Wireless Avionics Intra-Communications (WAIC) for Commercial Aircraft

Passive Wireless Sensor Technology Workshop 2017

WAIC Status Update

Mike Franceschini, Honeywell, AVSI WAIC Team

12 October 2017

What is Wireless Avionics Intra-Communications (WAIC)?

- **WAIC is:**
  - Radiocommunication between two or more points on a single aircraft.
  - Integrated wireless and/or installed components to the aircraft.
  - Part of a closed, exclusive network required for operation of the aircraft.
  - Only for safety-related applications.
  - Based on short range radio technology (< 100m).
  - Low maximum transmit power levels of 10mW for low rate and 50mW for high rate applications
  - Mostly internal - within fuselage/cabin.
- **WAIC does not:**
  - Provide off-board air-to-ground, air-to-satellite, or air-to-air service.
  - Provide communications for passengers or in-flight entertainment.

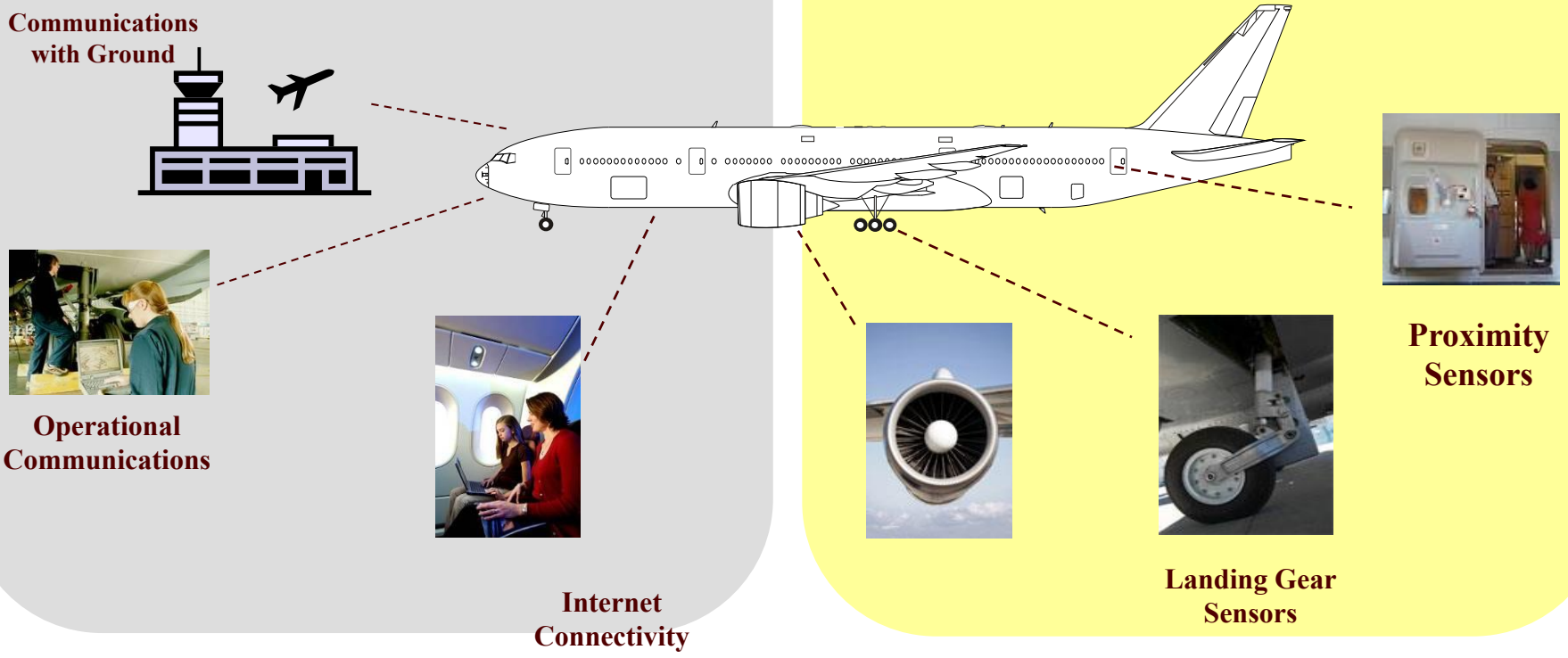
Examples of Aircraft Wireless Applications – Traditional systems vs. WAIC systems

