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To	Systems Architecture and Interfaces (SAI) Subcommittee	**Date**	January 5, 2021
From	P. J. Prisaznuk AEEC Executive Secretary pjp@sae-itc.org tel 1-443-254-0528	**Reference**	21-002/SAI-099 lth

Subject

Draft Circulation
Draft 3 of ARINC Project Paper 678: *Guidance for Distributed Radio Architectures*

Summary

The SAI Subcommittee CNS Radio Architecture Working Group is assessing next generation radio architectures intended for new airplane type designs per APIM 18-003.

ARINC Project Paper 678 is organized as follows:

1.0 Introduction
2.0 Applicable Systems
3.0 System Requirements
4.0 Objectives and Goals
5.0 Requirements on Supporting Technologies
6.0 CNS Distributed Radio Architectures
7.0 Remote Radio Units (RRU)
8.0 Antennas
9.0 Summary of Conclusions and Recommendations
Attachment 1 – Glossary
Attachment 2 – Acronyms and Abbreviations

This draft is updated to include a new material shown as **blue bold** text.

Action

This document will be reviewed by the CNS Radio Working Group. Comments may be sent in writing before February 26, 2021 to Paul Prisaznuk, AEEC Executive Secretary and Program Director.

cc

AGCS, DLK

SAE ITC
An SAE International Affiliate
16701 Melford Blvd., Suite 120, Bowie, Maryland 20715 USA
http://www.aviation-ia.com/activities/aeec

SAE Industry Technologies Consortia (SAE ITC)
16701 Melford Blvd., Suite 120
Bowie, Maryland 20715 USA

DRAFT 3
OF
ARINC PROJECT PAPER 678
GUIDANCE FOR DISTRIBUTED RADIO ARCHITECTURES

This draft dated: January 5, 2021

ARINC PROJECT PAPER 678
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ATTACHMENTS

1.0 INTRODUCTION

1.1 Purpose of this Document

The purpose of this document is to evaluate Communication, Navigation, and Surveillance (CNS) Distributed Radio architectures and the feasibility of distributing the RF and systems processing sections to ensure the following:

- Reduce cost of equipment
- Reduce Size, Weight, and Power (SWaP)
- Ease of aircraft integration
- Growth capability built into the design
- Maintain or improve system availability, reliability, and maintainability

It provides a framework to determine whether it is feasible to develop ARINC Standards that support CNS Distributed Radio architectures.

1.2 CNS Distributed Radio Concept

The CNS Distributed Radio concept distributes the RF transmit/receive (TX/RX) sensor portion as well as much of the processing portion of the system to areas of the aircraft near the antenna. The remaining digital portion of the system can be hosted on a general purpose computing platform such as Integrated Modular Avionics (IMA).

1.3 History

Since the mid-1990s, the air transport industry has been investigating ways to exploit new technologies for the purpose of developing smaller, lighter, and more cost effective avionics radio systems. Beginning in 1996, AEEC published **ARINC Characteristic 755:** *Multi-Mode Receiver – Digital*, which integrated the functions for Instrument Landing System, Global Navigation Satellite System (GNSS), GNSS Landing System (GLS), and Microwave Landing System (MLS).

In 2005, AEEC published **ARINC Characteristic 768:** *Integrated Surveillance System*, which integrated Air Traffic Control (ATC) Transponder, Traffic-alert Collision Avoidance System (TCAS), Weather Radar, and Terrain Awareness and Warning System (TAWS) functions.

In 2018, the AEEC recommended the development of this CNS Distributed Radio Architecture Framework document to determine the feasibility of developing ARINC standards that would separate the RF transmit/receive (TX/RX) sensor portion of specific CNS systems and the processing portion of these systems, so that reductions in cost, size, weight, and power can be realized.

1.4 ARINC 678 Overview

This document is organized into eight sections.

Section 1.0 introduces the document and provides background information leading to its development.

1.0 INTRODUCTION

Section 2.0 presents a list of Communication, Navigation, and Surveillance (CNS) systems that are addressed within this document.

Section 3.0 provides key system requirements for each of the listed CNS systems.

Section 4.0 presents the key objectives and goals.

Section 5.0 describes the expected baseline supporting technologies that are required to support the CNS distributed radio architectures.

Section 6.0 defines the possible candidates of distributed radio architectures and addresses specific Remote Radio Units (RRUs) and antenna design considerations. This section describes the expected installation environment, as well as a number of design factors including form factor, connectors, interfaces, etc.

Section 7.0 addresses specific **Remote Radio Units (RRUs) design considerations.**

Section 8.0 addresses specific antenna design considerations.

Section 9.0 is a summary of conclusions and recommendations for CNS distributed radio architectures.

2.0 APPLICABLE SYSTEMS

2.1 Communication Systems

This section provides a functional overview of the Communication Systems that are addressed in this document.

2.1.1 High Frequency (HF) Communications

The High Frequency (HF) Communication (HF Comm) system permits voice, and data (if HF data radio is installed), communication over longer distances than line-of-sight communication systems. It allows communication with ground stations or with other airplanes during long over-water flights. The HF Comm system operates in the HF aeronautical frequency band of 2 MHz to 30 MHz. The number of installed HF Comm systems depends on what route is being flown and what other long range communication systems (e.g., Satcom) are onboard.

2.1.2 Very High Frequency (VHF) Communications

The Very High Frequency (VHF) Communication (VHF Comm) system provides voice and data communication over line-of-sight distances. It allows communication between airplanes or between ground stations and airplanes. The VHF Communication system operates in the VHF aeronautical frequency band of 118 MHz to 137 MHz. There are typically two or three VHF Communication systems onboard the airplane [typically two for short range airplanes and three for long range airplanes].

2.1.3 Inmarsat Satellite Communications

The Inmarsat satellite communications (Inmarsat SATCOM) system uses Inmarsat satellites and ground station networks to transmit and receive data and voice messages. Inmarsat SATCOM supplies higher quality data and voice message signals for passengers and crew, over longer distances than VHF/HF communication systems. The Inmarsat satellite network covers the entire earth between -82° to +82° latitude. The system operates in the aeronautical receive frequency band of 1518 MHz to 1559 MHz and transmit band of 1626.50 MHz to 1675 MHz. The number of installed Inmarsat SATCOM systems depends on what route is being flown and what other long range communication systems are onboard (e.g., HF Comm and/or Iridium SATCOM).

2.1.4 Iridium Satellite Communications

The Iridium satellite communications (Iridium Satcom) system uses Iridium satellites and ground station networks to transmit and receive data and voice messages. Iridium Satcom supplies higher quality data and voice message signals for passengers and crew, over longer distances than VHF/HF communication systems. The Iridium satellite network covers the entire earth, including both poles. The system operates in the aeronautical frequency band of 1616.00 MHz to 1626.50 MHz. The number of installed Iridium Satcom systems depends on what route is being flown and what other long range communication systems are onboard (e.g., HF Comm and/or Inmarsat Satcom).

2.1.5 Aeronautical Mobile Airport Communication System (AeroMACS)

Aeronautical Mobile Airport Communication System (AeroMACS) is a wireless broadband technology that supports data communications and information sharing on the airport surface for both fixed and mobile applications. Based on the WiMAX standard (IEEE 802.16e), AeroMACS operates in the protected and licensed aeronautical frequency band of 5091 MHz to 5150 MHz.

2.1.6 L-band Digital Aeronautical Communication System (LDACS)

L-band Digital Aeronautical Communication System (LDACS) is an air-to-ground communications standard that is currently in development. ICAO SARPs are being developed. The LDACS deployment is still being defined.

LDACS is expected to use the 960 MHz to 1164 MHz frequency range. LDACS deployment will also need to consider the potential interference of LDACS on existing L-band systems (e.g., Distance Measuring Equipment (DME)).

2.2 Navigation Systems

2.2.1 Instrument Landing System (ILS) (Localizer/Glideslope)

The Instrument Landing System (ILS) function provides lateral (localizer) and vertical (glideslope) guidance to the runway on approach. The system uses signals from a glideslope ground station and a localizer ground station. The localizer station transmits signals to give a lateral path to keep the airplane centered on the runway. The glideslope station transmits signals to give the airplane a descent path to the touchdown point on the runway. The localizer and glideslope deviations are displayed to the flight crew on the Primary Flight Displays (PFDs), and are used by the Autopilot and TAWS systems. The ILS system provides station 1020 Hz Morse Code audio station identification signals carried by the ILS Localizer signal. The localizer station frequencies are from 108 MHz to 112 MHz. The paired glideslope station frequencies are from 328.6 MHz to 335.4 MHz. There are typically two ILS systems installed on the airplane [some aircraft models have three ILS systems installed to support Category 3B Autoland systems].

2.2.2 VHF Omni-directional Range (VOR)

The VHF Omni-directional Range (VOR) system is a navigation aid that provides magnetic bearing data to a VOR ground station. The VOR system receives the ground station signal from the tuned VOR station and calculates magnetic bearing data. The data goes to various systems, including the flight deck Navigation Displays and instruments for display of the VOR bearing, and to the Flight Management System (FMS) for use in calculating the airplane’s position. The station's audio identifier is typically a three-letter string in Morse code. The VOR operates in the frequency range of 108.00 MHz to 117.95 MHz. Single or dual VOR systems may be installed on the airplane.

2.2.3 Marker Beacon (MB)

The Marker Beacon (MB) system provides visual and aural indications when the airplane flies over ground-based marker beacon transmitters. It is used to determine the airplane's position along an established route to a destination (e.g., a runway). The MB receives only 75 MHz signals with modulations corresponding to the following MB audio outputs:

- Outer Marker (OM) is 400 Hz, continuous dashes (- - - -)
- Middle Marker (MM) is 1300 Hz, alternate dots and dashes (-.-.-.-.-)
- Inner Marker (IM) is 3000 Hz, continuous dots (......)
- Backcourse marker is 3000 Hz, continuous paired dots (.. .. .. ..)
- Airways marker is 3000 Hz with the Morse code identifier for that station.

There is typically just one Marker Beacon system installed on the airplane.

2.2.4 Low Range Radio Altimeter (LRRA)

The Low Range Radio Altimeter (LRRA) system measures the distance from the airplane to the ground and outputs radio altitude data. The LRRA system has a range of -20 to 5000 feet. The radio altitude is typically displayed on the pilot's Primary Flight Display (PFD). The flight crew and other airplane systems (e.g., Autopilot, TCAS, Predictive Windshear, etc.) use radio altitude during approach and landing. It is also used as an input source by the Terrain Awareness and Warning System (TAWS) to prevent collisions into terrain. There are typically two LRRA systems installed on the airplane [some aircraft types have three LRRA systems installed to support Category 3B Autoland systems].

2.2.5 Global Navigation Satellite System (GNSS)

The Global Navigation Satellite System (GNSS) receives navigation satellites' signals to calculate accurate airplane position, altitude, velocity, and time data which can be used by a number of airplane systems (e.g., FMS, TAWS, ADS-B, etc.). To-date, the most often used navigation satellite system is the United States' Global Positioning System (GPS) signal on L1 (1575.42 MHz +/-10 MHz) for civilian use. GPS satellites already transmit, or plan to transmit, signals for civilian use on the L5 (1176.45 MHz) frequency. There are other global navigation satellite constellations that are already in-work or planned, including: Europe's Galileo and China's Beidou, both of which have signals that also operate on 1575.42 MHz and 1176.45 MHz. GNSS services may also be provided by Russia's GLONASS constellation that transmit on the L1 (1602 MHz) and L2 (1246 MHz) frequencies. In addition, Satellite Based Augmentation Systems (SBAS) operate on the L1 frequency signal and will provide additional data on the L5 frequency signal to improve GNSS performance and ensure data integrity.

Typically, there are two GNSS systems installed on the airplane. Three GNSS systems may be installed to provide GNSS Landing System (GLS) outputs to support some airplane models' Autoland systems.

2.2.6 GNSS Landing System (GLS)/VHF Data Broadcast (VDB)

The GNSS Landing System (GLS) function provides lateral and vertical guidance to the runway on approach. GLS receives both GNSS differential correction data along with approach path data from a Ground Based Augmentation System (GBAS) ground station via the VHF Data Broadcast (VDB) receiver. The VDB receiver operates in the frequency range of 108.00 MHz to 117.95 MHz. The airplane's VDB antenna can be either the same antenna that is used for the VOR function or the same antenna that is used for the ILS localizer function, or both, since they operate in the same frequency range and have the same horizontal polarization. Typically, there are two GLS systems installed on the airplane. Three GLS systems may be installed to provide triplex GLS deviation outputs to support some airplane models' Autoland systems.

2.2.7 Distance Measuring Equipment (DME)

The Distance Measuring Equipment (DME) function provides slant range (line-of-sight) distance from an airplane to a selected DME ground station [DME ground stations are typically collocated with VHF Omni-directional Range (VOR) or Instrument Landing System (ILS) ground stations]. The DME distance can be presented to the flight crew on a flight deck display or instrument. DME frequency scanning mode can be used to provide multiple (up to 5 stations) distances and frequency data to the Flight Management System (FMS) for navigation purposes. The DME system also provides station audio information (1350 Hz Morse code 3-letter identity) to the flight crew. DME operates in the L-Band frequency range: 1025 MHz to 1150 MHz (transmit) and 962 MHz to 1215 MHz (receive). The DME ground station replies on a frequency that is either 63 MHz lower or 63 MHz higher than the interrogated frequency. There are typically two DME systems installed on the airplane.

2.3 Surveillance Systems

2.3.1 Air Traffic Control (ATC) Transponder

The Air Traffic Control (ATC) Transponder function replies to 1030 MHz interrogations from ground-based Secondary Surveillance Radars (SSRs) and from airborne TCAS systems. Mode A replies provide the aircraft's 4096 (aka squawk) code entered by the flight crew. Mode C replies provide the airplane's uncorrected barometric altitude. Mode S replies provide various aircraft data, including flight identification, heading, track, ground speed, Traffic Collision Avoidance System TCAS status, and other data. There are two ATC Transponder systems installed, but only one is active at any given time (the other is a hot spare).

2.3.2 Automatic Dependent Surveillance – Broadcast Out (ADS-B Out)

The Automatic Dependent Surveillance – Broadcast Out (ADS-B Out) function automatically transmits position, velocity, altitude, aircraft identification, and other pertinent aircraft systems data which can be received and used by ground-based ATC receivers (for separation services) and by other aircraft that have ADS-B In receivers (for use by ADS-B In applications). ADS-B Out transmits data on 1090 MHz signals both on the ground and in the air. The ADS-B Out function is typically collocated with the ATC Transponder function which transmits interrogation replies on 1090 MHz. There are two ADS-B Out systems installed, but only one is active at any given time (the other is a hot spare).

2.3.3 Traffic-Alert Collision Avoidance System (TCAS) and Airborne Collision Avoidance System (ACAS-X)

The Traffic-Alert and Collision Avoidance System (TCAS) helps the flight crew maintain safe separation from other ATC transponder equipped airplanes. TCAS is an airborne system that operates independently of the ground-based ATC system. TCAS sends 1030 MHz interrogation signals to nearby ATC transponder equipped airplanes which respond to these interrogations via 1090 MHz replies. TCAS provides a traffic display to the flight crew as well as Traffic Advisories (TAs) to alert the crew of closing aircraft. In addition, TCAS provides Resolution Advisories (RAs) that provide vertical guidance (e.g., climb or descend) audio and visual commands to the crew when a potential collision is determined. There are typically one or two TCAS systems onboard, but only one TCAS is operational at any given time (the other system is a hot spare).

2.3.4 Automatic Dependent Surveillance – Broadcast In (ADS-B In)

The Automatic Dependent Surveillance – Broadcast In (ADS-B In) function receives 1090 MHz ADS-B signals from other aircraft. These signals can be used in various ADS-B In applications including, but not limited to:

- Airborne Situational Awareness/Cockpit Display of Traffic Information (AIRB/CDTI)
- In Trail Procedure (ITP)
- Surface Situational Awareness (SURF)
- CDTI Assisted Visual Separation (CAVS)
- **Flight-deck Interval Management (FIM)**

The ADS-B In receive function is typically collocated with the TCAS function, since both require the reception of 1090 MHz signals. There are typically one or two ADS-B In systems onboard, but only one ADS-B In receiver is operational at any given time (the other is a hot spare).

2.4 Military Systems

Communication, Navigation, and Surveillance (CNS) systems that specifically support military-specific functions (e.g., Tactical Air Navigation (TACAN) and Interrogate Friend or Foe (IFF)) are not addressed within this document. However, note that some military aircraft are derived from commercial aircraft platforms. Therefore, when designing the system integration of the distributed radio architecture, consideration should be given where the commercial CNS functions may integrate with the military-specific CNS functions. For example, when designing the RF suppression network between commercial L-band systems (e.g., DME, ATC Transponder, and TCAS/ACAS), consideration should also be given for RF suppression interfaces to TACAN and IFF systems.

3.0 SYSTEM REQUIREMENTS

3.1 Safety Requirements

The safety requirements for the applicable Communication, Navigation, and Surveillance (CNS) systems identified in this report are documented as failure classifications based on a Functional Hazard Assessment (FHA) of each system. The failure classifications are further divided between loss of function hazards and misleading/erroneous data hazards. The different classifications of failure conditions are documented in FAA/JAA Advisory Circular AC/AMJ 25.1309 (Arsenal version, dated 6/10/2002) as follows (in increasing order of severity):

1. No Safety Effect: Failure Conditions that would have no effect on safety; for example, Failure Conditions that would not affect the operational capability of the airplane or increase crew workload.
2. Minor: Failure Conditions which would not significantly reduce airplane safety, and which involve crew actions that are well within their capabilities. Minor Failure Conditions may include, for example, a slight reduction in safety margins or functional capabilities, a slight increase in crew workload, such as routine flight plan changes, or some physical discomfort to passengers or cabin crew.
3. Major: Failure Conditions which would reduce the capability of the airplane or the ability of the crew to cope with adverse operating conditions to the extent that there would be, for example, a significant reduction in safety margins or functional capabilities, a significant increase in crew workload or in conditions impairing crew efficiency, or discomfort to the flight crew, or physical distress to passengers or cabin crew, possibly including injuries
4. Hazardous: Failure Conditions which would reduce the capability of the airplane or the ability of the crew to cope with adverse operating conditions to the extent that there would be:
    a. A large reduction in safety margins or functional capabilities
    b. Physical distress or excessive workload such that the flight crew cannot be relied upon to perform their tasks accurately or completely; or
    c. Serious of fatal injury to a relatively small number of the occupants other than the flight crew
5. Catastrophic: Failure conditions which would result in multiple fatalities, usually with the loss of the airplane.

In addition, each failure classification has a System Design Assurance Level (DAL) requirement associated with that particular classification. Table 3-1 below identifies the System DAL level based on FAR Part 25.1309 for each failure classification.

Table 3-1 – Design Assurance Levels (DALs)

Failure Classification	Design Assurance Level (DAL)
Catastrophic	A
Hazardous	B
Major	C
Minor	D
No Effect	E

3.0 SYSTEM REQUIREMENTS

The failure classifications, as well as the required DAL, for the applicable CNS systems identified in this report are listed in Table 3-2. These failure classifications are defined at the aircraft system level and not at the Line Replaceable Unit (LRU) level.

