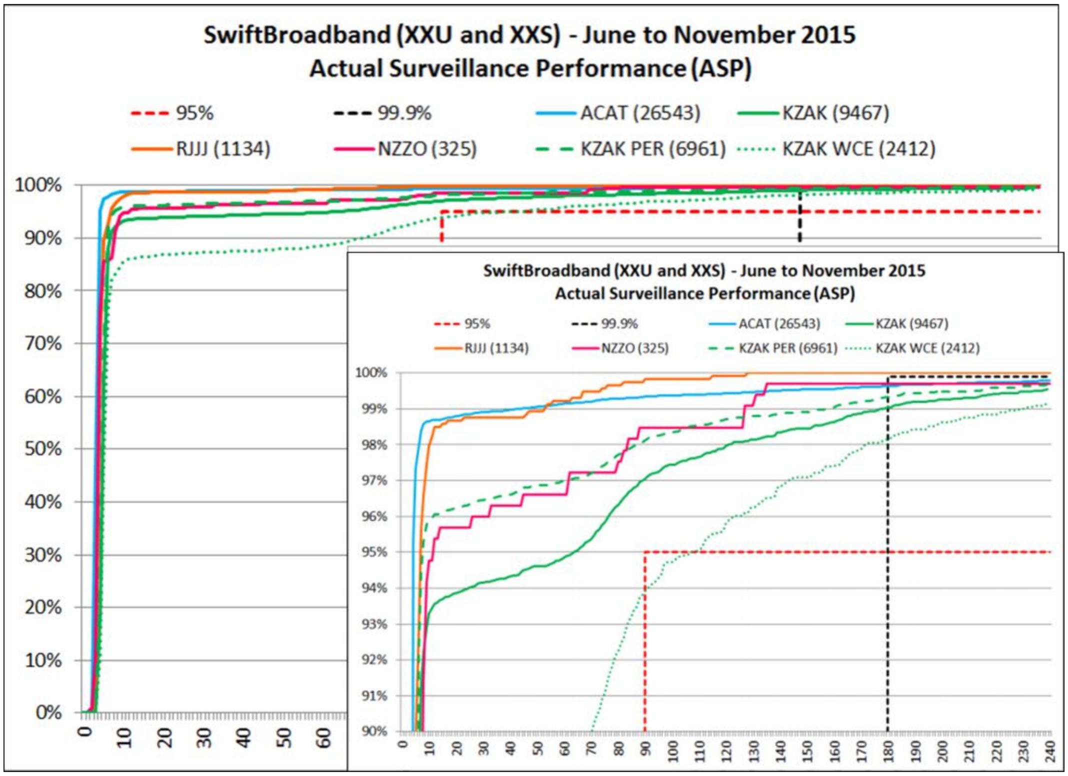

Figure 31: CWG 35 ASP - ACAT in light blue

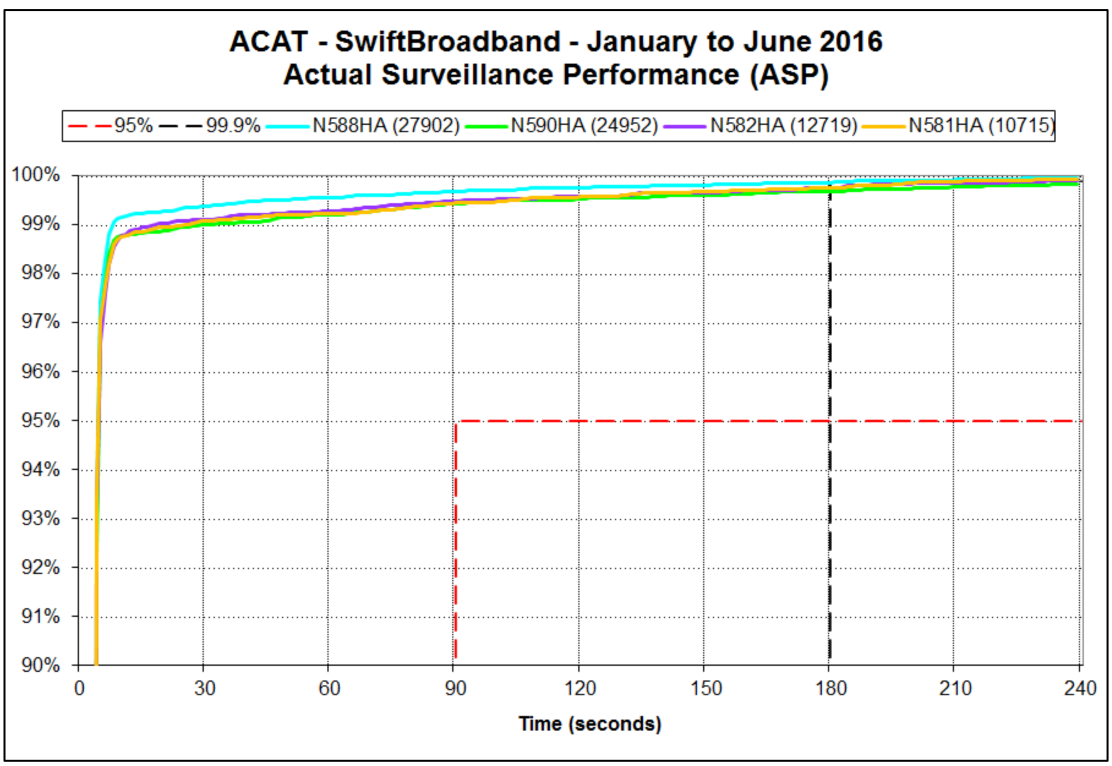

Figure 32: CWG 36 ACAT ASP by Aircraft

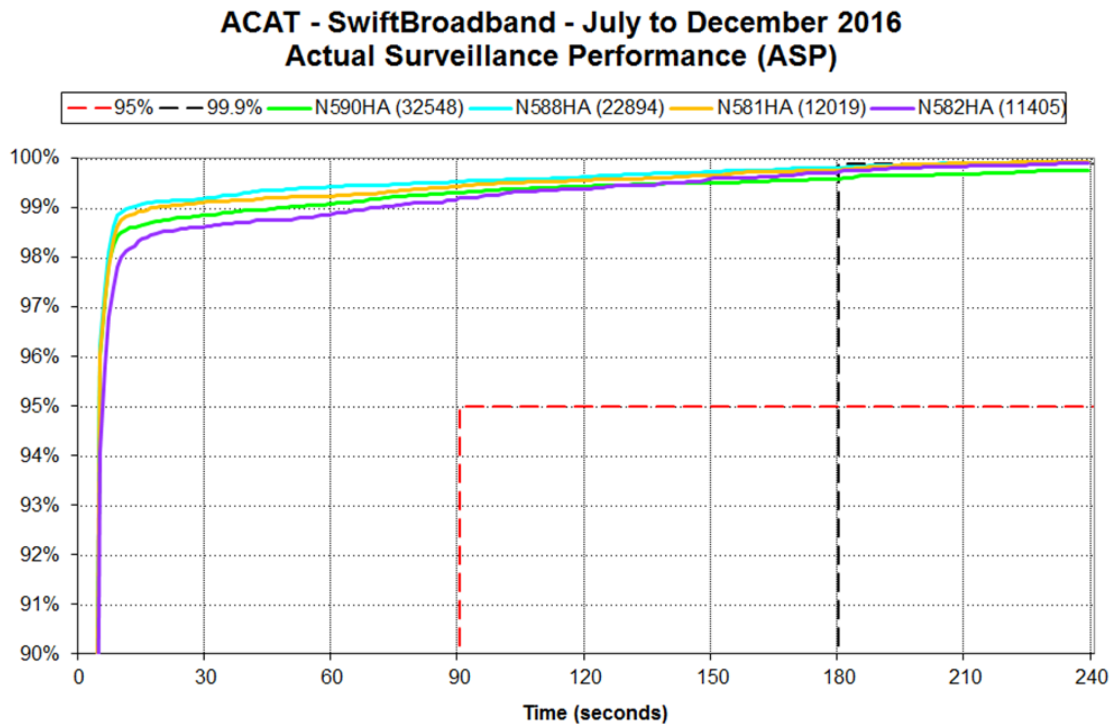

Figure 33: CWG 37 ACAT ASP by Aircraft

15.2 Actual Communication Technical Performance

The ACTP is the two-way uplink plus downlink time from the ATS provider (Boeing ACAT) sending an uplink, to the avionics receiving it, the avionics sending the downlink response, to the ATS provider receiving the response. The green areas shaded in Figure 34 visually display what is being measured by the ACAT system to emulate this ACTP. Note that the areas shaded in red require human interaction and are not being measured in this test.