Current Aircraft Communications:

- Safety-related communications
  - HF/VHF/Satellite communications
- Non-safety related communications
  - Passenger connectivity

WAIC Systems:

- Safety-related applications, e.g.
  - Sensors/Actuators
  - Additional wireless redundancy for wired communications



The Problem(s)

- A large commercial passenger aircraft has more than 100,000 wires with a total length of 470 km and weighing 5,700 kg
- There is about 30% of additional weight in harnessing and connectors
- About 30% of electrical wires are potential candidates for a wireless substitute!
- Wiring lacks dissimilar redundancy, has limited maintenance flexibility and access

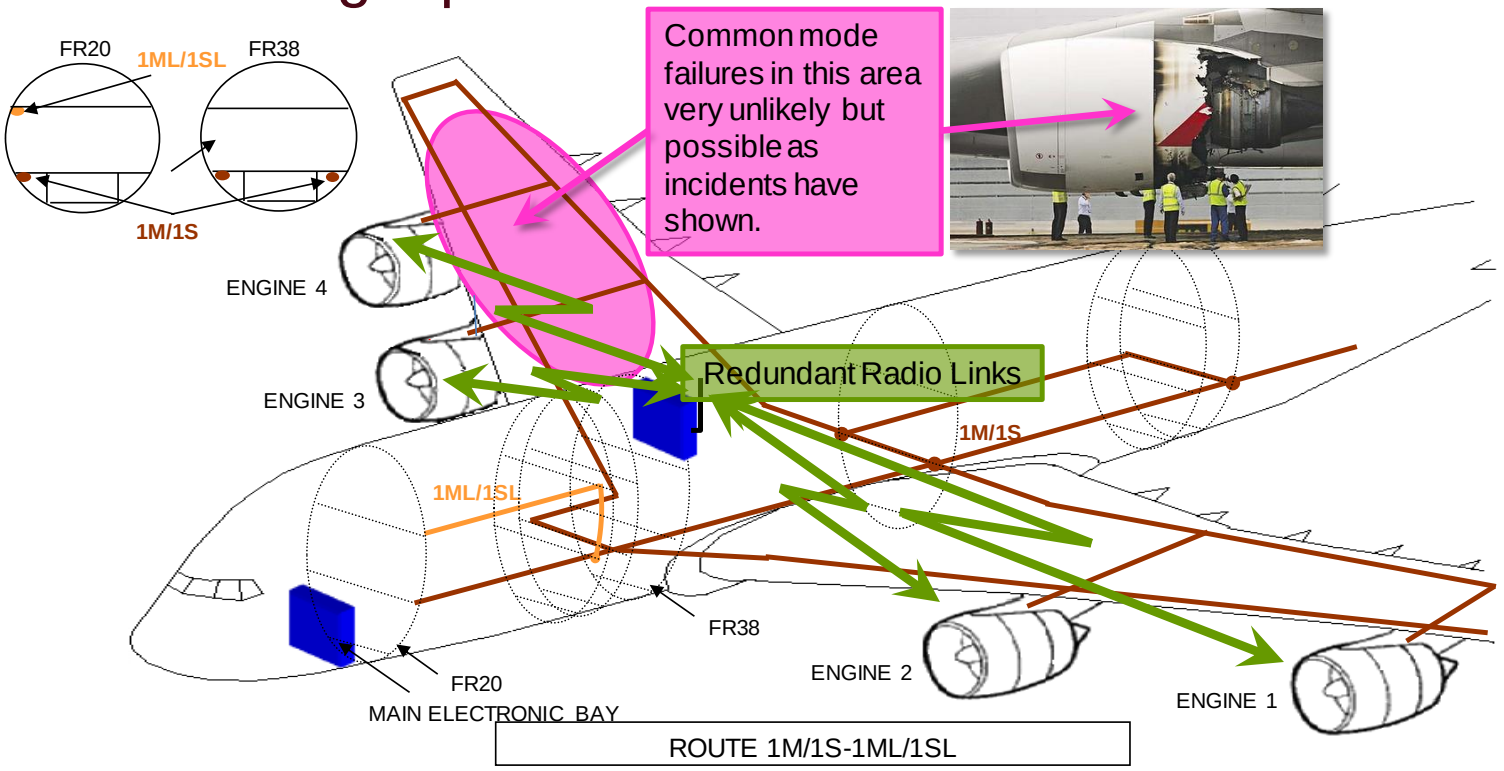
Importance of WAIC to Airlines

- **Safety Improvements:**
  - Provide dissimilar redundancy
  - Fewer wires means a reduction in connector pin failures, lower risk of cracked insulation & broken conductors.
  - Mesh networking could provide redundancy in emergencies.

- **Environmental Benefits:**
  - Reduced wiring and associated aircraft weight enables less fuel burn.
- **Increased Reliability**
  - Reduce amount of aging wiring; Simplify & reduce LCC of airplane wiring
  - Ability to obtain more data from aircraft systems and surfaces
  - Add new sensors and controls without additional wire routing
- **Provide operational efficiency & associated cost savings**
  - To monitor systems and surfaces that currently cannot be monitored without taking the aircraft out of service. (e.g., moving/rotating assemblies, parts)
  - Enhance reconfigurability, upgradability

Need for WAIC - Dissimilar Redundancy

- **Example: Redundant communication paths**
  - Route segregation, combined with redundant radio links, provides dissimilar redundancy and mitigates risk of single points of failure