Table 3-2 – CNS Failure Classifications and Design Assurance Levels (DALs)

		Failure Classification			
CNS	**System**	**Loss of Function**	**Undetected Erroneous Data**	**Radio DAL**	**Notes**
COMMUNICATION					
C	HF Comm	Minor	Minor	C	Applies to Voice and Data modes. Even though the most stringent failure classification is Minor, the HF radio DAL has traditionally been developed & certified to a DAL=C.
C	VHF Comm	Major	Major	C	Applies to Voice and Data modes
C	Inmarsat SATCOM Safety Applications	Minor	Major	D	Applies to Voice and Data modes. End-to-end data integrity is checked by higher-level application (e.g., FMS)
C	Iridium SATCOM Safety Applications	Minor	Major	D	Applies to Voice and Data modes. End-to-end data integrity is checked by higher-level application (e.g., FMS)
C	AeroMACS	Minor	Major	D	End-to-end data integrity is checked by higher-level application (e.g., FMS)
C	LDACS	Major	Major	C	Applies to Voice and Data modes
NAVIGATION					
N	ILS Loc/Glideslope	Major Hazardous	Catastrophic	A	Loss of function is Major. Loss of all ILS deviation data during an autoland is a Hazardous effect. Catastrophic classification for erroneous data is driven by the CAT III autoland function.
N	VOR	Minor	Major	C	
N	MB	Minor	Major	C	
N	LRRA	Hazardous	Catastrophic	A	Loss of all radio altitude data during an autoland is a Hazardous effect. Catastrophic classification for erroneous data is driven by the CAT III autoland function.
N	GNSS	Major	Hazardous	A	Hazardous classification for erroneous data is driven by the Navigation function. DAL A is to address the safety objectives for RNP and to address GLS CAT III safety requirements.
N	GLS	Major Hazardous	Catastrophic	A	Loss of function is Major. Loss of all GLS deviation data during an autoland is a Hazardous effect. Catastrophic classification for erroneous data is driven by the CAT III autoland function. CAT I and CAT II is DAL B.
N	DME	Minor	Major	C	
SURVEILLANCE					
S	ATC Transponder	Minor	Major	B	

		Failure Classification			
CNS	**System**	**Loss of Function**	**Undetected Erroneous Data**	**Radio DAL**	**Notes**
S	ADS-B Out	Minor	Major	C	When developed as standalone function
S	TCAS/ACAS-X	Minor	Major	B	Software is required to meet DAL B per AC 20-151c, §2.3.8.4
S	ADS-B In	Minor	Major	C	Most stringent FHA class of current ADS-B In applications is Major per AC 20-172B

In addition, the failure classifications for combined failures of CNS functions need to be addressed. The failure classifications for combined failures of the CNS systems identified in this report are listed in Table 3-3.

Table 3-3 – CNS Combined Failure Classifications

Note: Table to be Validated

CNS	System Failures	Failure Classification	Notes
C	Loss of all Radio Communications	Major	Applies to loss of voice and data
C	Undetected Erroneous Radio Communications	Major	Applies to data only
N	Loss of all Radio Navigation	Major to Hazardous	Depends on where and which phase of flight the loss of function occurs
N	Undetected Erroneous of Radio Navigation	Hazardous to Catastrophic	Catastrophic during CAT III approach
S	Loss of all Surveillance Radios	Major	
S	Undetected Erroneous of Surveillance Radios	Hazardous	
C+N	Combined failure (loss or undetected erroneous) of radio Communications and radio Navigation	Catastrophic	
C+S	Combined failure (loss or undetected erroneous) of radio Communications and Surveillance radios	Hazardous to Catastrophic	
N+S	Combined failure (loss or undetected erroneous) of radio Navigation and Surveillance radios	Hazardous to Catastrophic	
C+N+S	Combined loss or undetected erroneous failure of radio Communications + radio Navigation + Surveillance radios	Catastrophic	(from C+N)

3.2 Minimum Equipment List (MEL)/Dispatch Requirements

The Minimum Equipment List (MEL) identifies how long system/component repairs can be deferred. FAA MMEL Policy Letter 25, “MMEL and MEL Definitions” defines the following repair categories for all MELs approved under 14CFR Parts 91K, 121, 125, 129, 135, and 142:

Category A: Items in this category shall be repaired within the time interval specified in the Remarks column of the operator's approved MEL. For time intervals specified in “calendar days” or "flight days,” the day the malfunction was recorded in the aircraft maintenance record/logbook is excluded. For all other time intervals (flights, flight legs, cycles, hours, etc.), repair tracking begins at the point when the malfunction is deferred in accordance with the operator’s approved MEL.

Category B. Items in this category shall be repaired within three (3) consecutive calendar days (72 hours), excluding the day the malfunction was recorded in the aircraft maintenance record/logbook. For example, if it were recorded at 10 a.m. on January 26th, the three day interval would begin at midnight the 26th and end at midnight the 29th.

Category C. Items in this category shall be repaired within ten (10) consecutive calendar days (240 hours), excluding the day the malfunction was recorded in the aircraft maintenance record/logbook. For example, if it were recorded at 10 a.m. on January 26th, the 10 day interval would begin at midnight the 26th and end at midnight February 5th.

Category D. Items in this category shall be repaired within one hundred and twenty (120) consecutive calendar days (2880 hours), excluding the day the malfunction was recorded in the aircraft maintenance log and/or record.

The MEL categories for the applicable CNS systems identified in this report are listed in Table 3-4. Note that there are inter-relationships between equipment availabilities in order to be able to dispatch. For instance, dispatch is allowed when no GNSS systems are available if one DME is operative. This is an important consideration when considering integration of various radios on shared resources.

Table 3-4 – CNS Minimum Equipment List (MEL)

CNS	System	MEL Category	Number Installed	Number Required for Dispatch	Remarks or Exceptions
C	HF Comm - Voice	D	--	--	Any in excess of those required may be inoperative.
		C	--	1	May be inoperative while conducting operations that require two LRCS provided: a) Aircraft SATVOICE system operates normally, b) SATVOICE services are available as a LRCS over the intended route of flight, c) ICAO flight plan is updated to notify ATC of the communication status of aircraft, and

3.0 SYSTEM REQUIREMENTS

CNS	System	MEL Category	Number Installed	Number Required for Dispatch	Remarks or Exceptions
					d) Alternate procedures are established and used.
C	HF Comm – Data Link	C	1	0	May be inoperative provided alternate procedures are established and used.
		D	1	0	May be inoperative provided procedures do not require its use.
C	VHF Comm - Voice	D	3/2	-	Any in excess of those required, and not powered by a standby bus, may be inoperative.
C	VHF Comm – Data Link	C	1	0	May be inoperative provided alternate procedures are established and used.
		D	1	0	May be inoperative provided procedures do not require its use.
C	Inmarsat SATCOM	D	2	1	
		C	-	0	May be inoperative provided procedures do not require its use.
C	Iridium SATCOM	D	2	1	
		C	-	0	May be inoperative provided procedures do not require its use.
C	AeroMACS	C	-	0	May be inoperative provided procedures do not require its use.
C	LDACS	C	-	0	May be inoperative provided procedures do not require its use.
N	ILS Localizer/ Glideslope	C	3/2	0	Any in excess of those required may be inoperative provided approach minimums do not require their use.
N	VOR	C	2	0	Any in excess of those required may be inoperative.
N	MB	C	1	0	May be inoperative provided approach minimums do not require its use.
N	LRRA	C	3/2	2/1	One may be inoperative provided approach minimums or operating procedures do not require its use.
N	GNSS	C	2	0	May be inoperative provided alternate procedures are established and used.
		C	2	1	One may be inoperative provided operations do not require its use.
N	GLS	D	3/2	0	May be inoperative provided approach minimums do not require its use.
N	DME	D	2	0	Any in excess of those required may be inoperative.
S	ATC Transponder	D	2	1	Any in excess of those required may be inoperative.
S	ADS-B Out	D	2	0	May be inoperative provided procedures do not require its use.
S	TCAS/ACAS-X	C	2	1	
		B	2/1	0	May be inoperative provided enroute or approach procedures do not require its use.

CNS	System	MEL Category	Number Installed	Number Required for Dispatch	Remarks or Exceptions
S	ADS-B In	D	--	0	May be inoperative provided enroute operations do not require its use.

3.3 Regulatory Requirements

The regulations governing CNS systems are predominately operational regulations (e.g., 14CFR Part 121). The regulations along with applicable FAA Technical Standard Orders (TSOs)/European TSOs, FAA Advisory Circulars, and EASA Acceptable Means of Compliance (AMCs) for the applicable CNS systems identified in this report are listed in Table 3-5.

Table 3-5 – CNS Systems Regulatory Material

The latest versions of the following documents apply.

CNS	System	14CFR Regulation(s)	TSO/ETSO	AC/AMC	Notes
C	HF Comm	91.511, 121.99, 121.349, 121.351	HFDL: C158 Voice: C170	N/A	
C	VHF Comm	91.511, 121.99, 121.347, 121.349	C128() VDL: C160() Voice: C169()	AC 20-67()	
C	Inmarsat SATCOM	121.99, 121.351	C159()	AC 20-150()	
C	Iridium SATCOM	121.99, 121.351	C159()	AC 20-150()	
C	AeroMACS	N/A	C207()		
C	LDACS	TBD	TBD	TBD	Regulatory requirements have not yet been released.
N	ILS Loc/Glideslope	121.349	Loc: C36() G/S: C34()	AC 120-28, AC 120-29 **AC 120-118** **AC 20-191 (draft)** **NPA 2018-06 (draft)**	
N	VOR	121.349	C40()	AC 20-138	
N	MB	121.349	C35()	N/A	
N	LRRA	121.354	C87()	**AC 120-118**	
N	GNSS	121.351	L1 freq: C145(), C146()	AC 90-107 AC **20-138**	
N	GLS	N/A	GBAS: C161() VDB: C162()	**AC 120-118** **AC 20-191 (draft)** **NPA 2018-06 (draft)**	
N	DME	121.349	C66()	AC 120-38	

CNS	System	14CFR Regulation(s)	TSO/ETSO	AC/AMC	Notes
S	ATC Transponder	91.215, 121.356	C112	AC 20-151()	
S	ADS-B Out	91.225, 91.227	C166()	AC 20-165()	
S	TCAS/ACAS-X	121.356	C119() C207()	AC 20-151()	AC listed is for TCAS. The AC for ACAS-X$_A$ has not yet been released.
S	ADS-B In	N/A	Rcvr: C166() Apps: C195()	AC 20-172()	

3.4 Radio Frequency (RF) Signal Characteristics

The radio signal and antenna characteristics for the CNS systems being evaluated are included in Tables 3-6 below.

Table 3-6 – CNS Antenna Characteristics

CNS	System	Antenna Location	Antenna Type	Antenna Polarization
C	HF Comm	Top	Omni	Vertical
C	VHF Comm	Top (1 or 2) Bot (1 or 2)	Omni	Vertical
C	Inmarsat SATCOM	Top	HGA: Directional-Steerable	Right-hand Circular
C	Inmarsat SATCOM	Top	Enhanced LGA	
C	Iridium SATCOM	Top	ALGA: Omni	Right-hand Circular
C	Iridium SATCOM	Top	LGA	
C	AeroMACS	Top	Omni	Vertical
C	LDACS	Top (1) or Bot (1)	Omni	Vertical
N	ILS Loc/Glideslope	AC Nose	Directional, FWD Looking	Horizontal
N	VOR	Top	Omni	Horizontal
N	MB	Bot	Omni	Horizontal
N	LRRA	Bot	Directional	Linear
N	GNSS	Top	Omni	Circular
N	VDB	Top	Omni	Horizontal
N	DME	Bot	Omni	Vertical
S	ADS-B Out ATC Transponder	Top (1) Bot (1)	Omni	Vertical

CNS	System	Antenna Location	Antenna Type	Antenna Polarization
S	ADS-B In TCAS/ACAS-X	Top (1) Bot (1)	Top: Directional Bot: Omni/Directional	Vertical

Table 3-7 – CNS Receiver Characteristics (In Work)

CNS	System	Rx Freq (MHz)	Rx Sensitivity (dBm)	Rx Modulation
C	HF Comm	2.8-24	-93 to -100	AM-SSB
C	VHF Comm	118-137	-93 (DO-186/ ED-23) -100 (A716)	Voice: AM ACARS: AM-MSK
C	Inmarsat SATCOM	1525.0-1559.0		
C	Iridium SATCOM	1616.0-1626.5		
C	AeroMACS	5091-5150		
C	LDACS	960-1164	-104	FDD using OFDM
N	ILS Loc/Glideslope	LOC: 108-112 GS: 328-336	LOC: -86 GS: -76	AM
N	VOR	108-117.95	-92	AM/FM
N	MB	75	-60	AM
N	LRRA	4200-4400		
N	GNSS	1575.42 L1 L5	-134 Varies by constellation	CDMA (for GPS, SBAS, GALILEO, and BEIDOU). FDMA (for GLONASS)
N	VDB	108-118	-87	D8PSK
N	DME	962-1213	-83	PPM Pulse Pair
S	ADS-B Out ATC Transponder	1030	-74	PPM/DPSK
S	ADS-B In TCAS/ACAS-X	1090	-84	PPM/PAM

Table 3-8 – CNS Transmitter Characteristics (In Work)

CNS	System	Tx Freq (MHz)	Tx Power (dBm)	Tx Modulation
C	HF Comm	2.8-24	56 (400W)	AM-SSB
C	VHF Comm	118-137	44 (25W)	Voice: AM ACARS: AM-MSK
C	Inmarsat SATCOM	1626.5-1660.5	42 (EIRP)	
C	Iridium SATCOM	1616.0-1626.5	42 (EIRP)	

CNS	System	Tx Freq (MHz)	Tx Power (dBm)	Tx Modulation
C	AeroMACS	5091-5150		
C	LDACS	960-1164	42 per sub-carrier	FDD using OFDM
N	ILS Loc/Glideslope	n/a	n/a	n/a
N	VOR	n/a	n/a	n/a
N	MB	n/a	n/a	n/a
N	LRRA	4200-4400		
N	GNSS	n/a	n/a	n/a
N	VDB	n/a		
N	DME	960-1214	52 (ERP)	PPM, Pulse Pair
S	ADS-B Out ATC Transponder	1090	53 (ERP)	PPM, PAM
S	TCAS/ACAS-X	1030	52 (ERP)	PPM, PAM, DPSK
S	ADS-B In	n/a	n/a	n/a

3.5 System Design Constraints

System Performance, installation, and airworthiness approval considerations should be the initial objectives that may help to formulate System design constraints. Communication, navigation and surveillance radios, implemented using a distributed architecture, must be compliant with applicable Minimum Operational Performance Standard (MOPS) as specified in (E)TSO requirements. It is recommended that TSO performances applicable to a particular communications, navigation, or surveillance radio system be provided by a single entity to avoid performance, integration and airworthiness approval challenges.

COMMENTARY

> Multiple parties may provide components used in a single CNS radio function. However, this has the potential to increase the development cost and acquisition cost of the radio system when compared with the equivalent current federated radio system.

Each avionics radio system consists of both TSO and aircraft-specific (non-TSO) functionality. The aircraft-specific functionality may include the maintenance system interface, data loading system interface, analog or digital audio system interface, data link system interface, etc. To further reduce integration and testing costs, the same supplier/entity should supply both the Remote Radio Unit that hosts the TSO functionality and the aircraft specific software that may be hosted in a general-purpose computing platform that may not necessarily be provided by the same supplier. The physical interface between the Remote Radio Unit (RRU) and the general-purpose computing platform should be standardized.

The interface protocol between aircraft-specific applications and supplier-specific radio functions is expected to be defined by the airframe manufacturer and may be specific for that airframe type. To ensure seamless and cost efficient radio integration, each radio system supplier should control the data exchange between the functions hosted on the Remote Radio Unit and those hosted on the general-purpose computing platform – i.e., interface protocols may be unique to the radio system supplier.

Each distributed radio system consists of a Remote Radio Unit, interface communication lines, and software hosted on a general-purpose **computing platform** with an ARINC 653 operating system. The distribution of the radio system TSO and aircraft-specific (Non-TSO) functionality between the Remote Radio Unit and the software hosted on the general-purpose **computing platform** has been described above. Besides those design constraints, the installation constraints, including maximum weight, form-fit (volume), and heat dissipation for each radio system specific Remote Radio Unit should be standardized. To minimize development and acquisition costs, all airframe manufacturers are expected to use the same physical layer and connectors for the interface communication lines between each specific Remote Radio Unit, antennas, and the general-purpose **computing platform**.

In addition, it is recommended that audio signals not be processed through the computing platform as it will introduce significant latencies. The audio signals should be managed directly between the Audio Management system and the Remote Radio Unit(s).

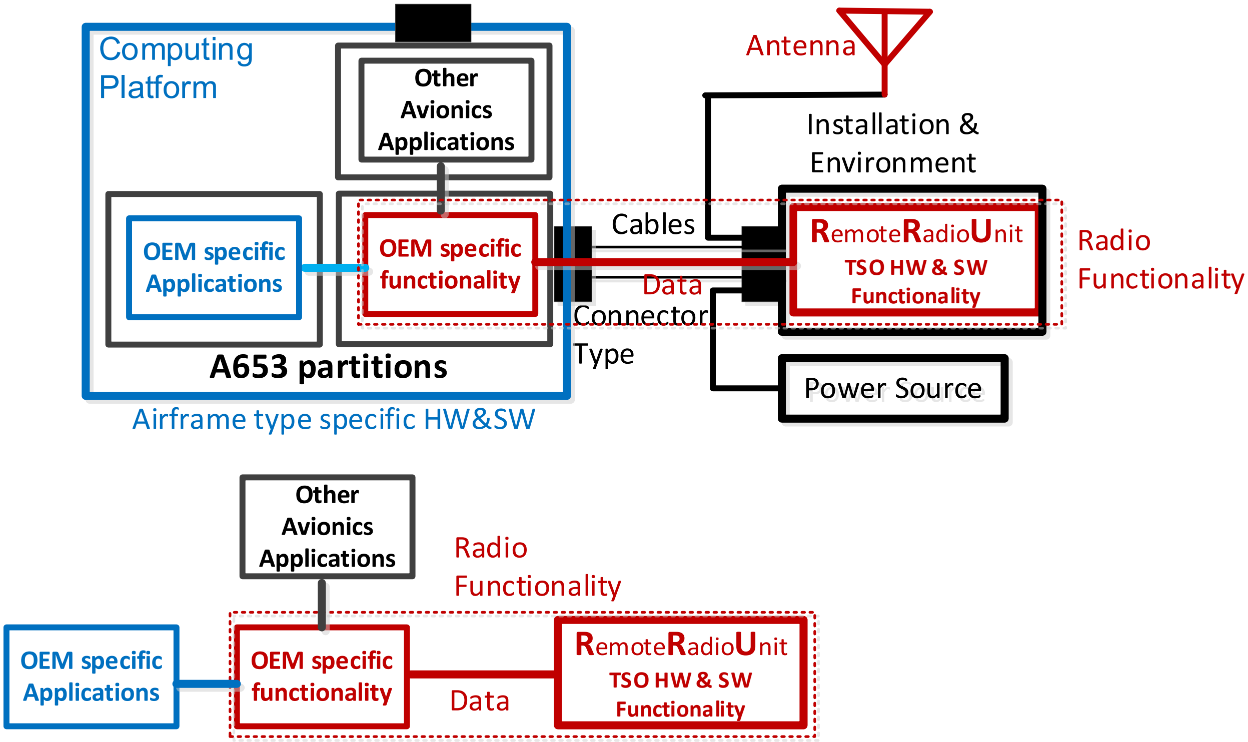

Figure 3-1 – Typical Architecture

Color coding in Figure 3-1 is as follows:

3.0 SYSTEM REQUIREMENTS

Airframe **Type Specific (blue)**

- Computing platform
- Airframe specific applications
- Interface with airframe- specific radio functions

Radio Supplier **Specific (red)**

- Remote Radio Unit TSO Software and Hardware
- Data interface between Remote Radio Unit and radio functions in **a central unit or a general-purpose computing** platform
- Antenna (in some cases)
- Non-TSO airframe-specific functionality

Standardized by ARINC **(black)**

- Form, Fit, Function, and Installation of the Remote Radio Unit
- Power supply to Remote Radio Unit
- Interconnection connectors, cables, physical layer
- Antenna interface
- Operating System Interface (ARINC 653)
- Control/Display Interface (ARINC 661)
- **Physical Network/Bus Interface to other avionics (e.g., ARINC 664, TSN, ARINC 429, or other)**
- [TBD] Interface protocols with other avionics
- Environmental requirements
- Digital audio distribution architecture and digital audio interface
- Software data loading, including associated configuration management support of Remote Radio Unit
- Security support (key management, authentication, encryption, etc.)
- **Data flow types are described in Figure 3-2**.