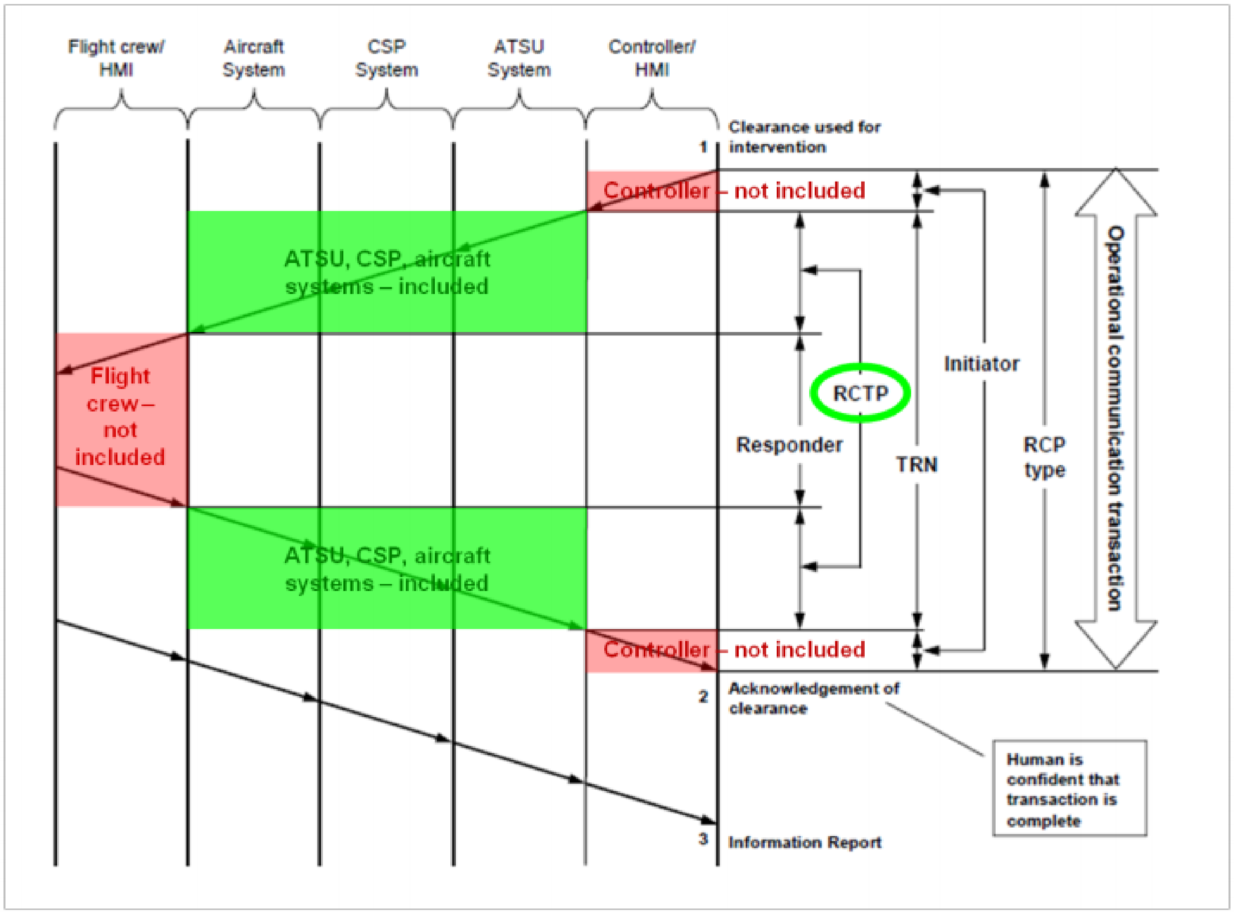

Figure 34: RCTP Emulated from ACAT (Matyas CWG 35)

15.3 Conclusions Derived From ACAT Data Analysis

Boeing's evaluation of FANS 1/A-over-SwiftBroadband performance shows that:

- RSP 180 ASP and RCP 240 RCTP 95% continuity requirement achieved
- RCP 240 RCTP 99.9% continuity requirement achieved
- Does not meet RSP 180 ASP 99.9% continuity
- RSP 180 ASP 99.0% continuity achieved