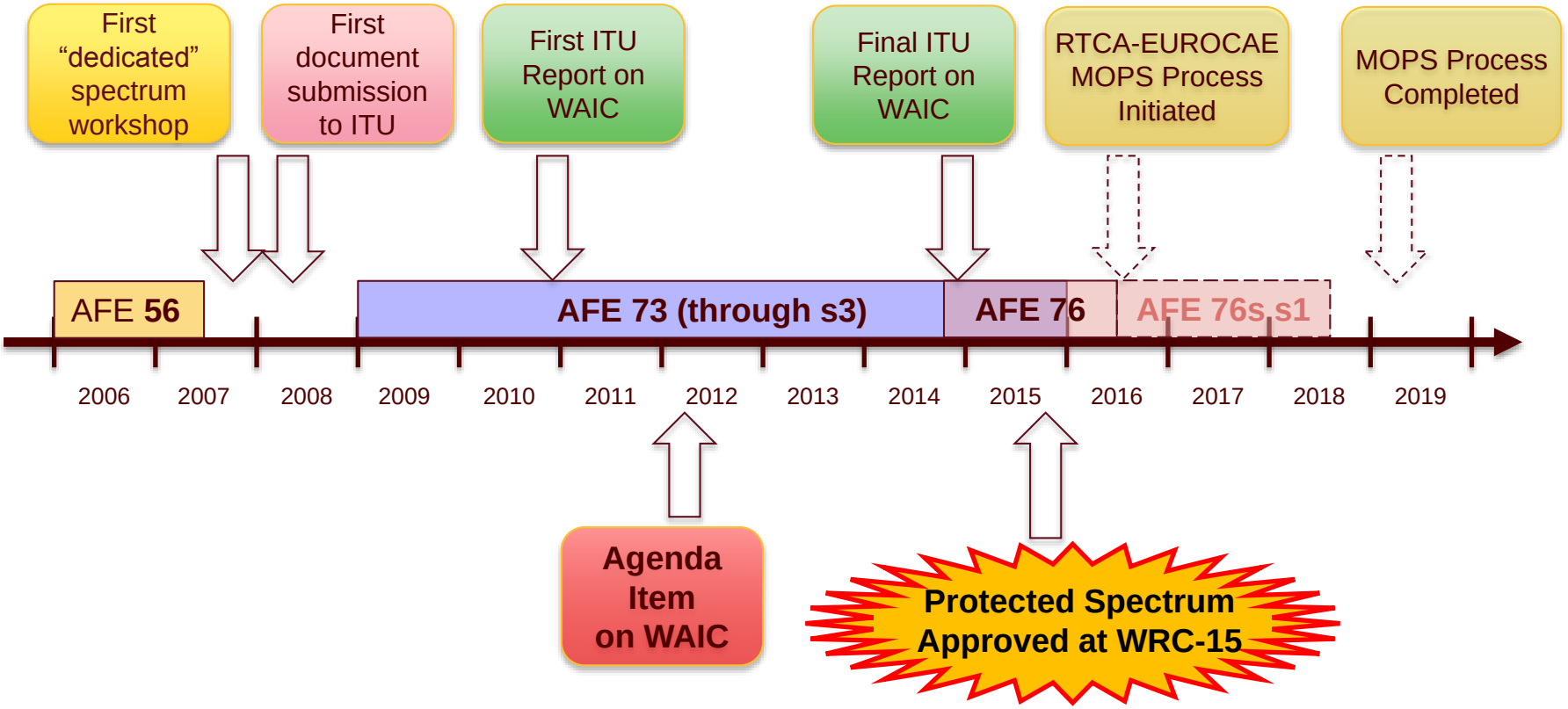


Questions

- Can existing wireless technologies be applied in a certified aircraft?
- What are the risks and requirements for implementing wireless technologies onboard?
  - Particularly to ensure safe operation between aircraft

- **Common industry/stakeholder stand is vital**
- **Wireless necessitates cooperation**
- **Regulations are required for safe co-existence (but not necessarily for interoperability)**
- **Stakeholders already addressing these questions through the AVSI, RTCA, EuroCae, ICAO**

WAIC Journey



Bandwidth requirements were developed by considering potential WAIC applications

- **Low Data Rate, Interior Applications (LI):**
  - Sensors: Cabin Pressure - Smoke Detection - Fuel Tank/Line – Proximity Temperature - EMI Incident Detection – Structural Health Monitoring - Humidity/Corrosion Detection
  - Controls: Emergency Lighting - Cabin Functions
- **Low Data Rate, Outside Applications (LO):**
  - Sensors: Ice Detection - Landing Gear Position Feedback - Brake Temperature - Tire Pressure - Wheel Speed - Steering Feedback - Flight Controls Position Feedback - Door Sensors Engine Sensors - Structural Sensors
- **High Data Rate, Interior Applications (HI):**
  - Sensors: Air Data - Engine Prognostic - Flight Deck/Cabin Crew Images/Video
  - Comm.: Avionics Communications Bus - FADEC Aircraft Interface - Flight Deck/Cabin Crew Audio / Video (safety-related)
- **High Data Rate, Outside Applications (HO):**
  - Sensors: Structural Health Monitoring
  - Controls: Active Vibration Control

WAIC Application Categories - Data Rate Estimates

High Rate -Outside

Application	Type of benefit	Period of operation	New or existing application
Avionics comm. bus			
Structural sensors			
External imaging sensors (camera etc.)			
Total			

High Rate - Inside

Application	Type of benefit	Period of operation	New or existing application
Avionics comm. bus			
Air data sensors			
FADEC aircraft interface			
Engine prognostic sensors			
Flight deck and cabin crew voice			
Flight deck and cabin crew still imagery			
Flight deck and cabin crew motion video			
Flight -Operations related digital data			
Total			

Low Rate - Outside

Application	No. of nodes simultaneously operational	Period of operation	New or existing application
Ice detec			
Landing (proximity)			
Landing gear tire pressure, brake tempera hard landing			
Landing gear wheel speed skid contr position feed steerin			
Flight contro sensors, po feedback and paramet			
Additional pr sensors, aircr			
Engine se			
Cargo comp data			
Structural s			