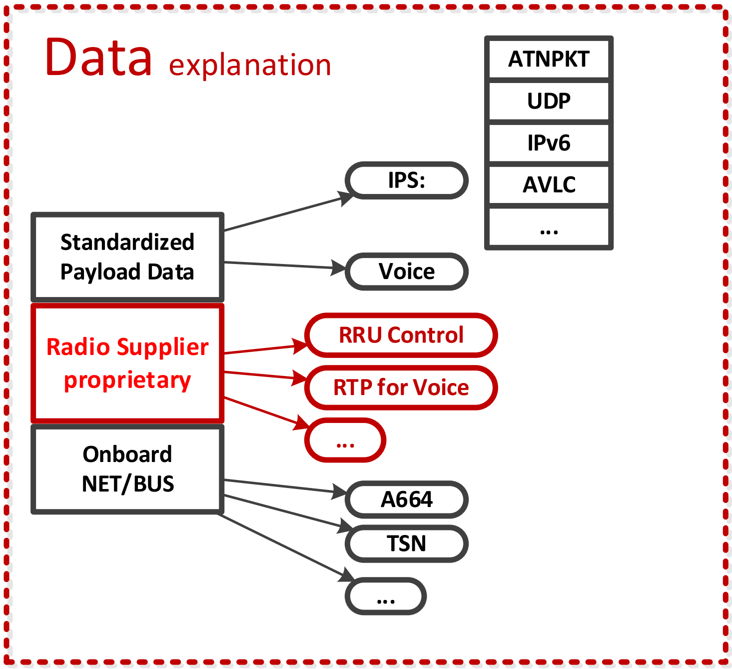

Figure 3-2 – Data Explanation

3.6 Digital Interface (RF-to-Processing) Constraints

TBD – (Action Item: Thales with AvtechTyee and Honeywell providing review.)

3.7 System Processing Requirements

As mentioned above, TSO functionality (e.g., RF translation, waveform processing/modem, etc.) should be implemented in the Remote Radio Unit, whereas non-TSO “system functionality” may be implemented in a general-purpose **computing platform.** Utilizing a general-purpose **computing platform** avoids unnecessary duplication of system functions and isolates the Remote Radio Unit from aircraft-specific dependencies. Candidate system functions for the general-purpose **computing platform** include:

- Aircraft system interfaces (I/O data concentration/abstraction)
- Health/Maintenance support (fault logging/reporting, aircraft installation testing and troubleshooting)
- Dataload (including associated configuration management support)
- Datalink Router interface
- Radio HMI support
- **Remote Radio Unit (RRU) mode control function and radio system configuration function**
- **Upper layers (or application layer) of the radio system**
- **Security support (key management, authentication, encryption, etc.)**

3.8 Audio Requirements

CNS radios should provide audible signals in compliance with the function provided.

3.8.1 Audio Reference Documents

The latest version of the following documents should be considered in the design of audio system functions:

RTCA DO-214A: *Audio Systems Characteristics and Minimum Operational Performance Standards for Aircraft Audio Systems and Equipment*

EUROCAE ED-112A: *Minimum Operational Performance Specifications for Crash Protected Airborne Recorder Systems*

IETF RFC 3550 RTP: *A Transport Protocol for Real-Time Applications*

IEEE 1588-2008 *Precision Time Protocol (PTPv2)*

The AES67 audio networking interoperability standard includes a PTP profile compatible with SMPTE ST2059-2

3.8.2 Bandwidth and Dynamic Range Considerations

The relationship of frequency bandwidth to dynamic range for communications/navigation and interphone interfaces is defined in RTCA DO-214A. As noted in RTCA DO-214A, full speech bandwidth extends from below 100 Hz to over 8 kHz for an adult male. However, the octave with the greatest energy (30%) is between 300 Hz to 600 Hz for an adult male, and 550 Hz to 1100 Hz for an adult female. The majority of intelligibility is found between 1 kHz and 5 kHz. Reduction in bandwidth from 6 kHz is stated to reduce intelligibility in the presence of noise. Each of these factors contributes to the overall response of 300 Hz to 6 kHz for the interphone interface. Therefore, radio systems are expected to provide audio response between 300 Hz and 3 kHz.

Although RTCA DO-214A recommends no more than a -3 dB reduction in power at the pass-band edges, the overall response must remain within a 3 dB envelope. The use of extended frequency response elements is encouraged where practical. This minimizes the cumulative effect of cascaded components (microphone, audio system, headphones) on total system intelligibility. For example, a microphone, an audio system, and headphone, each having a 300 Hz to 6 kHz (-3 dB) response, may produce a total system response of 600 Hz to 3 kHz (-3 dB) given a gradual roll-off in each component. The net effect is a reduction by four in the speech signal bandwidth and its energy.

Implementation of digital filtering can extend the bandwidth as recommended by RTCA DO-214A. Sample rate selection can balance the digital filter complexity versus consumption of network bandwidth. Typical sampling rates for 3 kHz radio paths and 6 kHz interphone paths are 8 kHz and 16 kHz, respectively. Maintaining dynamic range (minimum signal to maximum signal) is critical for maximizing intelligibility. Wiring practices in aircraft must maintain noise at levels 40dB below the desired speech level with the dynamic range of VHF and UHF audio Absolute and Differential Delay varying from 6 dB to greater than 40 dB. RTCA DO-214A requires the audio system to have greater than 50 dB to 60 dB of dynamic range, measured as ((S+N)/N) depending on the environmental category. To ensure system performance requirements are met, this minimum dynamic range must be maintained.

Choosing the appropriate quantization to balance the dynamic range versus consumption of network bandwidth is also important. The greater the dynamic range, the lower the audible background hiss when the system is idle (noise floor). The dynamic range requirement of 60 dB (suggested by RTCA DO-214A) may be achieved by using 11 bits or more per sample (using 2’s complement). Recommended audio quantization of 16 bits per sample is specified, yielding 90 dB of dynamic range.

3.8.3 Absolute Delay

Absolute (Envelope) delays are specified in RTCA DO-214A. The absolute delay value must be defined due to the potential for adverse system affects like halted speech between operators. It is noted in RTCA DO-214A that the person speaking can become confused when the sidetone is delayed given sufficient amplitude. RTCA DO-214A minimizes the effects of latent sidetone by requiring less than 10 ms of absolute delay one way. Audio systems with greater latency in their digital audio transmission may use a local (internal) sidetone to meet the specification. However, careful consideration must be given to the microphone to radio/interphone delay and radio/interphone to headphone delay so as to not impede two-way communication. The maximum value for absolute delay (any microphone to any headset) using digital audio is 20 ms round trip for digital audio distribution. This value is based on industry studies of the acceptable tolerance of this delay by the speaker.

EUROCAE ED-112A places further restrictions on absolute delay as follows:

The delay in recording the flight crew audio signals from the time of reception at the microphones to the time of recording on the protected recording medium shall not exceed 250 milliseconds.

3.8.4 Differential Delay

RTCA DO-214A mentions the possible case of two radios tuned to the same frequency and summed to the headphone. The resultant signal will be 6 dB louder if the signals have identical delay. However, a difference in delay may cause frequency nulls in the spectrum of the summed signal. This may reduce speech intelligibility due to the loss of formants. It may also result in the loss of pure tones such as 1020 Hz. Therefore, it is recommended to force the first null outside the system bandwidth by minimizing the differential delay.

RTCA DO-214A requires less than 9 dB of attenuation throughout the frequency bandwidth of the system when two identical signals are summed to the same output. The minimum differential delay to produce 9 dB of attenuation can be derived by analysis of the highest frequency in the pass-band. Only the 3 kHz pass-band edge for radio to headphone paths shall be considered since interphone to headphone paths have unique sources all the time. Of the 9 dB attenuation allowed, 3 dB is consumed by the -3 dB pass-band attenuation at 3 kHz, leaving 6 dB of attenuation due to differential delay. It requires only one third of a wavelength in time (period) of differential delay to achieve 6 dB of attenuation in the summed signal, or 114 µs at 3 kHz.

Constant differences in the sampling intervals between asynchronous equipment due to sampling clock drift will result in timing errors. These timing errors may cause performance problems when the samples are too late or too early to properly replicate the audio signal. Accurate sample clocks are required to ensure adequate sampling performance.

3.8.5 Architecture

This section describes several architecture variations with a few key implementation notes as described below. The architectures assume **a shared digital** network that carries all audio and control traffic.

Figure 3-3 shows a mixed scenario with two Audio Gateway functions that bridge between the digital audio domain and legacy CNS radio assets. Two digital only examples, a distributed VHF radio function and a distributed Satcom function, are shown below as examples where there is no analog to digital or digital to analog transfer taking place across the function boundary.

A further example illustrates a paired distributed Satcom function providing IEEE 1588 Precision Time Protocol (PTP) synchronization and Audio Management function connected via the **shared digital** network to the Remote Radio Unit.

On the right side of the diagram, three flight deck user positions are shown, highlighting the digital to analog and analog to digital conversion at each station, synchronized via PTP with all other audio system assets.

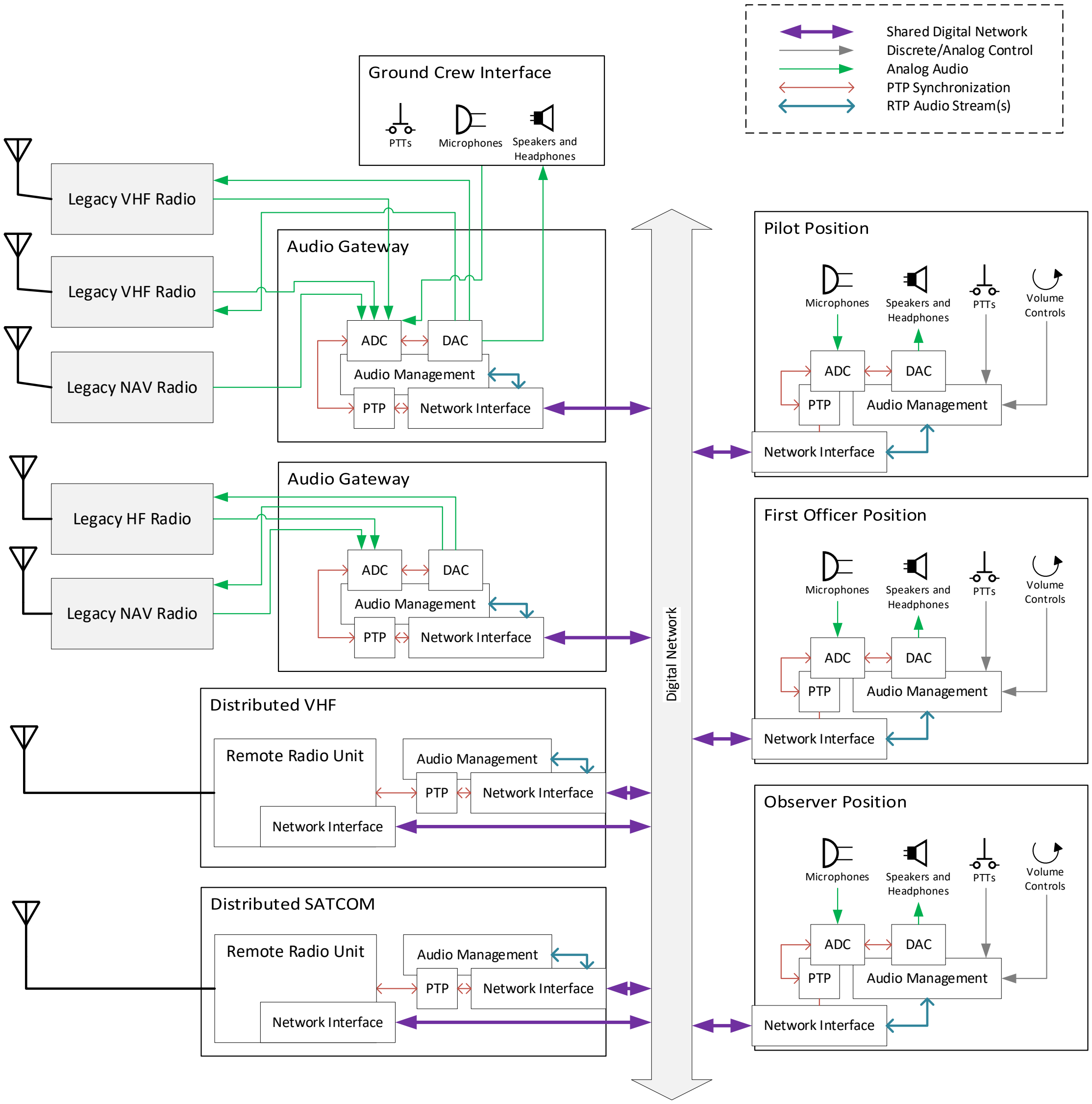

Figure 3-3 – Audio Distribution Example

3.8.6 Transport Considerations

Digital audio places additional requirements on the audio distribution method due to the discrete nature of the digital audio sampling process. Digital transmission has the potential to affect audio quality in the event of timing errors. The relationship of these errors to the basic requirements described above is fundamental to establishing a digital audio distribution standard for the flight deck.

Real-time distribution of digital audio is often referred to as an audio stream. Ideally the digital audio stream is a continuous and steady flow of audio samples like the analog audio signal.

When samples are grouped together to create a network message payload, variable network transport delays may result in timing errors. These timing errors can result in payloads arriving too late to ensure adequate samples are available for replication.

Proper buffering is required to ensure adequate streaming performance. These buffers are known as jitter buffers.

Network performance that can bound the nominal transport delay and maximum transport delay will provide predictable digital audio distribution performance. Bounding the maximum network delay allows the jitter buffer to be sized. The combination of the payload time interval, nominal network delay, and jitter buffer size is the audio distribution latency. Figure 3-4 Illustrates.

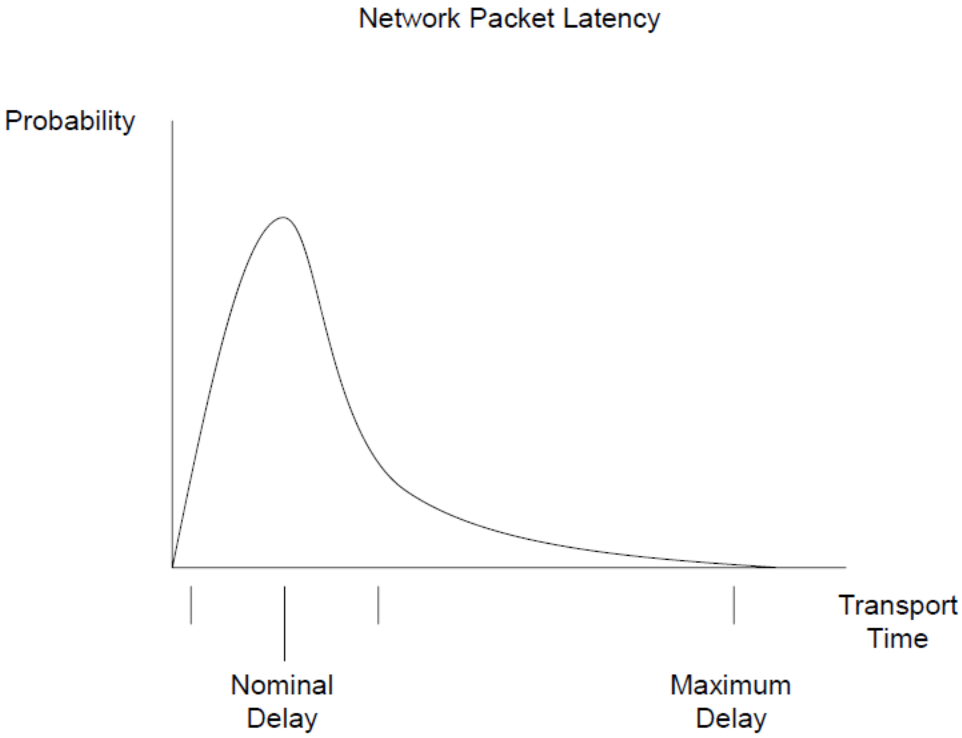

Figure 3-4 – Network Packet Latency

Additionally, the loss of a group of samples in a network message requires the need for special handling. Without special handling, loss of a single message may result in an audible “pop” or “click.” At the destination, each message must be in the same sequence as it was at the source. If the messages are out of order, the network interface must reorder them. A highly deterministic network is required to minimize the problems due to loss of samples or out-of-order samples.

This document recommends using RTP protocol less QoS, SIP, **and RTCP**.

Audio streams are multicast when a stream from the publisher needs to be distributed to more than one subscriber.

There is a need to develop a standard specifying the **payload and sampling rate of distributed digital audio signals. An example** of **this could be an RTP packet with 4ms of** uncompressed audio, 16 bit, 16 kHz samples.

Maximum network latency **should be considered to ensure** meeting the 10ms one way **absolute** delay requirement.

3.8.7 Synchronization Considerations

Synchronization between real-time publishers and subscribers is required to minimize audio noise due to dropped or added samples and to meet the RTCA DO-214A differential delay requirement.

There is a need to standardize these synchronization considerations. An example is the use of PTP per IEEE 1588-2008, where real-time publishers and subscribers synchronize their system and sample clocks to within 100µs of the master system time. This provides compliance with the RTCA DO-214A differential delay requirement and minimizes noise due to dropped/added samples which would otherwise occur due to buffer over/underruns in real-time. This is illustrated in Figure 3-5.

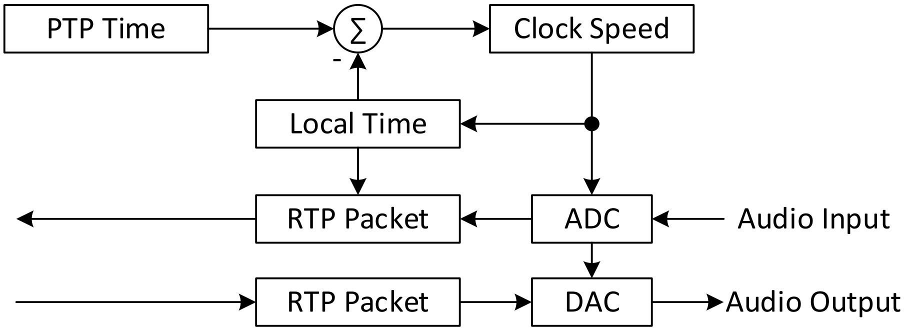

Figure 3-5 – Precision Time Protocol (PTP) Synchronization

The Audio System should have a method to compensate for clock differences between the publishers and subscribers of audio streams when the clock sync between audio equipment is lost.

The Audio System should provide a means to determine when clock sync between audio equipment is lost for the publishing audio equipment.

EUROCAE ED-112A, § I-2.1.8 places additional requirements on channel synchronization as follows:

The recordings for separate channels shall be made such that, when replayed, the relative time between channels can be deduced to better than 4 **milliseconds** irrespective of recording delay.

However, meeting the differential delay requirement is much more restrictive (the system must be synchronized to within 114 µs). Once synchronized, a system meeting the differential delay requirement will also meet the EUROCAE ED-112A requirement.

3.8.8 Sidetone Considerations

Radio systems using local sidetone should ensure that the HF tune tone is heard in the local sidetone audio when present.