16 Appendix C – HAL Aircraft ADS-C Contract and Keep-alive Regimes

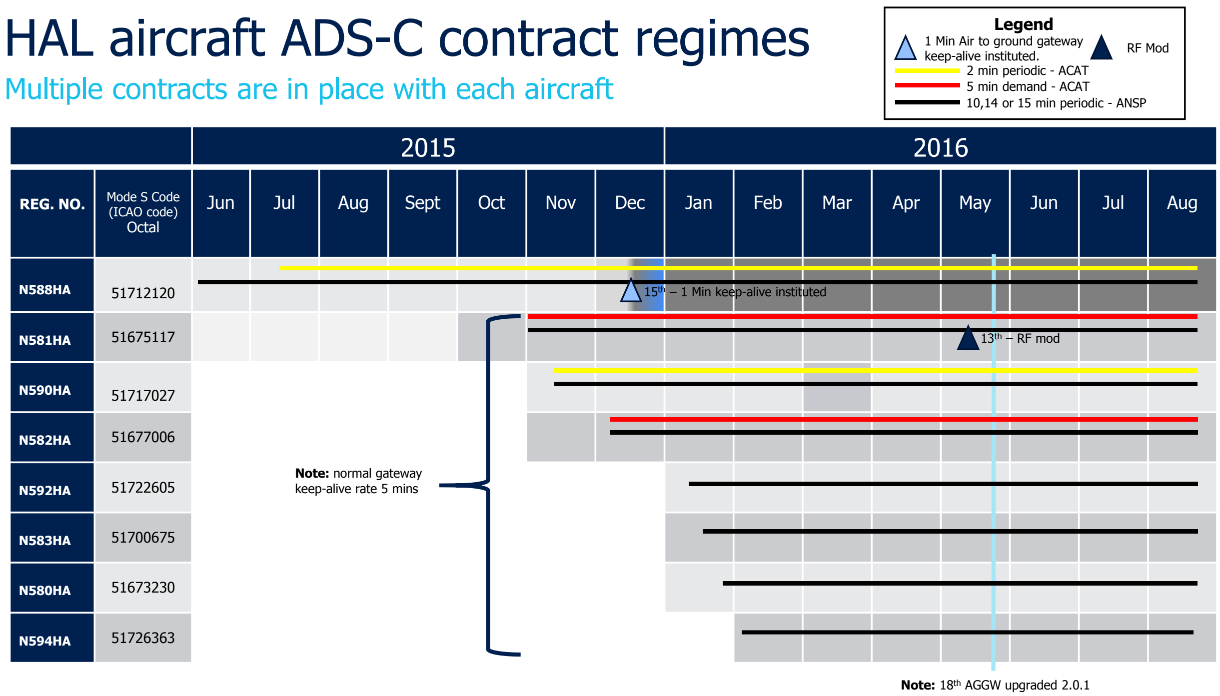

Figure 35: HAL Aircraft ADS-C Contract Regimes (1 of 2)