Low Rate - Inside

Application	Type of benefit	Net peak data rate per data-link (kbps)	Net average data rate per data-link (kbps)	No. of nodes simultaneously operational	Period of operation	New or existing application
Cabin pressure	Wire reduction			11	Park, taxi, takeoff, cruise, landing	Existing
Engine sensors	Wire reduction, maintenanc enhancement			108	Park, taxi, takeoff, cruise, landing	Existing and new
Smoke sensors (unoccupied areas)	Wire reduction, maintenance enhancement, safety enhancement	0.1	0.1	30	Park, taxi, takeoff, cruise, landing, taxi	Existing
Smoke sensors (occupied areas)	Wire reduction, flexibility enhancement safety enhancement	0.1	0.1	30	Park, taxi, takeoff, cruise, landing	Existing
Fuel tank/line sensors	Wire reduction, safety enhancement, flexibility enhancement, maintenance enhancement	0.2	0.2	80	Park, taxi, takeoff, cruise, landing, taxi	Existing
Proximity sensors, passenger and cargo doors, panels	Wire reduction, safety enhancement, operational enhancement	0.2	0.02	60	Park, taxi, takeoff, cruise, landing, taxi	Existing
Sensors for valves and other mechanical moving parts	Wire reduction, operational enhancement	0.2	0.2	100	Park, taxi, takeoff, cruise, landing, taxi	Existing and new
ECS sensors	Wire reduction, operational enhancement	0.5	0.05	250	Park, taxi, takeoff, cruise, landing	Existing and new
EMI detection sensors	Safety enhancement	1.0	0.01	30	Park, taxi	New
Emergency lighting control	Wire reduction, flexibility enhancement	0.5	0.1	130	Park, taxi, takeoff, cruise, landing	Existing
Aircraft lighting control	Wire reduction, flexibility enhancement	0.5	0.1	1 000	Park, taxi, takeoff, cruise, landing	Existing
Cabin removables inventory	Operational improvement	0.1	0.01	1 000	Park	New
Cabin monitoring	Wire reduction, flexibility enhancement	0.5	0.05	500	Park, taxi, takeoff, cruise, landing	Existing and new
Structural sensors	Wire reduction, flexibility enhancement, safety enhancement	0.5	0.3	300	Park, taxi, takeoff, cruise, landing	New
Temperature / humidity for corrosion detection	Wire reduction, safety enhancement, operational enhancement	0.1	0.01	260	Park, taxi, takeoff, cruise, landing	Existing and new
Electrical power distribution, control and monitoring	Wire reduction, operational enhancement	0.1	0.01	250	Park, taxi, takeoff, cruise, landing	Existing and new
	Totals:	1 420.2*	394.3*	4 139		

WAIC spectrum requirements for all application categories

WAIC application category	Application data rate in kbps (P_{eff})	Protocol overhead factor (α)	Channelization overhead factor (β)	Multiple-aircraft factor (m)	Modulation efficiency in bps per Hz (η)	WAIC Spectrum requirements *MHz* (F)
Low data rate Inside (LI)	394	1.38	1.92	1.0	0.096	**11**
Low data rate Outside (LO)	856	1.38	1.92	1.7	0.096	**40**
High data rate Inside (HI)	18385	1.04	1.20	1.0	0.723	**32**
High data rate Outside (HO)	12300	1.04	1.20	2.9	0.723	**62**