3.9 Data Security

This section and its sub-sections provide data security aspects that should be addressed as part of the design of a distributed radio architecture.

3.9.1 Security Assurance Level

Because the radio system has interfaces that are exposed to the outside world, system development activities should include adequate security compliance in accordance with RTCA DO-326A/EUROCAE ED-203A. While the precise assurance levels are architecture-dependent, the document may give minimum assurance levels.

3.9.2 Segregation

The proposed architecture may rely on different shared resources (e.g., networks, computing resources, and antennas). Shared resources are generally associated to risks of threat propagation and interference between different parts. To address such risks, the design should characterize the needs for segregating data flows and computing/processing resources. This also includes the segregation of data plane CNS traffic and aircraft-internal maintenance interfaces (e.g., for data loading, BITE and other centralized services).

3.9.3 Radio Frequency Interference (RFI) Monitoring

Generally, wireless interfaces are directly exposed to RFI security threats. The system should put in place monitoring detecting such threats.

3.9.4 Input Validation and Robustness

With any proposed architecture, the processing of CNS signals has several stages (antenna, RRU, aircraft-specific functionality, aircraft-specific applications). An adequate level of input validation / robustness to malformed inputs should be considered for each stage.

3.9.5 Tamper Resistance

The design should contain requirements for the system to be resistant to unauthorized changes.

3.9.6 Data Loading

Assuming that the system will include Loadable Software Parts, the design should include requirements on securing data loading.

3.9.7 Centralized Security Functions

The system would benefit from centralized security services such as a key management, crypto functions and security log collectors. If applicable standards are not yet available, recommendations to define these services may be necessary.

3.9.8 Security Logging

As part of the system development, the following security logging aspects should be considered:

- Provide designers of the system with a set of security logging guidelines
- Establish a baseline for security related data that should be logged
- Define the security and integrity of logs
- Consider log file formats for interoperability

The focus should be on the generation, storage, transfer, and export of security logs. It does not consider the analysis of security logs which generally is performed on-ground.

ARINC Specification 852 provides additional guidelines.

4.0 OBJECTIVES AND GOALS

4.1 Introduction

This section describes the key goals and objectives for the design, implementation, and service of Distributed Radio architectures. These include design objectives, cost objectives, and the desire for interchangeability, reliability, and maintainability of avionics.

4.2 Scope of This Section

The scope of this section is limited to describing the motivations and expected goals of Distributed Radio architectures in the context of total life-cycle costs, i.e., aircraft first cost, operational costs, cost of changes and additions, and maintenance cost. It attempts to categorize the benefits as they pertain to integration, fault tolerance, and modularity. It describes both direct and indirect benefits of applying Distributed Radio architectures to future aircraft systems.

4.3 Distributed Radio Benefits

The Distributed Radio concept is expected to satisfy the objectives of the groups that traditionally participate in the definition of commercial aircraft avionics: the airlines as users and operators of the aircraft, the airframe manufacturer that design, build, and support commercial aircraft, and the equipment manufacturers that contribute to the innovative design, efficient production, and support of the components and subsystems

4.3.1 Benefits to the Airlines

Reduced life-cycle cost through:

- Increased operational performance, reduced empty weight, increased payload volume
- Reduced unscheduled maintenance, reduced spares requirement
- Simplified service life changes and additions to the avionics

4.3.2 Benefits to the Airframe Manufacturer

Reduced first cost and cost of service life support of the aircraft through:

- Reduced development, certification, and aircraft production costs
- Reduced avionics weight and increased payload volume
- Flexibility to efficiently meet customer requirements and to implement improvements

4.3.3 Benefits to Equipment Manufacturers

Increased marketing opportunities of specialty components and subsystems through:

- Increased market volume
- Longer production runs
- Flexibility to efficiently meet customer requirements

4.4 Operational Objectives

There are several operational improvements that the airlines expect to achieve from the Distributed Radio concept. One prospect is to introduce new avionics maintenance philosophies which result in the ability to schedule maintenance actions so that no maintenance is required when the aircraft is away from a maintenance station. There is also an objective to reduce or eliminate unconfirmed removals through improved fault diagnostics.

Distributed Radio architectures are expected to allow the avionics equipment to take full advantage of technology changes and to expand efficiently. It is an objective to provide a capability to upgrade systems and to add new functions through on-board software loading of revised or all new software applications.

4.5 Design Goals

Once the desired functional performance and operational safety are achieved, then the cost of ownership over the life of the aircraft is the primary criterion against which a system is judged. Cost of ownership should be used to trade off all other factors. The designer should provide avionics in which the sum of all contributing cost factors - development, amortization, materials, spares, weight, volume, operation, maintenance, test equipment, growth, etc. is minimized over the life of the aircraft. It is not acceptable to reduce one cost factor and neglect others. Particularly, it is not acceptable to favor first cost effects over continued life-cycle costs.

Airlines desire that cost of ownership models be developed and be maintained current for use in avionics upgrade programs and new development programs. Where cost of ownership models exist, users expect them to be employed in the cost analysis.

4.5.1 Goals of Integration

The system design should make maximum use of shared resources to reduce resource duplication to a minimum. Such integration lowers the cost of ownership by reducing the acquisition cost, spares requirements, weight, and volume of the avionics equipment.

While hardware integration is desired, software functional independence is essential, and a certifiable method for partitioning these independent software elements from each other is necessary. Hardware integration should be limited by the desire to minimize complexity and spare unit costs.

The level of integration proposed in CNS Distributed Radio architectures suggests that software be on-board loadable to facilitate software updates to a function. This should be accomplished without removing from the airplane hardware relating to that function or any other hardware where the function is integrated.

4.5.2 Goals of Fault Tolerance

4.5.2.1 Performance/Integrity

The approach to redundancy in Distributed Radio architecture can be viewed on two levels: functional level redundancy and component redundancy. Traditional systems achieve functional redundancy by duplicating the complete system. The network architecture of IMA could allow a hardware integrated approach and consequently reduce the number of components needed for a given level of function availability. In an IMA system, functional availability is ensured by providing multiple paths for the data from its source, to the processing required to the sink for the data (whether a display, audio, or other function). Component redundancy is necessary, but the emphasis is on a much greater use of fault containment techniques to allow other components in the system to continue functioning in the presence of failures.

The level and the physical method of redundancy used in each of the components should be totally transparent to the application software. Hardware should be designed independently of the application software so that changes in either do not affect each other. A detailed interface definition allows this approach to be possible. Thus, a standard interface allows competing or dissimilar designs to be used in different IMA processing modules without affecting the design of the application software. This will minimize the validation effort required and allow equipment manufacturers to have flexibility in the design of their equipment. Only the integrity of the integration has to be verified each time either the hardware or software changes. Separation of the environmental and application design allows the hardware and software to develop and mature at their own rates.

4.5.2.2 Scheduled Maintenance

The Distributed Radio architecture maintenance philosophy is built upon the desire for scheduled maintenance intervals. To achieve scheduled maintenance, it is necessary to establish fault containment areas throughout the architecture. Through this approach it is possible to quickly detect any failure and isolate it to a given fault containment area. A very high percentage of faults should be detected. Each of these fault containment areas should detect and annunciate the validity of its data to all users of that data. This approach allows the system to accurately report the status of its own health and enables users to achieve the maintenance goals that were previously unattainable. Therefore, it is a goal to make all avionics first failures transparent to the flight crew, annunciate all failures when interrogated by the maintenance crew, and allow maintenance to be scheduled at a convenient time.

COMMENTARY

Airline maintenance shops report that an excessive contributor to the cost of maintenance is unconfirmed (“No Fault Found”) removals. These costs are attributed to the time it takes to test and return good boxes to service and the cost of spares necessary to support this practice. Unnecessary equipment removal and handling is also known to cause maintenance-induced failures. The message from the users is to <u>keep the good avionics on the airplane!</u>

It is necessary to provide some level of resource redundancy to extend the Mean-Time Between Unscheduled Removal (MTBUR). The resource redundancy required to defer maintenance on a detected failure is dependent upon the reliability, accessibility, and the statistical probability of successfully operating for the deferral interval. Resource redundancy should be made available through secondary redundancy at the component level or it may be made available at a system level (as part of the aircraft architecture) by automatic reconfiguration.

It is recognized that desired reliability and extended maintenance interval are based upon individual airline maintenance philosophy. An individual avionic function should demonstrate graceful degradation. Furthermore, it is desired that the full avionic function continues to be available for at least a scheduled “A Check” maintenance interval. The overall system architecture design should contribute to the reliability goals for each avionics function.

4.6 Equipment Packaging and Location

4.6.1 Weight and Volume Considerations

Generally, users desire that avionics equipment be as light-weight and compact as possible. However, the desire for such equipment should not result in complex packaging designs that result in high-cost spares and compromise overall system integrity or life-cycle costs. The packaging designer is encouraged to work closely with the system designers and airframe manufacturers to evaluate the trade-offs of small, light-weight equipment.

4.6.2 Location and Accessibility of Components

The trends toward the use of small, light-weight equipment with high Mean-Time Between Failures (MTBFs) and toward the use of **a shared digital aircraft** network provides the freedom to distribute equipment on the airplane in a variety of locations, thus eliminating the traditional Electrical And Electronics (E/E) bay. This will increase the aircraft’s useable payload volume. Equipment location should be determined based on a number of factors. It is the system integrator’s responsibility to analyze these factors before distributing equipment on the aircraft:

- Function and operational performance
- Environmental concerns
- Physical access for maintenance
- Remote access for software maintenance
- Remote access for monitoring software logs
- Maintenance philosophy
- Integration with other systems
- Growth potential and access for modifications
- Lengths and number of wire runs and number of interconnects with source systems
- Security threat concerns

Equipment access for maintenance purposes should minimize the impact to passengers and crew.

4.7 Interchangeability

One of the continuing goals of airline users is interchangeability of avionics equipment, which is also desired by the airframe manufacturers. Interchangeability is necessary to achieve economies of scale, to distribute design and development costs, and to reduce the spares inventory. Ideally, interchangeability can be applied to any manufacturers' components and between any two aircraft types and models. This has been achieved often enough in the past to prove that interchangeability is a worthy goal.

4.8 Spares Provisioning

Spares provisioning is based on the maintenance plan developed for a particular airplane and the extent that they are adapted to meet the needs of an individual airline. The objective of the users is to procure the fewest number of spares without jeopardizing aircraft dispatchability.

The goal is to employ fault tolerance to defer maintenance actions and reduce the number of spares required.

4.9 Distributed Radio Implementation

As a follow-up to this document, the industry may establish ARINC Standards for individual hardware LRUs and associated interfaces. This will allow individual LRUs to be installed in multiple locations on the airplane and on multiple airplane types. Standardization is expected to result in interchangeability between various manufacturers products.

The airlines desire reduced cost of ownership through improvements in aircraft operational areas that affect day-to-day costs. Notably, higher dispatch availability is expected using high-MTBF equipment. The application of fault tolerant design is expected to reduce the number of unplanned maintenance actions. Improved diagnostic capability should make flight line maintenance actions swift when failures do occur.

For some equipment, the low frequency of maintenance action may result in airlines finding it economically practical to defer component maintenance action to the equipment suppliers. This situation results in closer relationships between the user and the supplier. Furthermore, users may choose to employ the supplier to perform other enhancements or modifications to equipment.

Airline users expect the airframe manufacturer to assume the responsibility for system integration. This includes installation of equipment, communication between subsystems, and ensuring fault data integrity to the LRU or Line Replaceable Module (LRM) level.

In a CNS Distributed Radio architecture implementation, a particular function may be divided into smaller pieces resulting in the potential for more suppliers to contribute to the complete function. However, as previously stated in Section 3.5, System

Design Constraints, it is recommended for CNS Distributed Radio architectures that TSO performances applicable to a particular communications, navigation, or surveillance radio system be provided by a single entity to avoid performance, integration, and airworthiness approval challenges. System integrators can be negatively affected where equipment from various suppliers is integrated to perform a specific radio function. Care should be taken to ensure that problems identified during the integration process and throughout the product life are handled in an expedient and cost effective manner.

In the Distributed Radio architecture concept, there is need to prove the operational compatibility for all equipment used in the design. Airframe manufacturers, as system integrators, will need to work closely with avionics suppliers to assure this compatibility.

In the software area, the IMA concept will introduce a standardized operating system interface based on ARINC 653. This will add significant lines of code and associated complexity. Likewise, remote units are evolving from pure hardware implementations to software defined radios. This enables suppliers to competitively supply software to implement different avionics applications. It is expected that users, hardware suppliers, and software suppliers will establish closer relationships as a result.

4.10 Distributed Radios in Flight Simulators

Flight simulators as well as maintenance trainers are now recognized as an essential part of the aviation industry. Airlines have become more and more dependent upon such simulators for flight crew and maintenance crew training. Airlines typically require these simulators to be available as early as possible to allow for crew training prior to equipment introduction into revenue service.

The functions required to support the airlines training needs are specified in the latest version of **ARINC Report 610:** *Guidance for Design and Integration of Aircraft Avionics Equipment in Flight Simulators.*

As a general rule, avionics designers should develop hardware/software architectures and algorithms that are compatible with the simulator functions. Each software application should be capable of being individually controlled and should also report its operational status. A keep-alive signal may also be transmitted continuously to the software to indicate the installation in a simulator.

5.0 REQUIREMENTS ON SUPPORTING TECHNOLOGIES

5.1 Introduction

The Distributed Radio architecture will depend on the application of established supporting technologies which can be applied to form complete systems. This section describes those elements which form a fundamental part of the architecture.

5.2 ARINC 664 – Avionics Full-Duplex Switched Ethernet Network

Since the target for the Distributed Radio architecture are new aircraft **types, the general purpose computing** platforms could use ARINC 664 Part 7 as the data network used for intra-avionics communications. Therefore, Remote Radio Units **could use** the ARINC 664 interface standard. The details of the ARINC 664 data network are documented in **ARINC Specification 664:** *Aircraft Data Network, Part 7, Avionics Full-Duplex Switched Ethernet Network.* **The use of ARINC 664 Part 7, current version, or future evolution of that standard, needs to be considered.**

Alternatively, **in order to support high bandwidth needs, including** audio data flows, the use of a Time Sensitive Network (TSN) could be considered.

The treatment of digital audio is discussed in Section 3.8 of this document.

5.3 ARINC 653 – Application Software Interface

A standardized application software environment is part of the Distributed Radio concept. It is envisioned that some of the system processing is accomplished with one or more software applications hosted on an IMA platform. ARINC Specification 653 defines an interface standard between the operating system software and the system's application software. ARINC 653 defines the communication services and memory management facilities expected to be used with Distributed Radios.

The placement of software applications is distributed among the IMA's network of processors. There are several applications hosted on each processor. These applications may originate from different avionics sources and be integrated into the selected implementation of the core processing hardware. It is necessary to ensure reliable software partitioning to create "brick walls" between applications, especially where these applications may be different levels of software criticality. **Common services such as codecs, crypto, communalized interfaces are TBD.**

Reliability and availability goals may be satisfied by hosting software applications on multiple IMA platforms capable of self-monitoring and fault tolerance.

5.4 ARINC 624 – Onboard Maintenance System

ARINC Report 624 is a design guide for On-Board Maintenance Systems (OMS). The OMS design guide discusses a variety of maintenance concepts such as Built-In Test Equipment (BITE), BITE access, and Aircraft Conditioning and Monitoring Systems (ACMS). The document recommends an English-based user interface, non-volatile BITE storage, and Onboard Maintenance Documentation (OMD).

5.5 ARINC 661 – Cockpit Display System (CDS) Interfaces

ARINC Specification 661 defines the data structures used to communicate radio control and display commands to the flight deck display equipment.

5.6 ARINC 8xx – Radio Packaging Standard

Packaging standards defined by **ARINC Specification 836A**: *Cabin Standard Enclosures* were discussed as a possible starting point for the development of radio packaging standards. ARINC 836A is intended for cabin installation environments that are relatively benign compared to radio installation locations.

5.7 Fiber Optic Interfaces

Fiber optic connections are light-weight and immune to RF interference. Fiber optic hardware definitions continue to be standardized and should be utilized to the greatest extent possible. ARINC Specification 801 provides standardization of a fiber optic interconnect assembly, which is composed of a connector, fiber optic cable, and fiber optic termini. In addition, ARINC Specification 845 defines a fiber optic Expanded Beam (EB) termini for the air transport industry with the goal to avoid the proliferation of different designs of termini to serve the same functions on different aircraft models.

5.8 Related Documents

The latest version of the following documents apply:

EUROCAE ED-14: *Environmental Conditions and Test Procedures for Airborne Equipment (latest revision)*

EUROCAE ED-12: *Software Considerations in Airborne Systems and Equipment Certification (latest revision)*

RTCA DO-160: *Environmental Conditions and Test Procedures for Airborne Equipment*

RTCA DO-178: *Software Considerations in Airborne Systems and Equipment Certification*

RTCA DO-254: *Design Assurance Guidance for Airborne Electronic Hardware*

RTCA DO-326: *Airworthiness Security Process Specification*

6.0 CNS DISTRIBUTED RADIO ARCHITECTURES

6.1 Introduction

This section defines some terms to allow a common vocabulary to be used when describing Distributed Radio system architectures.

The physical architecture is targeted, in particular the allocation of functionality between central and remote areas, with a view of increasing the use of remote locations in order to reduce overall system Size, Weight, and Power (SWaP).

This architecture section looks at various architectures and makes some assessments of the potential advantages and disadvantages that each bring.

6.1.1 Architecture Scope

There are a large and growing number of CNS systems on a modern airplane, each of which should be considered for the potential benefits of the application of a distributed architecture. Figure 6-1 describes the general situation and shows two dimensions that need to be assessed to define the scope of this study. A further dimension is time, which may be used to separate the introduction, and potentially specification, of distributed radio architectures for each new aircraft type.

Furthermore, discussions are underway that may lead to decisions on whether to allow individual systems, or groups of systems, to have different architectures or be implemented independently of each other.

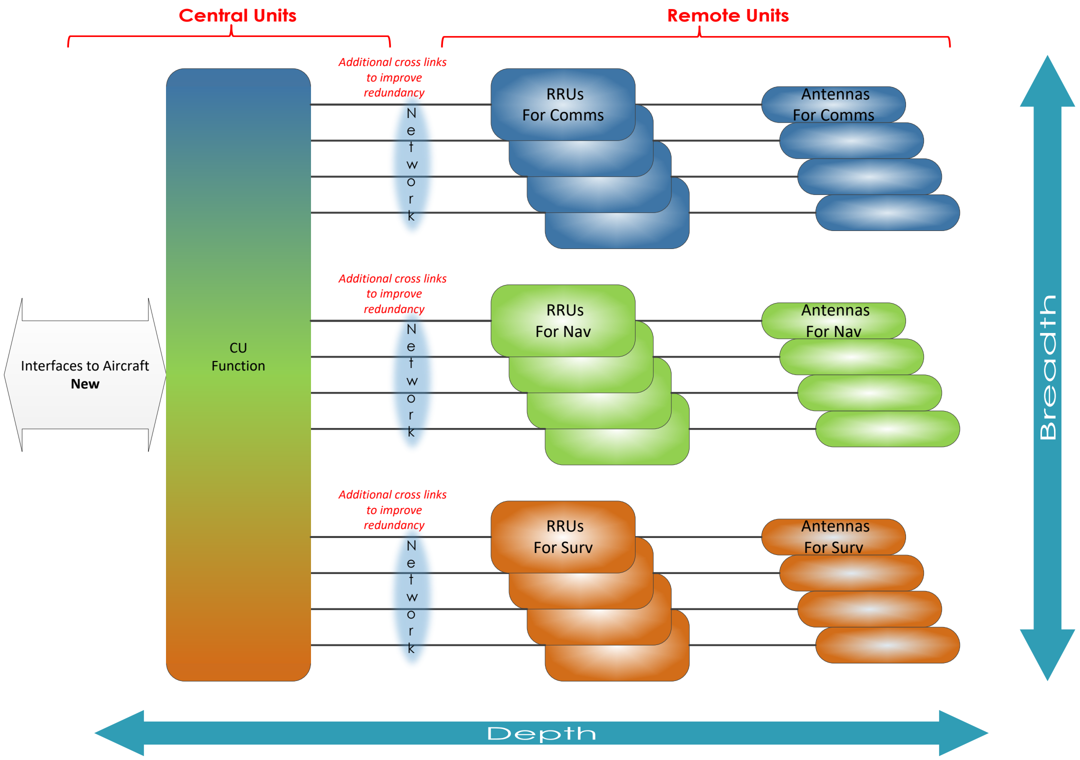

Figure 6-1 – Potential Scope of Distributed Architecture for CNS Systems

6.2 Distributed Architecture [Functional Allocation Options and Proposed Nomenclature]

It is the intention within this section to discuss the various options for locating parts of the functionality of each radio system and to introduce some nomenclature that can be used to refer to them.