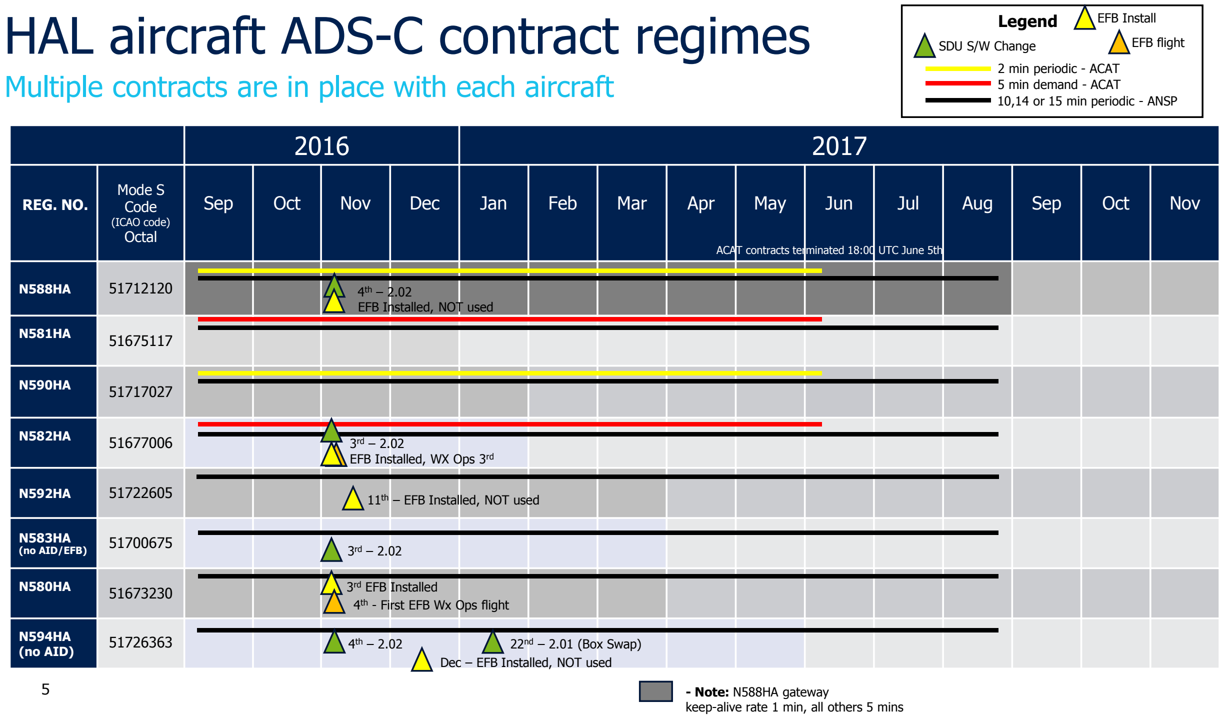

Figure 36: HAL Aircraft ADS-C Contract Regimes (2 of 2)

17 Appendix D – Avionics Downlink Retransmission and Media Transition Logic

Figure 37 below is a typical message sequence diagram showing avionics downlink retransmission logic for VHF (POA) and then satcom.

The VAT7 timer is random between 10 and 25 seconds (random to avoid synchronized collisions) and the VAC1 counter has a maximum value of 8. (This diagram has been used by Boeing (Mike Matyas) in the AEEC DLK as rationale for developing the new RAT1 timer to improve ACARS performance for FANS during transitions from VHF to SATCOM.)

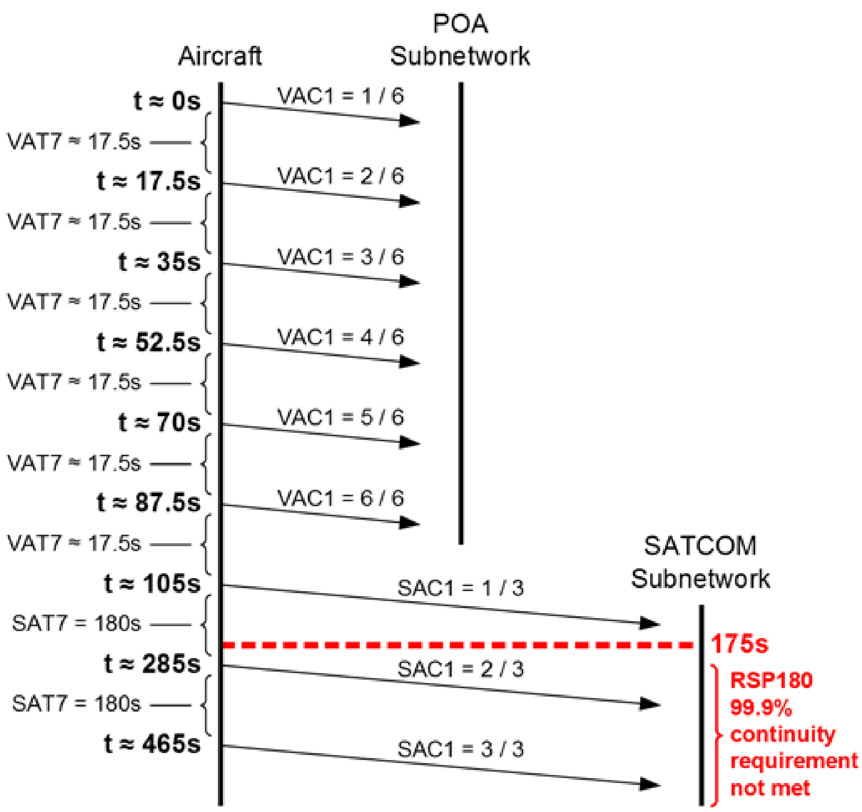

Figure 37: Message Sequence Diagram Showing Typical Avionics Downlink Retransmission Logic for VHF (POA) and then Satcom

--END -