Estimated that 145 MHz Total Spectrum Allocation Needed

Proposed Allocation: Radio Altimeter Band

- **200 MHz from 4.2-4.4 GHz: incumbent allocation is Aeronautical Radionavigation Service (ARNS) used exclusively by Radio Altimeters**
- **Pros:**
  - Already existing aeronautical allocation, as suggested by WRC Agenda Item
  - An internal aeronautical matter – less outside opposition
  - Radio Altimeters are “under control” of OEMs – band sharing is easier to coordinate
  - Aviation has been criticized for inefficient use of spectrum, and adding another user could strengthen this bands’ protection against attacks from hostile interests
- **Cons:**
  - Interference from altimeters potentially difficult to deal with
  - Up to three independently operating altimeters per aircraft
  - Spectrum effectively available at any given time is less than 200 MHz
  - Much less bandwidth than initially contemplated in Report M.2197
  - No officially recognized protection criteria existed for Radio Altimeter – difficult to demonstrate coexistence
- **Final decision: add AM(R)S allocation for WAIC to the band**
  - All other alternatives proved much less attractive
  - This was the only truly feasible choice; co-existence is still mandated & challenging

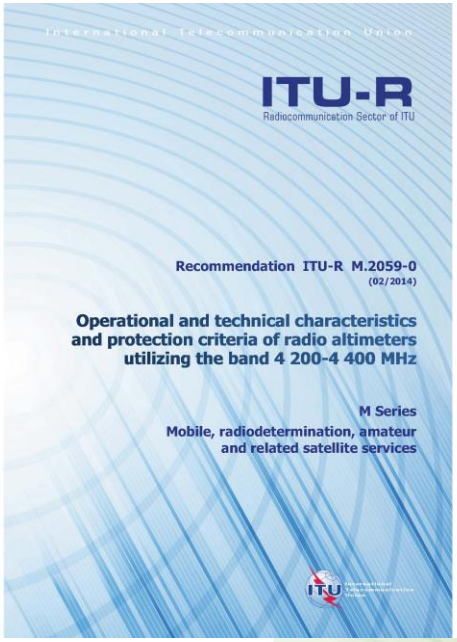
ITU-R Documents and Studies Completed by AVSI WAIC Team

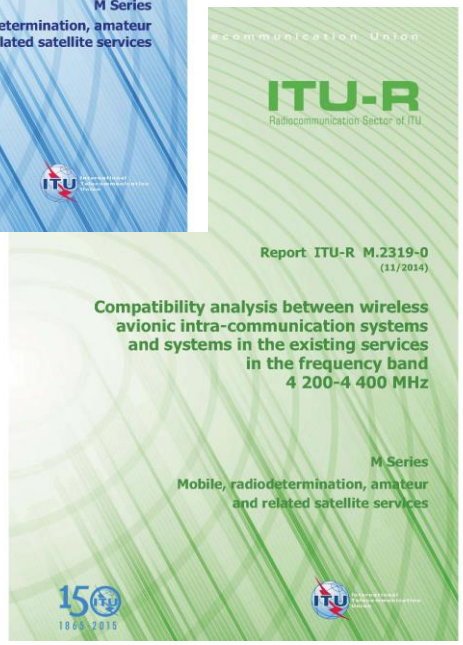
- ITU-R Documents Finalized by Study Group 5
  - Generated for Agenda Item 1.17 in Working Party 5B
- Relevant ITU-R Recommendations and Reports:
  - Recommendation ITU-R M.2059
    - Radio Altimeter Protection Criteria, for non-interference analyses
  - Report ITU-R M.2283 – WAIC Technical Characteristics (*replaces M.2197*)
  - Recommendation ITU-R M.2067 – WAIC Characteristics (new)
  - Recommendation ITU-R M.[WAIC Conditions] –
    - recommends transmitter PSD limits – but not incorporated in Radio Regs
  - Report ITU-R M.2319 - WAIC_SHARING at 4 200-4 400 MHz
  - Report ITU-R M.2318 – WAIC Bands Studied below 15.7 GHz
  - Report ITU-R M.[WAIC_SHARING_22/23 GHz]
  - *Recommendation ITU-R P.525-2 – free space attenuation (ref)*