For the purpose of this discussion a generic radio has been broken into five sections of functionality which apply to both transmit and receive paths and are described below. It is likely that not all radios will fall neatly into this categorization; however, the general principles will still apply. In particular there are implications on the interfacing requirements between units that are determined by where these functions are located and are important when considering a distributed architecture.

AMP Amplification

This is typically a power amplifier stage in the transmit path and an Low Noise Amplifier (LNA) or first stage of receiver to control noise figure. Also, any RF functionality between these and the antenna(s) such as filtering, switching, and duplexing.

ASP Analogue Signal Processing

This stage includes up/down frequency conversion and the analogue signal conditioning prior to analogue to digital conversion and conditioning after digital to analogue conversion. Critically, this stage includes any analogue to digital conversion and consequently the interface to following receive and preceding transmit stage is digital. This will have to operate at the sampling rate with consequently higher bandwidth.

DSP Digital Signal Processing

A significant proportion of modern radios are implemented in the digital domain and this section would cover the Digital Signal Processing (DSP) processors and supporting systems for these functions. The interface is now only passing data at the information bandwidth with a small overhead for line and network protocols.

L/NP Line/ Network Protocols

Many radio systems include complex protocols to deal with lossy lower layers and to enable multiple users to interact on a network. These are typically implemented using a General Purpose Processor (GPP).

R I M	Radio Interfaces Management

This is the physical and software interfaces from the radio function to the aircraft that enables the radio to be controlled and data transferred.

6.2.1 Central and Remote Locations

The term “central” is used in this document to refer to units located in a central location on the aircraft, typically specifically designed to accommodate electronics enclosures and which provides a degree of environmental protection. Such an area would be the EE bay where racking providing cooling air is also available.

The term “remote” is used in this document to refer to a number of potential locations that are generally around the periphery of the aircraft such that they are close to the antenna. It is assumed that these will be in pressurized areas but that there will not be any specific racking or cooling provided. Consequently, the SWaP of these units is important. Likely locations are the crown area (green) and the triangle area (red) as shown in Figure 6-2.

Figure 6-2 – Proposed Remote Locations

6.2.2 Remote Unit Options – Passive Antenna

Each row of Figure 6-3 below represents a different allocation of the functionally to the physical architecture where a simple passive antenna is used. Specifically, between units located in a central location, a remote location assumed to be near a corresponding antenna, or the antenna on the outside of the aircraft.

6.0 CNS DISTRIBUTED RADIO ARCHITECTURES

Existing radio architectures are federated and broadly have the functionality allocated to the physical architecture represented in the first row of Figure 6-3. Here, all of the functionality is contained in a unit located in a central environmentally controlled location in the aircraft, usually the EE bay, and is connected to an antenna mounted externally via a low loss coaxial cable. The term "collocated" is used, since all of the functionality is located in one area. In this case there is no need for a remote unit, other than an antenna, as all functionality is contained in the central unit(s).

A collocated allocation results in the need for long runs of coaxial cable between the central area and the external antenna which must have low loss. The consequence is typically a requirement for long thick cables (high mass) which constitutes a significant proportion of the overall system mass. This is compounded by the need for more radio frequency power output from the transmitter to compensate for cable loss.

The second row shows a different allocation to the physical architecture, which has been introduced for some communication radios e.g., L-Band Satcom. Here the location of the final RF stages for power amplification and low noise amplification (including diplexing) are located near the antenna in a remote location to reduce losses to and from the antenna. This reduces the transmitter power output required and combined with an LNA, to control the noise figure, allows higher loss coaxial cabling to be used for the long runs between the remote and central unit(s). This arrangement is referred to as an analog split because the interface between the central and remote units will remain analog.

The third row provides additional functionality to the remote unit, critically the digital to analog conversation stage, thus allowing the use of a high speed point-to-point digital interconnect between the remote and central units carrying sample rate data. This allocation is therefore referred to as a digital split. This architecture is common in mobile phone base station designs where the remote unit is referred to as a Remote Radio Head. While this architecture has advantages, it is not considered to be fully distributed since it requires a sample rate digital interface which may prevent its application where remote units are connected using digital network interfaces.

In the final two rows, most functionality is provided in the remote unit allowing the use of digital networks to connect the remote and central units since the bandwidth is reduced close to the data rate and interface stability and latency is less critical. These two allocations are considered to be fully distributed. To distinguish the remote unit in these options, from that in the previous digital split architecture, the unit is referred to as a Remote Radio Unit (RRU).

6.0 CNS DISTRIBUTED RADIO ARCHITECTURES

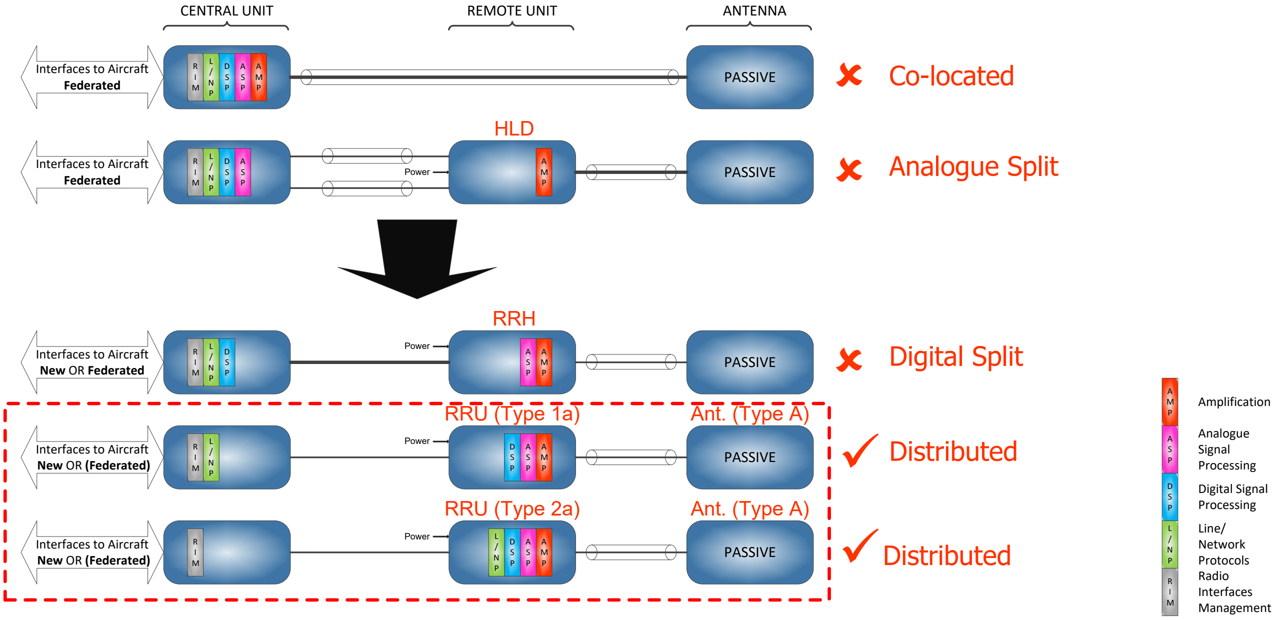

Figure 6-3 – Progression from Federated to Distributed (Passive Antenna)

6.2.3 Remote Unit Options – Active Antenna

If active antenna configurations are considered, then further possibilities for the allocation of the functionality between the RRU and antenna exist. Figure 6-4 shows the potential options for Type 1 RRUs intended for use with active antennas.

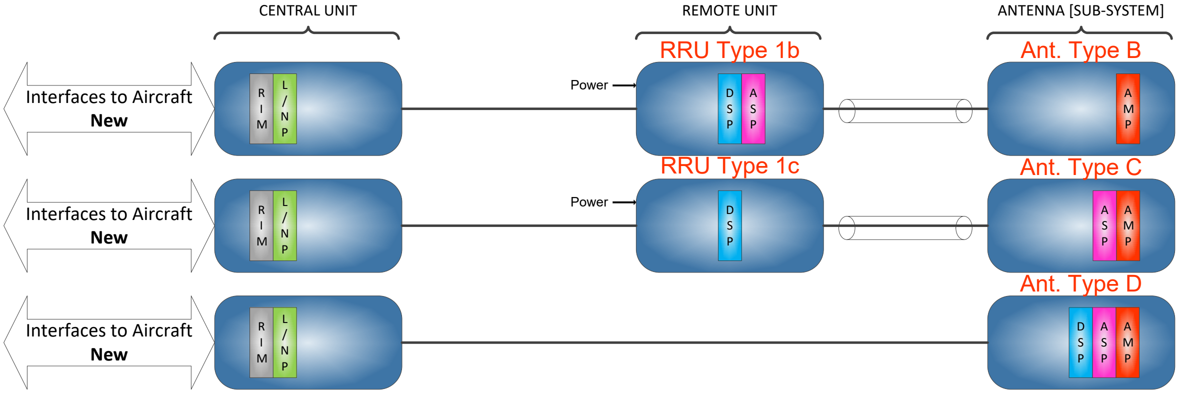

Figure 6-4 – Further Distribution – Type 1 RRU Options (Active Antenna)

Figure 6-5 shows the equivalent active antenna options for Type 2 RRUs. However, it should be noted that one row has been indicated as unlikely to provide significant benefit due to the limited functionality that would be incorporated into the RRU type that it generates.

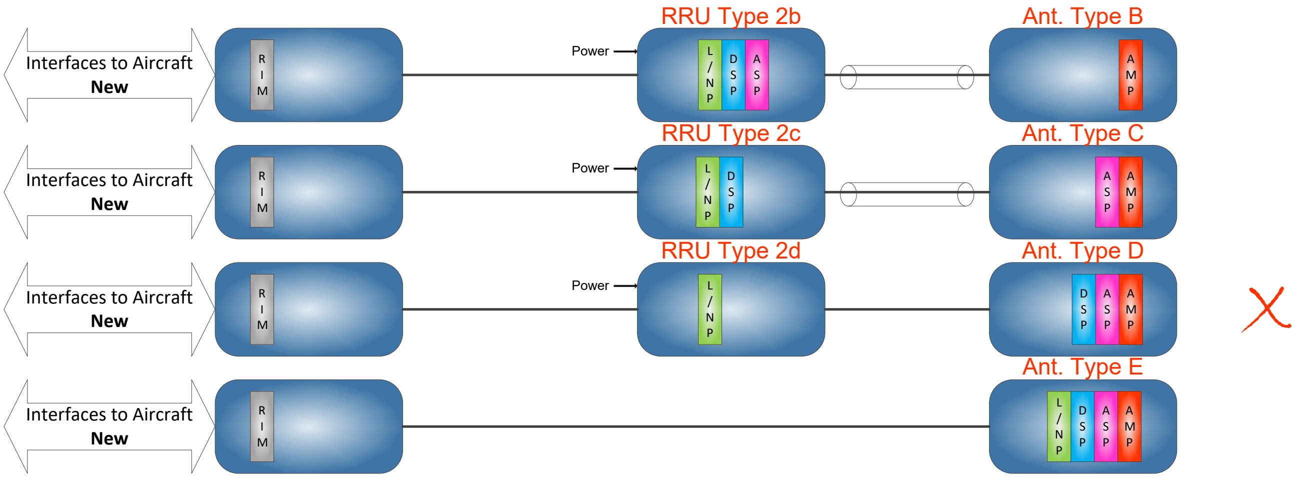

Figure 6-5 – Further Distribution – Type 2 RRU Options (Active Antenna)

The final row in Figure 6-4 and Figure 6-5 above shows the situation where a remote unit is not required, and all the functionality is provided in the antenna.

6.2.4 RRU Type Definition

Remote Radio Unit (RRU) types are classified by the amount of radio functionality provided in a centralized unit(s) versus the remote units(s) and the specific interface requirement between the **remote units, the** central unit(s), and **the general-purpose computing platform.**

- RRU Type 0 – (TBD)
- RRU Type 1 – All functionality apart from Radio Interface Management and Line/Network Protocols is located in remote units.
- RRU Type 2 – This provides the most extensive amount of functionality located in a remote location leaving only the Radio Interface Management within a **general-purpose computing platform**.

The term RRU Type 0 refers to a type of radio where the digital signal processing is performed in a unit that resides outside **the general-purpose computing platform. It may** require a high-speed point-to-point digital interface, rather than the aircraft's shared digital network.

A second character is appended to detail the allocation of the functionality between the RRU and antenna.

When a RRU Type 1 or RRU Type 2 unit is intended to operate with a passive antenna it has an "a" suffix which indicates that no active signal path functionality is migrated into the antenna.

When the RRU is designed as part of a system that incorporates an active antenna, and where some functionality is located in the antenna, the second alpha character denotes how much functionality is located in active antenna systems. The figures above show the RRUs labeled accordingly.

- RRU Type Xa – Passive antenna only

- RRU Type Xb – Power amplifier (and LNA) located within antenna sub-system
- RRU Type Xc – Analog Signal Processing additionally located in antenna sub-system
- RRU Type Xd – Digital Signal Processing additionally located in antenna sub-system

Note: The utility of RRU Type Xd appears to be very limited and consequently could be removed.

Where antennas contain powered devices that do not form part of the RF signal path they are considered to be “passive” in the nomenclature defined above. Antenna examples are TBD.

6.2.5 Antenna Type Definition

Antennas are classified by the amount of functionality they contain. This list is arranged such that a Type A antenna will correspond to a Type Xa RRU.

- **Antenna Type A – Passive Antenna**
- **Antenna Type B – An active antenna which contains Tx power amplification, Rx LNA and any RF switching, or duplexing required. The signal interface to/from the antenna are low power RF with control functionality provided by a separate physical interface or multiplexed over coaxial cable.**
- **Antenna Type C - An active antenna, which in addition to Type B, also contains the radio analog signal processing and digital-to-analog conversion such that a digital interface is required which is capable of transferring sample rate data and any corresponding timing constraints.**
- **Antenna Type D – An active antenna, which in addition to Type C, also contains any digital signal processing required for the signal path. The digital interface is required to pass data at the information bit rate with a corresponding lower bandwidth and more relaxed timing.**
- **Antenna Type E – This provides the most extensive amount of functionality located in the antenna (external to the aircraft) such than no RRU is required and the antenna itself connects directly to a centrally located control unit.**

6.2.6 Multiple Bearer RRU Options

It is possible to include two, or possibly more, radios within a single remote enclosure to create a multiple bearer (i.e., channel/radio) RRU.

Multiple instances of the same radio type (multiple channel), or different radio types (multiple radio) could be considered.

When considering multiple radios there are many possible ways of selecting the radios to be grouped, for example: **{Editor’s Note: Break each of the following concepts into different sub-sections}.**

- Identical function (e.g., multiple instances of a VHF radio)
- Related function (e.g., within Communications, rather than Navigation or Surveillance)
- Frequency bands close (e.g., Iridium and Inmarsat L-Band satcom)
- Similar or identical DAL (e.g., DAL C)

When more than one radio is included within an RRU there is the potential to share a single antenna. Clearly, there are a number of further considerations to be taken into account when determining if this is viable. These considerations are discussed in other sections of this report. This section focusses on the architecture only.

Clearly, various combinations are possible. The option represented in Figure 6-6 is one of many possible combinations.

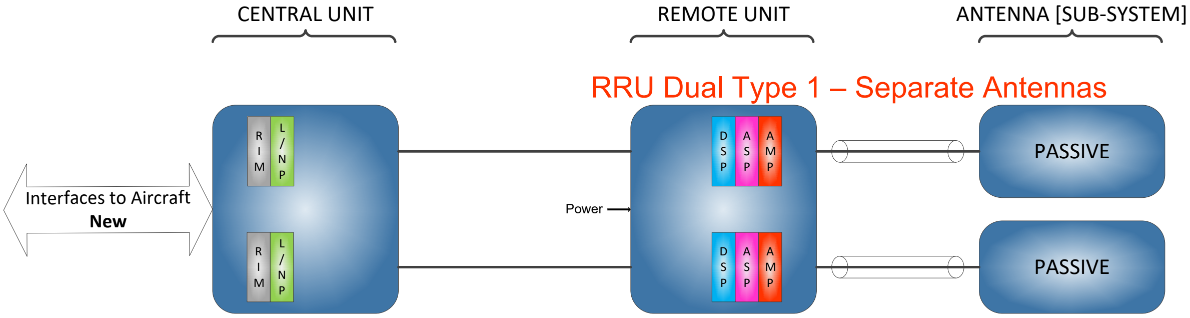

Figure 6-6 – Example of Dual Channel or Dual Radio RRU (Separate Antenna)

A further option is to combine multiple radios and share a single antenna as shown in Figure 6-7 below,

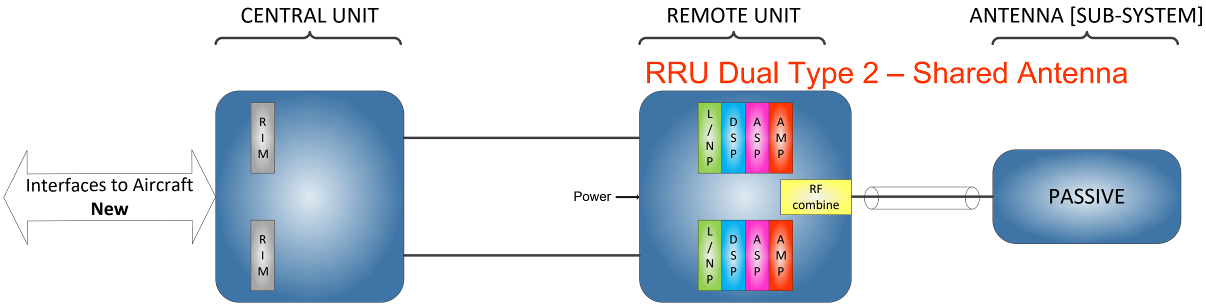

Figure 6-7 – Example of Dual Channel or Dual Radio RRU (Shared Antenna)

6.2.7 Consistency of Architectures Across Breadth of CNS

There is no reason, in principle, to constrain the architectures employed by each RRU to be consistent across all of the CNS systems. It is likely that permitting variation may provide a more optimized solution overall.

In Figure 6-8 below, mixed RRU architectures are shown that are deployed both between CNS and within each unit TBD.

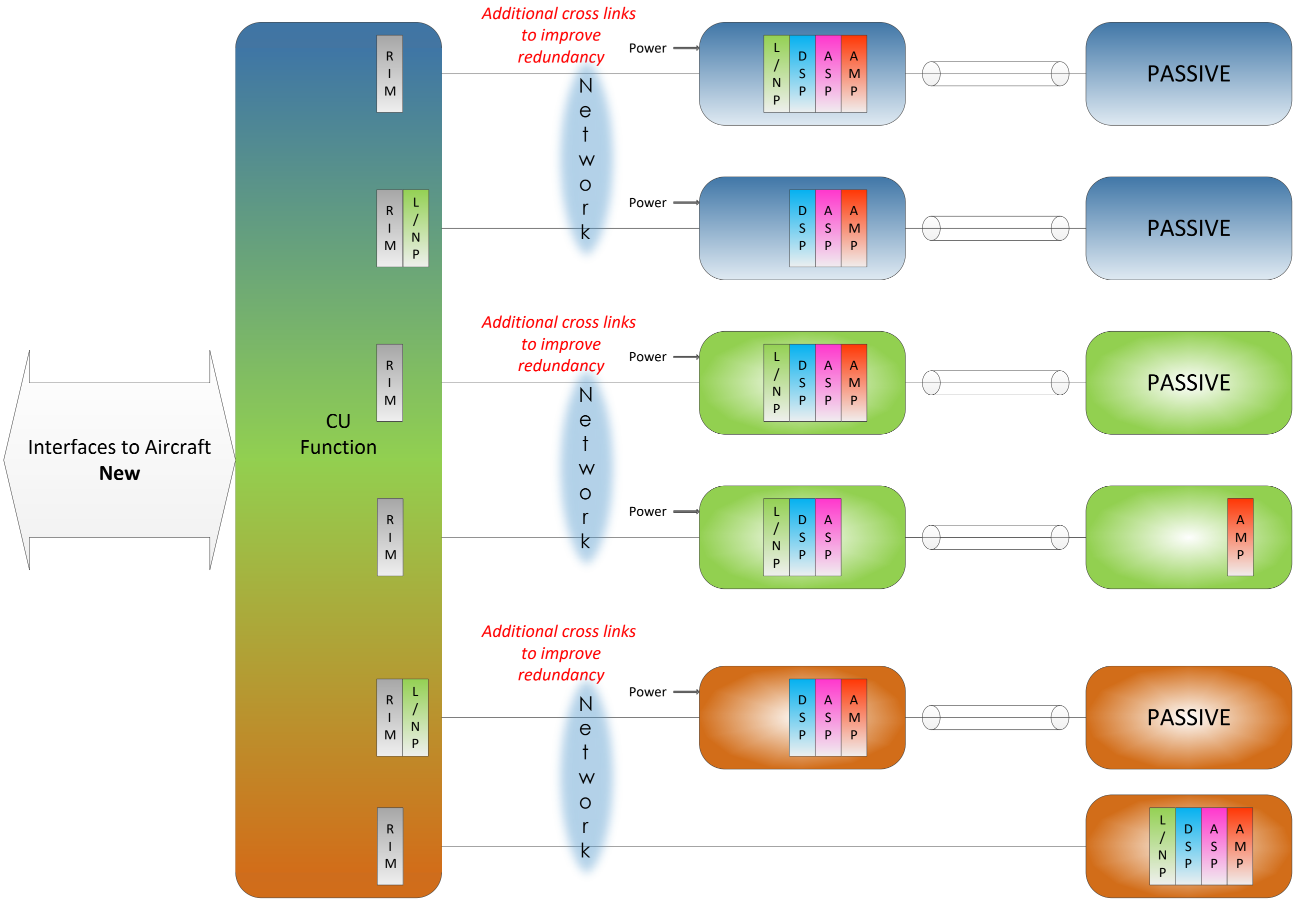

Figure 6-8 – Example of Mixed Architectures across CNS Systems

It is proposed that the CU function be implemented on an IMA like platform. This will enable the support of more than one radio function. While this can reduce the SWaP of the CNS system(s), it does potentially introduce a growth in the design assurance level required by any shared component – since the DALs assigned to current federated equipment are based on the assumption that each federated equipment operates independently.

{Address DAL here and its potential increase where single point failures, such as a shared CU(s), are introduced?

Further, would it be sensible to look at RU architectures – perhaps dual redundant etc?}

6.3 Legacy Radio Architectures (Communications)

This section shows the existing Communication architectures in a consistent style to that being used for discussion of future distributed radio architectures.

6.3.1 HF Federated

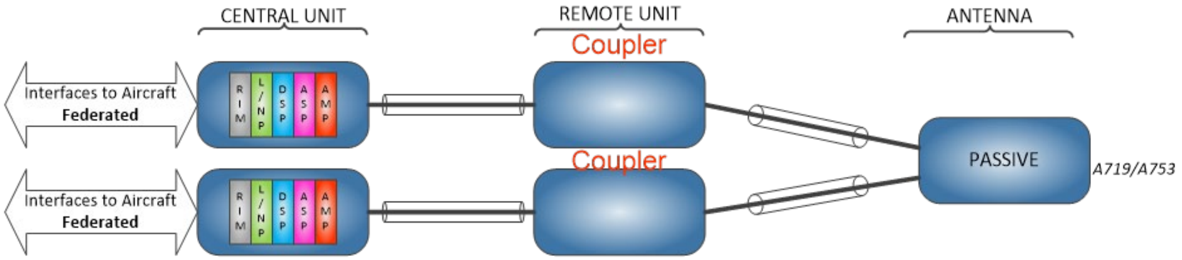

Figure 6-9 – Federated HF Radio Example

6.3.2 VHF Federated

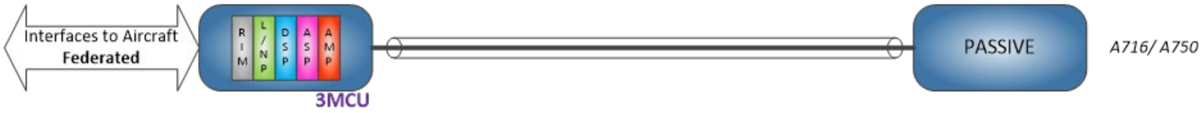

Figure 6-10 – Federated VHF Radio Example

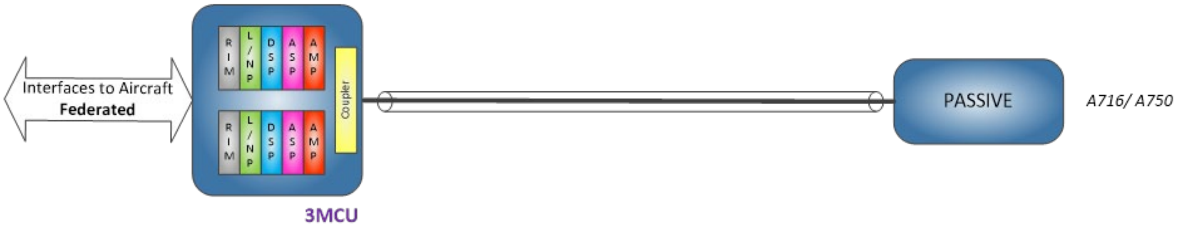

Figure 6-11 – Dual VHF Radio Example

6.3.3 L-Band Satcom (Inmarsat) Federated (Compact Configurations)

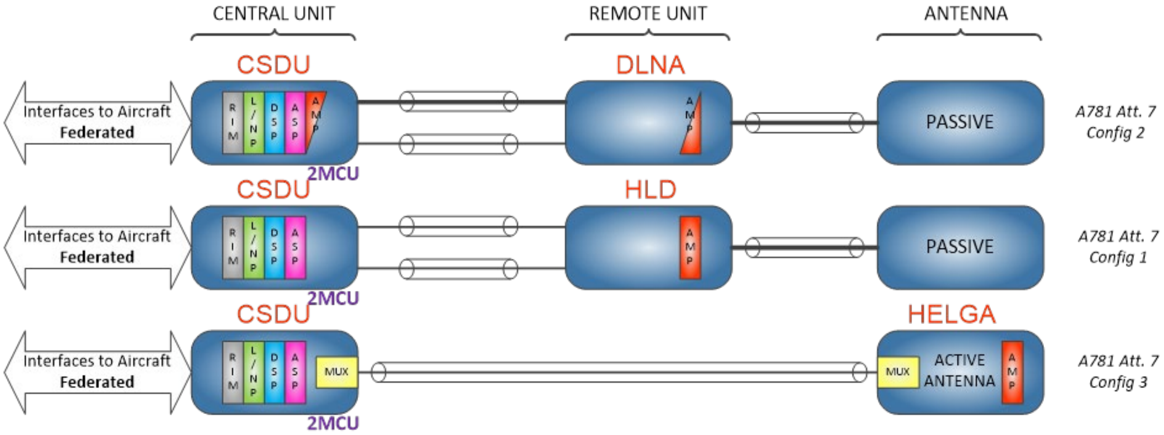

Figure 6-12 – L-Band Satcom Example 1

6.3.4 L-Band Satcom (Iridium) Federated

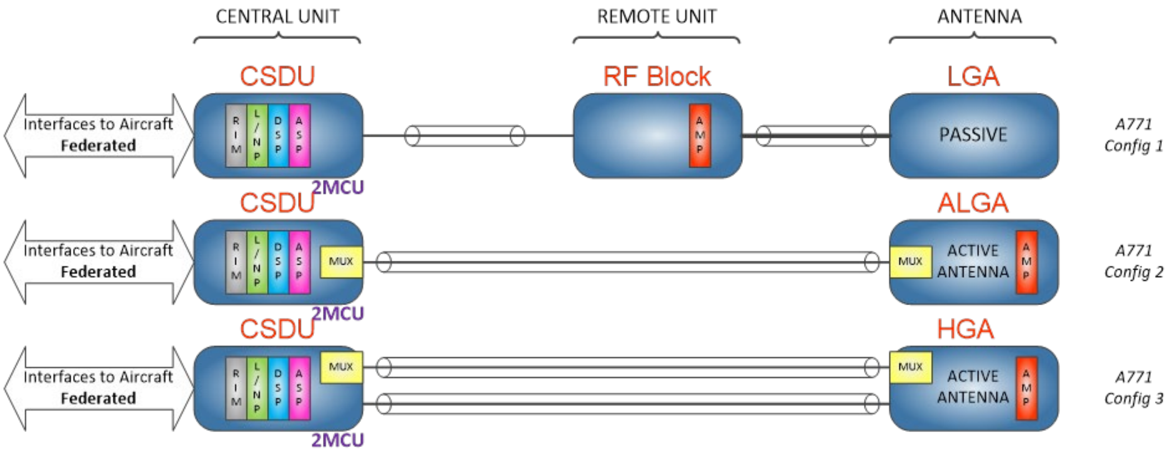

Figure 6-13 – L-Band Satcom Example 2

6.3.5 LDACS

No physical architecture defined (standardized) at this time.

6.3.6 AeroMACS

No physical architecture defined (standardized) at this time.

6.4 Legacy Radio Architectures (Navigation)

This section shows the existing Navigation architectures in a consistent style to that being used for discussion of future distributed radio architectures.

6.4.1 ILS (Localizer/Glideslope) Federated

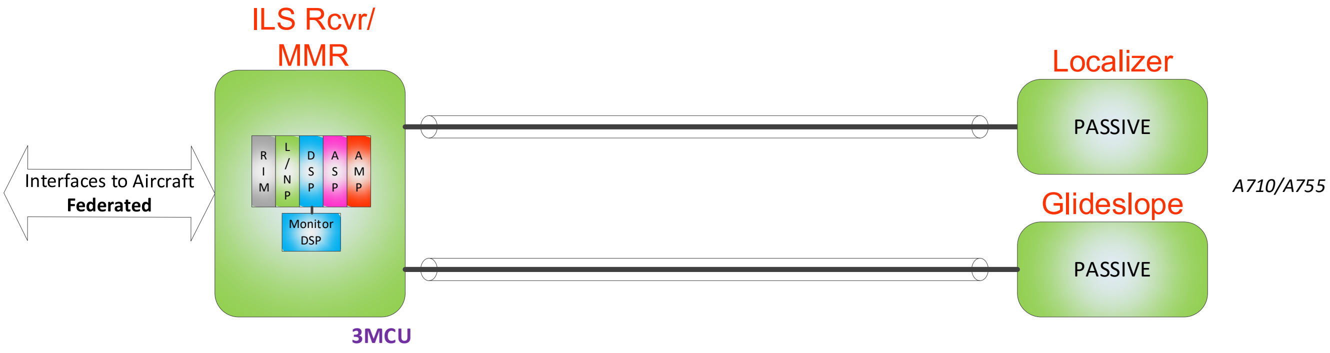

Figure 6-14 – Federated ILS Example

6.4.2 VOR Federated

Figure 6-15 – Federated VOR Example

6.4.3 Marker Beacon (MB) Federated

Figure 6-16 – Federated MB Example

6.4.4 LRRA Federated

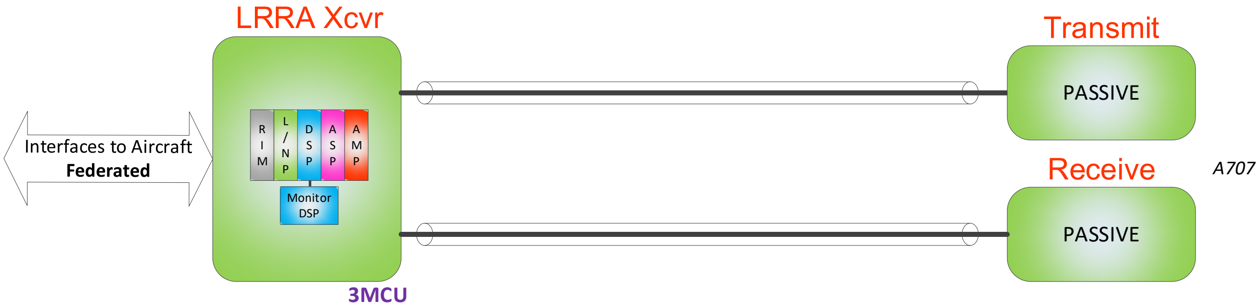

Figure 6-17 – Federated LRRA Example

6.4.5 GNSS Federated

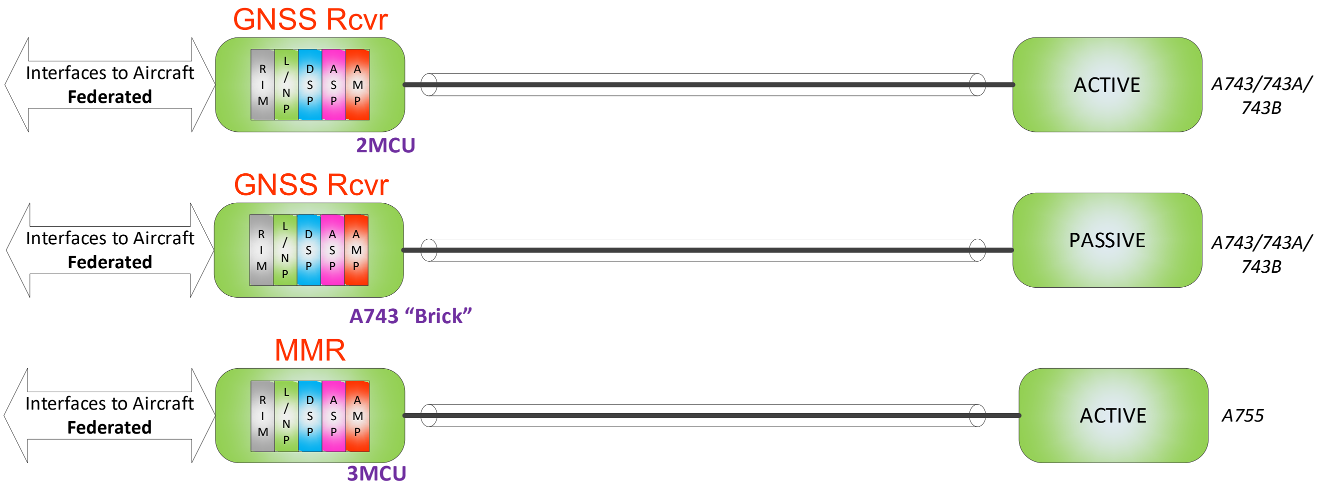

Figure 6-18 – Federated GNSS Example

{Editor's Note: For MMR and GNSS Rcvr config, move AMP block into the Active Antenna. Also, show A743 Brick at a remote location}.

6.4.6 GLS/VDB Federated

Figure 6-19 – Federated GLS/VDB Example

6.4.7 DME Federated

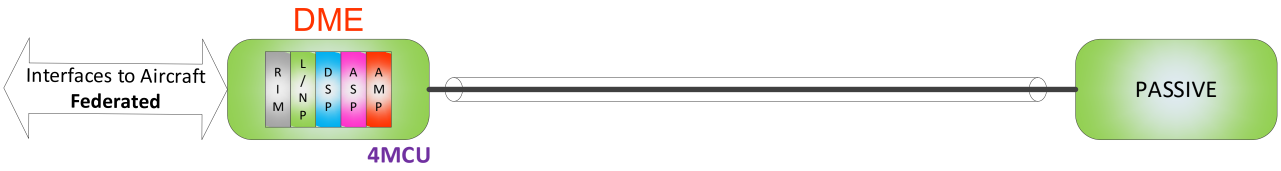

Figure 6-20 – Federated DME Example

{Editor's Note: Reference A709}.

6.5 Legacy Radio Architectures (Surveillance)

This section shows the existing Surveillance architectures in a consistent style to that being used for discussion of future distributed radio architectures.

6.5.1 ATC Transponder

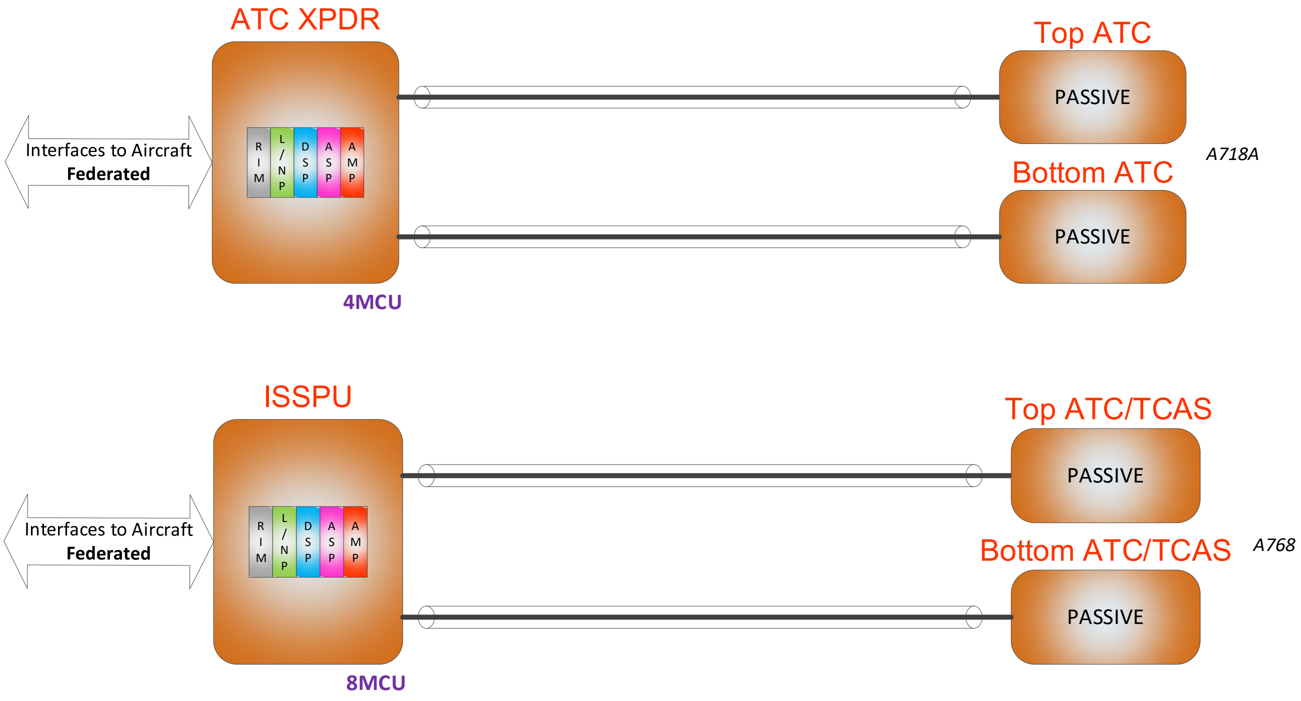

Figure 6-21 – Federated ATC Example

6.5.2 ADS-B Out

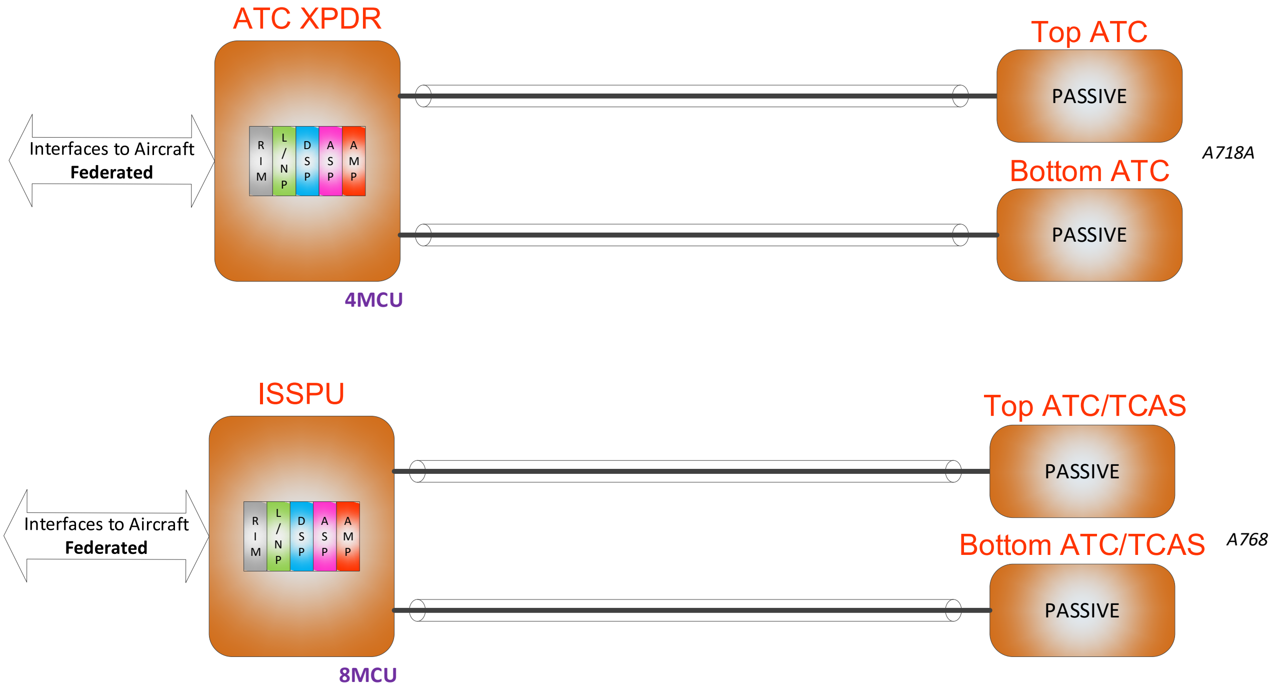

Figure 6-22 – Federated ADS-B Out Example

6.5.3 TCAS/ACAS-X$_A$

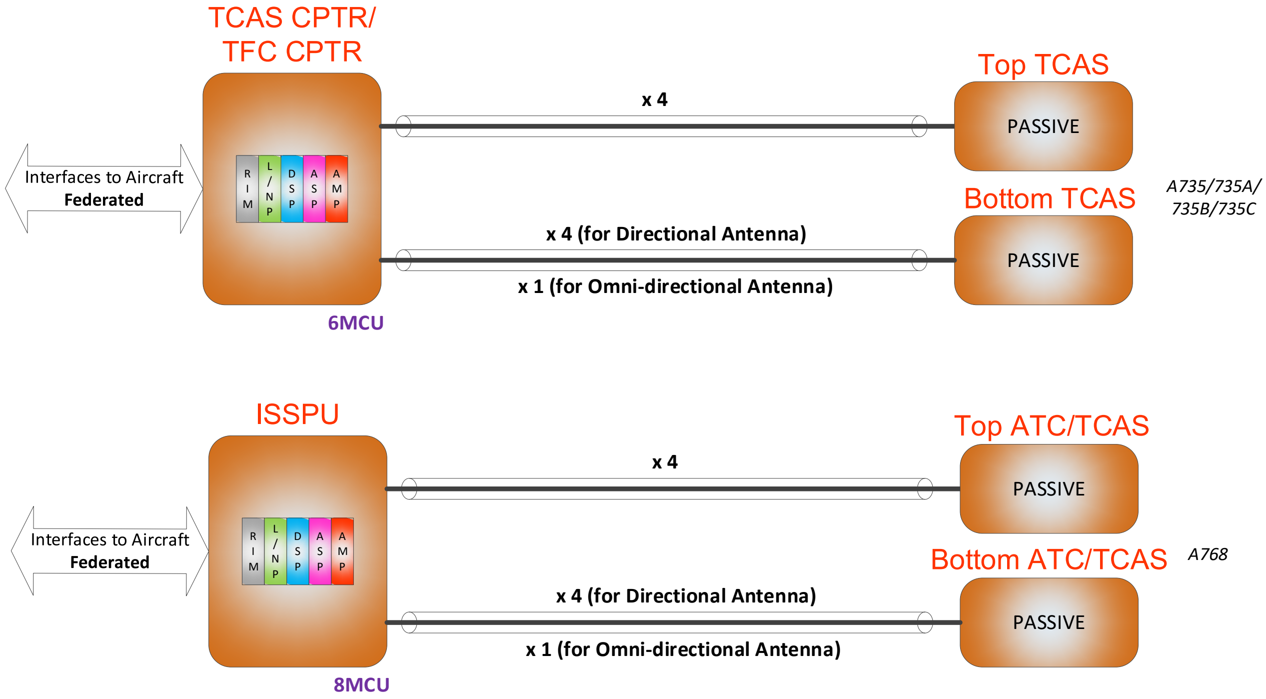

Figure 6-23 – Federated TCAS/ACAS-X$_A$ Example

6.5.4 ADS-B In

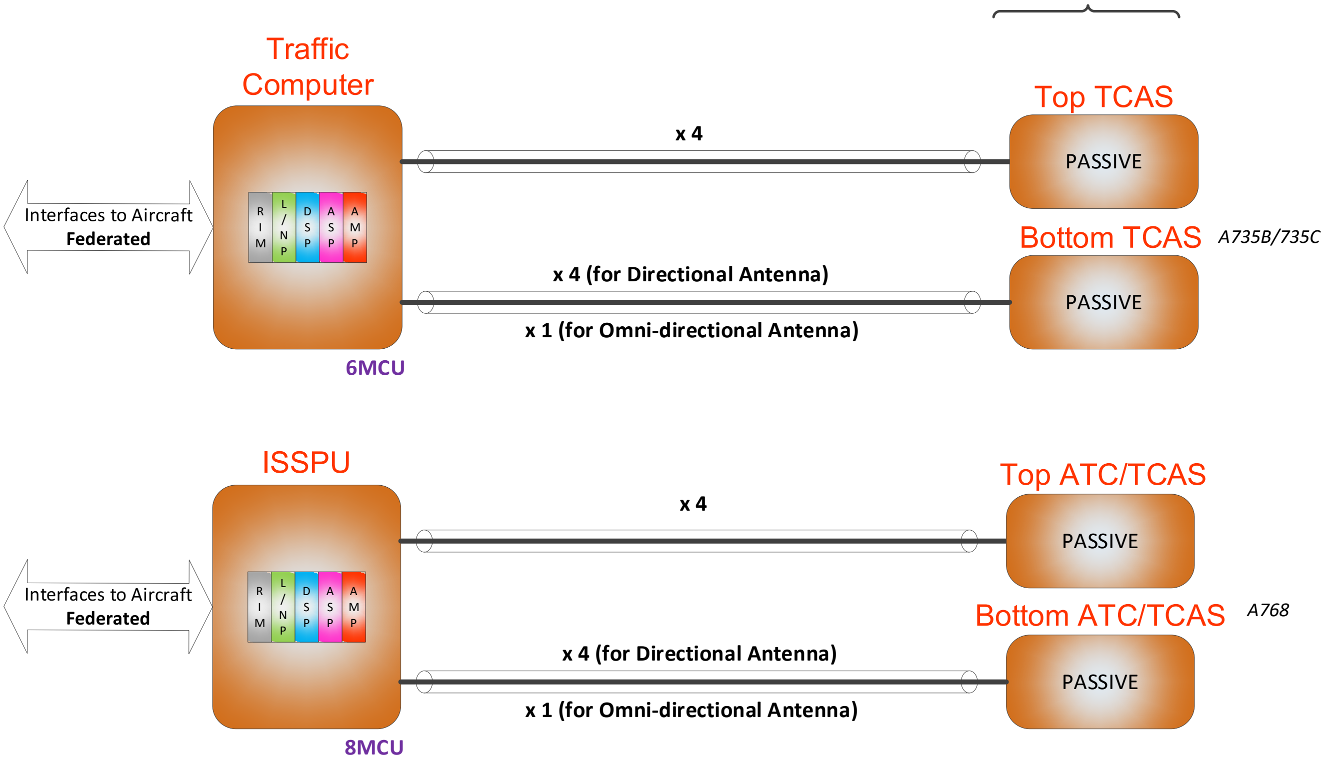

Figure 6-24 – Federated ADS-B In Example

6.6 Hybrid Distributed Architecture

Note: The inclusion of this section in the final document will depend on the utility of this approach which is to be determined.

It is likely that the introduction of a fully distributed architecture with new interfaces into other aircraft systems will require a new aircraft type and, even then, will lack the necessary pedigree from in- service operation to make this possible.

A potential route to obtaining the necessary pedigree would be to accommodate a mix of distributed radios with the traditional federated radios. Further, those systems which are distributed may make use of a centralized unit that provides interfaces to the aircraft systems which are compatible with the existing federated standards. **They may interface directly to a general-purpose computing platform using a network interface.**

The examples below are for L-Band Satcom, but the principle can easily be applied to any other radio system.

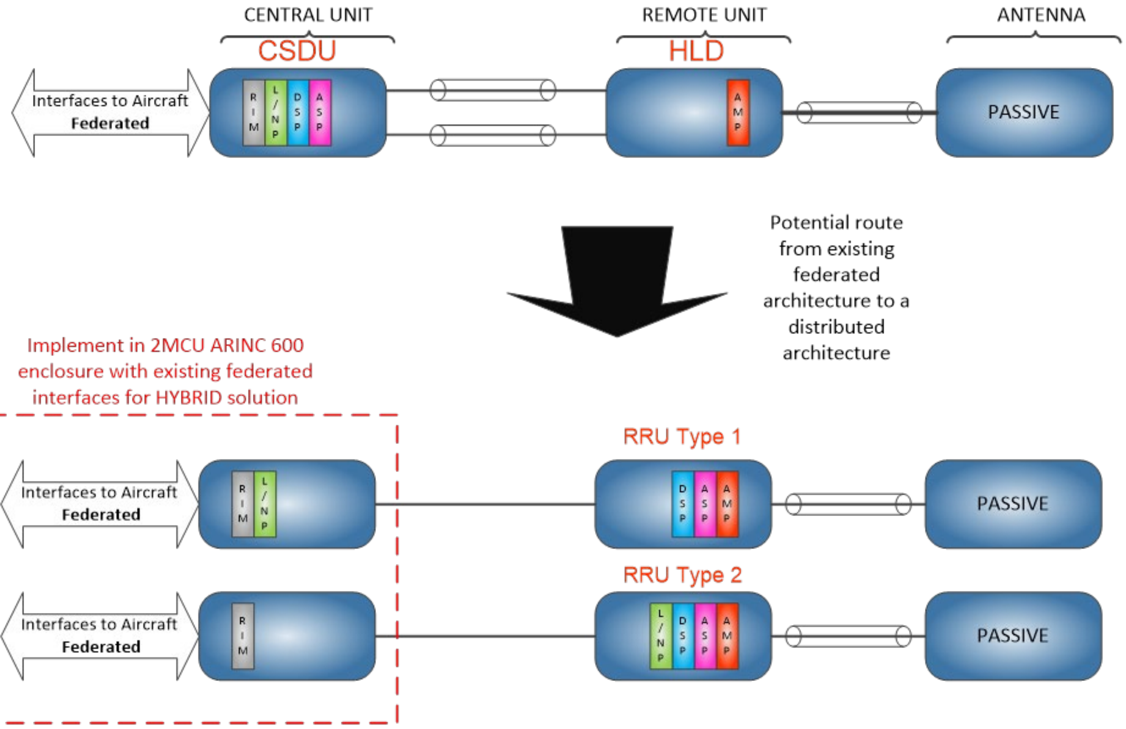

Figure 6-25 – Example Compact Satcom (ARINC 781)

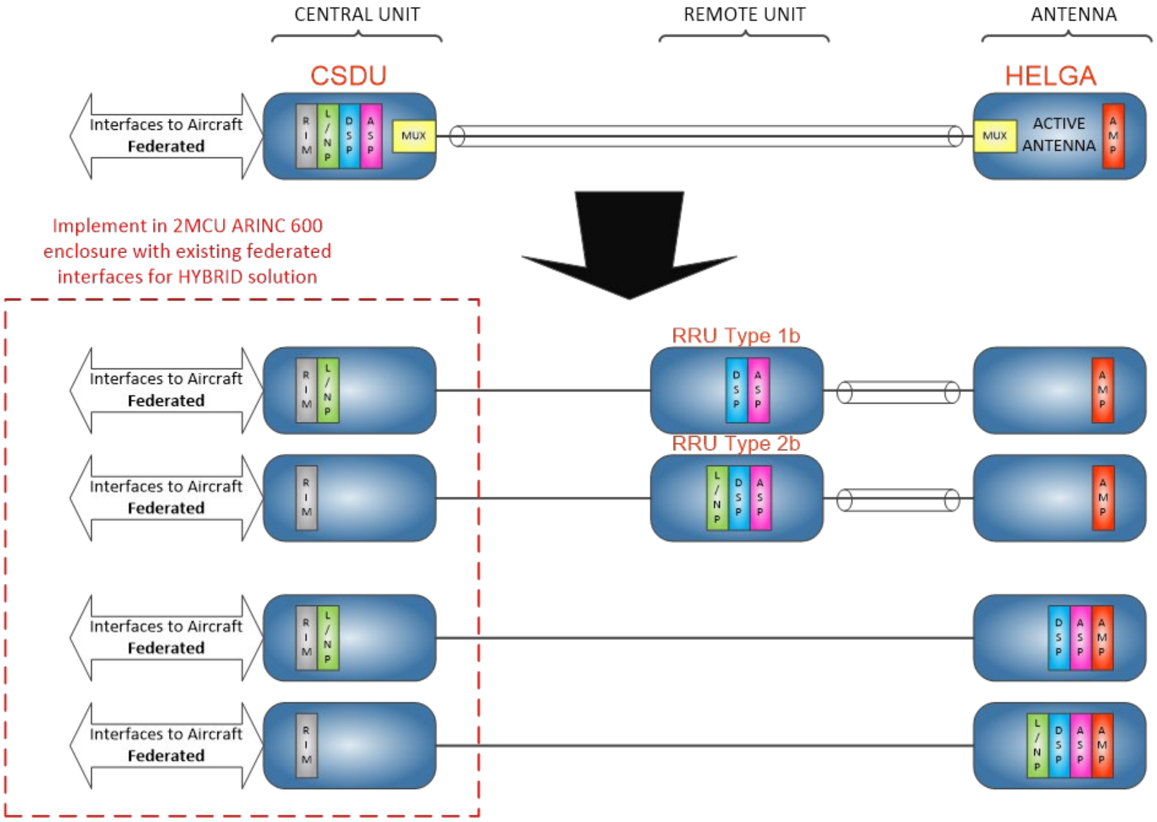

Figure 6-26 – Hybrid Architecture Example

7.0 REMOTE RADIO UNITS (RRU)

7.1 Installation

Remote Radio Units (RRUs) are envisioned to be mounted between the fuselage and the cabin panels of the aircraft, or in other distributed installation locations outside the avionics equipment bay. In these cases, the traditional packaging standards defined by ARINC Specification 600 may not be appropriate. For example, ARINC 600 forced-air cooling will not be available. The equipment may also be subjected to condensing moisture conditions which will restrict the use of cooling holes.

Internal RRU fans could be used to provide air circulation for cooling. However, internal cooling fans are undesirable from a noise and reliability perspective and would need to be assessed. EMI performance needs may vary by fuselage types and equipment locations, especially when considering that the electronics may be mounted in close proximity to its own antenna, or the antenna(s) of other systems. Radio packaging concepts are shown in Section 7.4.

Figure 7-1 illustrates potential areas where Remote Radio Units could be installed.

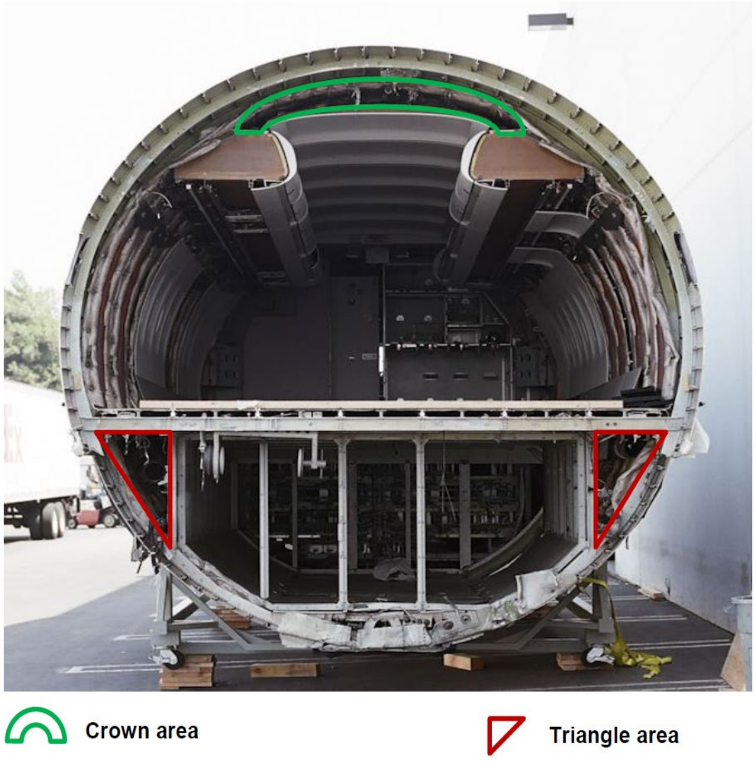

Figure 7-1 – Potential Remote Radio Unit Location Areas

7.2 Power

Remote Radio Units should use 28 Vdc input power.

7.3 Environmental Requirements (In-Work)

Table 7-1 – RRU Environmental Requirements

Environmental Requirements	ED-14/ DO-160 Section	Category	Applicability Criteria	Airframe Requirements
Temperature & Steady State Altitude	4	A1	Flight deck/cabin (pressurized and controlled temperature areas, not including crown)	(1)
		A2	Any other pressurized and partially controlled temperature areas (e.g., cargo areas)	
Altitude: Decompression / Overpressure	4	A1	Flight deck or cabin	
		A2	Any other pressurized section	
Temperature Variation	5	C	Flight deck or cabin (temperature controlled areas)	
		B	Any other internal area of the aircraft (non-temperature controlled or partially temperature controlled areas)	
Humidity	6	A	Pressurized area	
Operational Shock	7	A / D / B / E	All zones	(2)
Crash Safety Impulse	7	B, E	Equipment or part thereof that, if detaches from installation in the event of a crash, could cause injury to people or damage to the following equipment: Equipment belonging to fire detection or extinguishing system Emergency evacuation equipment	(2)

7.0 REMOTE RADIO UNITS (RRU)

Environmental Requirements	ED-14/ DO-160 Section	Category	Applicability Criteria	Airframe Requirements
			Equipment belonging to fuel, hydraulic, or oxygen systems, whose leakage could fuel a fire during a crash event	
Operational Vibration	8	R	For equipment for which resistance to the effects of long exposure to vibration is required	(2)
		H	**High-level, short duration transient vibration encountered during engine fan blade loss.**	(2)
Explosion Proofness	9	N/A	Not required for any CNS system	
Waterproofness	10	R	Pressurized areas close to a door or hatch that can be exposed to the outside environment	
		W	Internal areas where condensation occurs	
Fluids Susceptibility	11	F	All areas	(3)
Sand & Dust	12	S	Pressurized areas close to a door or hatch that can be exposed to the outside environment and not protected (e.g., by a lining)	
		D	Other equipment located in pressurized areas	
Fungus Resistance	13	F	All areas	
Salt Fog	14	T	**Category T: 2 cycles of 48 hours each.** **This is the most severe category [for RRU installed in pressurized**	

7.0 REMOTE RADIO UNITS (RRU)

Environmental Requirements	**ED-14/ DO-160 Section**	**Category**	**Applicability Criteria**	**Airframe Requirements**
			areas close to a door or hatch that can be exposed to the outside environment and not protected (e.g., by a lining)]	
Magnetic Effects	15	**Z, A, B, or C**	**Category is dependent on equipment location and distance from magnetic compass:** **Z: D ≤ 0.3m** **A: 0.3m < D ≤ 1m** **B: 1m < D ≤ 3m** **C: D ≥ 3 m** Equipment located close to the flight deck could affect the standby magnetic compass.	
Power Input	16	**A, B, or Z + sub-category R (ripple test)**	**Test category is dependent upon the type of 28 Vdc aircraft power source.**	
Voltage Spike	17	**A**		
Audio Frequency Conducted Susceptibility – Power Inputs	18	**R, B, or Z**	**Test category is dependent upon the type of 28 Vdc aircraft power source.**	
Induced Signal Susceptibility	19	**C() or Z() depending upon the installation and the aircraft's primary power source**	**CC is for installations with long wire runs or minimum separation.**	(6)
Radio Frequency Susceptibility	20	W / R	EMH Category A, EMH Category B, C, D	(6)
Radio Frequency Emissions	21	**L, M,H, P or Q**	**Category is dependent on equipment location.**	(6)
Lightning Indirect Effects	22	**Per DO-160G §22.3**		(6)
Lightning Direct Effects	23	N/A		
Icing	24	N/A		

7.0 REMOTE RADIO UNITS (RRU)

Environmental Requirements	ED-14/ DO-160 Section	Category	Applicability Criteria	Airframe Requirements
Electrostatic Discharge	25	A		
Flammability	26	C		(4)
Smoke & Toxicity	--N/A	N/A		(5)

Notes:

1. Ground Survival High Temperature for equipment in Crown area is +95 °C.
2. For equipment + fixture; each airframe manufacturer has specific vibration and acceleration requirements (including PRA: Nose Wheel Imbalance, Fan Blade Out, and Sustained Engine Imbalance).
3. Each airframe manufacturer has specific list of fluids and temperatures.
4. Each airframe manufacturer has specific requirements: RTCA DO-160 Section 26 could be an acceptable means.
5. Each airframe manufacturer has specific requirements.
6. Each airframe manufacturer has specific requirements. Test levels vary depending on safety objectives and criticality (i.e., DAL), as well as Electromagnetic Hazard category of the equipment.

7.4 Form Factors/Packaging

General requirements for the packaging and installation of remote radio units presents a challenge when compared to traditional avionics located in the equipment bay. In order to place the radio electronics near the antenna, the installation must consider the volume of space available, structural mounting performance, thermal performance, EMI, and a change in the maintenance concept of the installation.

When mounted between the fuselage and the cabin panels of the aircraft, or in other distributed installation locations outside the avionics equipment bay, ARINC 600 forced-air cooling is not available. The equipment may also be subjected to condensing moisture conditions which restricts the use of cooling holes. Additionally, internal RRU fans could be used to provide air circulation for cooling. However, internal cooling fans are undesirable from a noise and reliability perspective and would need to be assessed. EMI performance needs may vary by fuselage types and positions, especially when considering that the electronics may be mounted in close proximity to its own antenna, or the antenna(s) of other systems.

By way of an example to address design requirements and promote a standard approach to packaging, **ARINC Specification 836A:** *Cabin Standard Enclosures* provides some level of standardization. The reader should keep in mind that ARINC 836A was prepared to support cabin systems. ARINC 836A provides general guidelines for design of the enclosure.

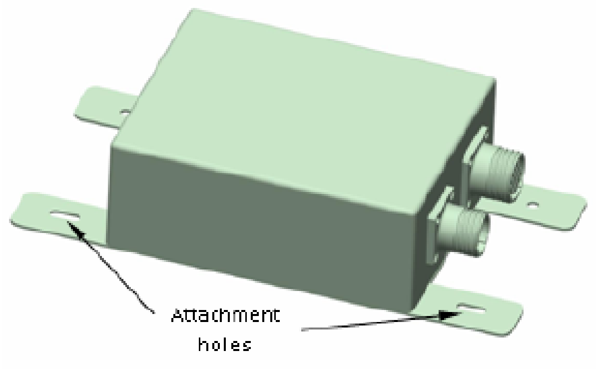

Figure 7-2 – ARINC 836A Type I Enclosure Example

The benefits of ARINC 836A Type I packaging include standardization of mounting footprint and enclosure volume. Thermal dissipation is achieved through conduction to the attachment points, or convection into the surrounding air. Though increase in temperatures within the cabin and a lack of forced-air cooling may reduce predicted reliability when compared to electronics installed in the avionics equipment bay, it has been determined analytically and through prototype testing that relatively power-dense avionics can be sufficiently cooled in these conditions when designed for conductive thermal dissipation.

When considering downsides, ARINC 836A Type I packaging offers full freedom for connector selection and position, which can create challenges when desiring a standardized connector solution.

ARINC 836A defines a Type II small form-factor enclosure tailored to the cabin environment. It includes a tray installation/ejection mechanism that requires no tools. This form factor is referred to as a Miniature Module.

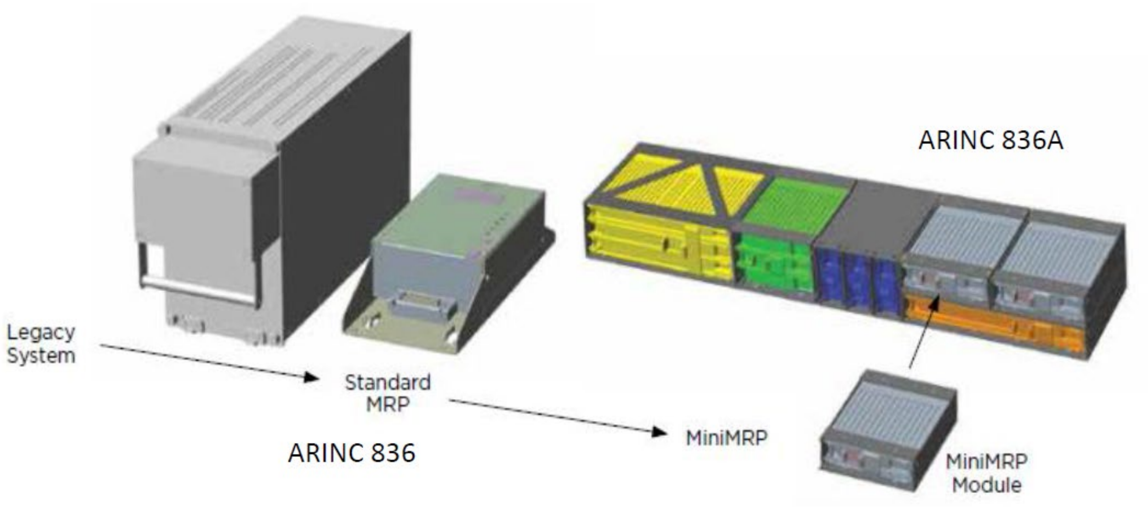

Figure 7-3 – Design Progress using ARINC 836A as an Example

ARINC 836A Type II packaging is not well-suited for thermal dissipation. The specification includes very little conductive dissipation, while convective dissipation is limited by the enclosure volume and installation. The specification also offers only four form-factors, which may not be sufficient when considering the variations between radios in the CNS suite.

In order to meet requirements for RF-based CNS systems, design concepts similar to that provided in ARINC 836A show promise, but it need refinement to meet packaging considerations for the Distributed Radio concept.

7.5 Connectors

Note that each Airframe manufacturer has a list of connectors that are allowed to be used. This list is used to limit the variability and the number of different connector part numbers.

While ARINC 836A Type I provides guidelines for connector position, it does not specify connector size, shape, or composition. This may meet the needs of the radio designer, but it is undesirable for industry standardization. ARINC 836A Type II specifies the connector shell size and position, however, the modular nature of ARINC 836A Type II enclosures limits the positioning of connectors to each quadrant. This is opposed to a centerline position that adjusts with the size of the box, similar to ARINC 600. While the connector series is addressed by EN-4165, connector suppliers will need to develop standardized plugs and backshells to meet the needs of avionics at the same level of detail provided by ARINC 600. Standard plug types and standard layouts are not specified in ARINC 836A.

Circular connectors, such as the Mil-Std 38999 series, are expected to meet the functional requirements and the environmental conditions.

At present, collaboration between the CNS system supplier and the airframe manufacturer is necessary to select a connector that meets specific system requirements.

Connector standards that meet the needs of this Distributed Radio concept are TBD.

7.6 Interfaces

A shared digital aircraft network is the recommended RRU interface to the general purpose processor unit.

Power is expected to be supplied as defined Section 7.2.

Antenna interface.

Configuration programming (e.g., location installation)

7.7 Separation/Isolation

Avionics equipment must be installed with separation requirements outlined in FAR 25.1309 and other appropriate standards.

Regarding aircraft with carbon fiber composite fuselage, the data obtained from the Airbus A350 shows there is no risk to the structure if the system produces local temperatures of no more than 95° C.

7.8 Interoperability

The RRU is a component of the radio system. The radio system provides both TSO and aircraft-specific (non-TSO) functionality. The aircraft-specific functionality may include the maintenance system interface, data loading system interface, analog or digital audio system interface, data link system interface, etc. The same supplier/entity should supply both the Remote Radio Unit that hosts the TSO functionality and the aircraft-specific software that may be hosted in a general-purpose computing platform that may not necessarily be provided by the same supplier. The physical interface between the Remote Radio Unit and the general-purpose computing platform should be standardized.

8.0 ANTENNAS

8.1 Installation

Currently, most CNS antennas are mounted on the fuselage surface. Some antennas (e.g., localizer and glideslope antennas) are located under the nose radome. The antennas are mounted using threaded fasteners. Various methods are used in order to reduce moisture intrusion and for corrosion prevention, including the use of primer or conductive gel gaskets.

Antennas which have a large baseplate area (e.g., TCAS antennas and Satcom antennas) are mounted using an antenna adapter plate in order to match the aircraft’s radius of curvature. The adapter plate will be flat on the antenna side that matches the antenna’s flat baseplate, and the side facing the fuselage will be curved in order to match the fuselage’s curvature. The adapter plate is typically furnished by the airframer as part of the antenna installation.

8.2 Power

Most CNS antennas are passive and do not require input power. However, some current CNS antennas do have internal amplifiers that receive power. These include:

1. ARINC 743 Active GNSS Antennas which receive power via the coaxial cable center conductor.
2. ARINC 781 Inmarsat Satcom HELGA which receive power via the coaxial cable center conductor.
3. ARINC 771 Iridium Satcom ALGA and HGA which receive power via the coaxial cable center conductor.

8.3 Environmental Requirements

Table 8-1 – Antenna Environmental Requirements

Environmental Requirements	ED-14/ DO-160 Section	Category	Applicability Criteria	Airframe Requirements
Temperature & Steady State Altitude	4	D2	Unpressured and uncontrolled temperature areas operating up to 50,000 ft. (15,200 m) MSL	
Temperature Variation	5	A	External/unpressurized area of the aircraft; 10° C/min (minimum)	
Humidity	6	C	External humidity environment.	
Operational Shock	7	A / D / B / E	All zones	(1)
Crash Safety Impulse	7	B, E	If antenna detaches from installation in the event of a crash, it could cause injury to people or damage to equipment belonging to fuel, hydraulic, or oxygen systems, whose leakage could fuel a fire during a crash event	(1)
Operational Vibration	8	R	For equipment for which resistance to the effects of long exposure to vibration is required	(1)
		H	High-level, short duration transient vibration encountered during engine fan blade loss.	(1)
Explosion Proofness	9	N/A	Not required for any CNS system	

8.0 ANTENNAS

Environmental Requirements	ED-14/ DO-160 Section	Category	Applicability Criteria	Airframe Requirements
Waterproofness	10	R	Antenna subjected to driving rain or where water may be sprayed on it from any angle.	
		W	Antennas installed in internal areas (e.g., nose radome) where condensation occurs	
Fluids Susceptibility	11	F	Antennas installed in all areas	(2)
Sand & Dust	12	S	Antennas installed in all areas	
Fungus Resistance	13	F	Antennas installed in all areas	
Salt Fog	14	T	Antennas exposed directly to the air during normal aircraft operations	
Magnetic Effects	15	Z, A, B, or C	Category is dependent on equipment location and distance from magnetic compass: Z: $D \leq 0.3m$ A: $0.3m < D \leq 1m$ B: $1m < D \leq 3m$ C: $D \geq 3$ m Antennas located close to the flight deck that could affect the standby magnetic compass.	
Power Input	16	N/A	Active antennas do not receive power directly from aircraft power.	
Voltage Spike	17	N/A	Active antennas do not receive power directly from aircraft power.	

8.0 ANTENNAS

Environmental Requirements	ED-14/ DO-160 Section	Category	Applicability Criteria	Airframe Requirements
Audio Frequency Conducted Susceptibility – Power Inputs	18	N/A	Active antennas do not receive power directly from aircraft power.	
Induced Signal Susceptibility	19	C() or Z() depending upon the installation and the aircraft's primary power source	C() is for installations with long wire runs or minimum separation	(3)
Radio Frequency Susceptibility	20	W / R	Test Cat. W required for EMH Category A. Test Cat. R required for EMH Category B, C, D	(3)
Radio Frequency Emissions	21	L, M,H, P or Q	Category is dependent on equipment location.	(3)
Lightning Indirect Effects	22	Per DO-160G §22.3		(3)
Lightning Direct Effects	23	1A/1B/1C/2A/2B/3N	Test category depends on the location of the antenna on the fuselage. Test applies to externally mounted antennas (not under the radome). In addition, antenna should not break apart such that it would create a hazard to the rest of the aircraft.	
Icing	24	A		
Electrostatic Discharge	25	A		
Flammability	26	N/A		
Smoke & Toxicity	--	N/A		

Notes:

1. For equipment + fixture; each airframe manufacturer has specific vibration and acceleration requirements (including PRA: Nose Wheel Imbalance, Fan Blade Out, and Sustained Engine Imbalance).
2. Each airframe manufacturer has specific list of fluids and temperatures.
3. Each airframe manufacturer has specific requirements. Test levels vary depending on safety objectives and criticality (i.e., DAL), as well as Electromagnetic Hazard (EMH) category of the equipment.

8.4 Form Factors/Packaging

{COMMITTEE DISCUSSION OF MATERIAL TO BE PLACED HERE}

8.5 Connectors

{COMMITTEE DISCUSSION OF MATERIAL TO BE PLACED HERE}

Circular connectors, such as the Mil-Std 38999 series, are expected to meet the functional requirements and the environmental conditions.

At present, collaboration between the CNS system supplier and the airframe manufacturer is necessary to select a connector that meets specific system requirements.

Connector standards that meet the needs of Antennas are TBD.

8.6 Interfaces

TBD

8.7 Separation/Isolation

Avionics equipment must be installed with separation requirements outlined in 14CFR 25.1309 and other appropriate standards.

8.8 Interoperability

TBD

9.0 SUMMARY OF CONCLUSIONS AND RECOMMENDATIONS

(This Section TBD)

ATTACHMENT 1 GLOSSARY DEFINITIONS

ATTACHMENT 2 ACRONYMS AND ABBREVIATIONS

ACAS-X	Airborne Collision Avoidance System
ACMS	Aircraft Condition and Monitoring Systems
ADS-B	Automatic Dependent Surveillance – Broadcast
AeroMACS	Aeronautical Mobile Airport Communication System
AIRB/CDTI	Airborne Situational Awareness/Cockpit Display of Traffic Information
AMC	Acceptable Means of Compliance
ATC	Air Traffic Control
BITE	Built In Test Equipment
CAVS	CDTI Assisted Visual Separation
CDN	**Common Data** Network
CDS	Cockpit Display System
CDTI	Cockpit Display of Traffic Information
CNS	Communication, Navigation, and Surveillance
DAL	Design Assurance Level
DME	Distance Measuring Equipment
DSP	**Digital Signal Processing**
EB	Expanded Beam
EE	Electrical and Electronics
EMH	**Electromagnetic Hazard**
EMI	Electromagnetic Interference
FHA	Functional Hazard Assessment
FIM	**Flight-deck Interval Management**
FMS	Flight Management System
GBAS	Ground Based Augmentation System
GLS	GNSS Landing System
GNSS	Global Navigation Satellite System
GPP	**General Purpose Processor**
GPS	Global Positioning System
HF	High Frequency
IFF	**Interrogate Friend or Foe**
ILS	Instrument Landing System
IM	Inner Marker
IMA	Integrated Modular Avionics

ATTACHMENT 2
ACRONYMS AND ABBREVIATIONS

ITP	In-Trail Procedure
LDACS	L-band Digital Aeronautical Communication System
LNA	**Low Noise Amplifier**
LRRA	Low Range Radio Altimeter
LRM	Line Replaceable Module
LRU	Line Replaceable Unit
MB	Marker Beacon
MEL	Minimum Equipment List
MM	Middle Marker
MOPS	Minimum Operational Performance Standard
MSL	Mean Sea Level
MTBF	Mean-Time Between Failure
MTBUR	Mean-Time Between Unscheduled Removal
OM	Outer Marker
OMD	Onboard Maintenance Documentation
OMS	On-Board Maintenance Systems
PFD	Primary Flight Displays
PTP	Precision Time Protocol
RA	Resolution Advisory
RF	Radio Frequency
RFI	Radio Frequency Interference
RRU	Remote Radio Unit
RTP	Real-Time Protocol
Satcom	Satellite Communication
SSR	Secondary Surveillance Radar
SURF	Surface Situational Awareness
SWaP	Size, Weight, and Power
TA	Traffic Advisory
TACAN	Tactical Air Navigation
TAWS	Terrain Awareness and Warning System
TCAS	Traffic Collision Avoidance System
TSN	Time Sensitive Network
TSO	Technical Standard Order
VDB	VHF Data Broadcast

ATTACHMENT 2
ACRONYMS AND ABBREVIATIONS

VHF	Very High Frequency
VOR	VHF Omni-directional Range