Second WAIC Characteristics Report

- Brought to full report status in December 2013
  - More than one year before the 2015 CPM
  - Well In-time to substantiate allocation proposal
- Largely a modification of the first report
  - On ground (airport) multi-aircraft scenario added
  - Airframe compartmentalization model for spectrum reuse
  - On-board RF propagation model used – AVSI measurement campaign and TAMU data analysis
  - Out of aircraft emissions characterized – needed for coexistence studies
- Specific spectrum needs calculated
  - Total of 145 MHz now needed for all classes of WAIC systems
  - Less than the 200 MHz available in radio altimeter band
  - By this time, the team had already abandoned hope for an additional allocation for high data rate systems above 15.7 GHz

Two additional crucial documents





- Protection criteria for radio altimeters
  - Finalized in February 2014
  - Needed to perform compatibility studies
  - Define interference levels that altimeters may tolerate
  - Motivated by WAIC and also by IMT's attempts to get more spectrum
  - Non AVSI radio altimeter data compiled from Rockwell Collins and Thales
- Compatibility study for WAIC operating in 4.2-4.4 GHz
  - Finalized November 2014
  - Mandated by the Agenda Item
  - Interference from WAIC to Radio Altimeters – to demonstrate that altimeter protection criteria may be satisfied by fully functional WAIC
  - Interference from Radio Altimeter to WAIC – to demonstrate that WAIC has a chance to fully function while installed in presence of altimeters
- Once compatibility study was completed, the PMC expert's confidence in new allocation was nearing 99%

WRC-15: New Allocation Approved

MOD

2 700-4 800 MHz

Allocation to services		
Region 1	**Region 2**	**Region 3**
4 200-4 400	AERONAUTICAL MOBILE (R) ADD 5.A117 AERONAUTICAL RADIONAVIGATION MOD 5.438 5.439 5.440 ADD 5.B117	

ADD

5.A117 Use of the frequency band 4 200-4 400 MHz by stations in the aeronautical mobile (R) service is reserved exclusively for wireless avionics intra-communication systems that operate in accordance with recognized international aeronautical standards. Such use shall be in accordance with Resolution **COM4/1 (WRC-15)**. (WRC-15)

- One of the two Agenda Items completed first – in less than a week
- Controversy and frantic last-minute negotiations about Resolution wording did happen
- AVSI team held a celebratory reception for WAIC supporters

- Aeronautical Mobile Route Service – AM(R)S – was added to 4200-4400 MHz band, in addition to the previously existing Aeronautical Radionavigation Service used by Radio Altimeters
- Only WAIC can use the new AM(R)S allocation
- The new use must be in accordance with internationally recognized aeronautical standards

Resolution COM4/1 (WRC-15)

RESOLUTION COM4/1 (WRC-15)

Use of Wireless Avionics Intra-Communications in the frequency band 4 200-4 400 MHz

The World Radiocommunication Conference (Geneva, 2015),

considering

a) that aircraft are designed to enhance their efficiency, reliability and safety, as well as to be more environmentally friendly;

b) that Wireless Avionics Intra-Communications (WAIC) systems provide radiocommunications between two or more aircraft stations integrated into or installed on a single aircraft, supporting the safe operation of the aircraft;

c) that WAIC systems do not provide radiocommunications between an aircraft and the ground, another aircraft or a satellite;

d) that WAIC systems operate in a manner that ensures the safe operation of an aircraft;

e) that WAIC systems operate during all phases of flight, including on the ground;

f) that aircraft equipped with WAIC systems operate globally;

g) that WAIC systems operating inside an aircraft receive the benefits of fuselage attenuation to facilitate sharing with other services;

h) that Recommendation ITU-R M.2067 provides technical characteristics and operational objectives for WAIC systems,

recognizing

that Annex 10 to the International Civil Aviation Organization (ICAO) Convention on International Civil Aviation contains Standards and Recommended Practices (SARPs) for safety aeronautical radionavigation and radiocommunication systems used by international civil aviation,

resolves

1 that WAIC is defined as radiocommunication between two or more aircraft stations located on board a single aircraft, supporting the safe operation of the aircraft;

2 that WAIC systems operating in the frequency band 4 200-4 400 MHz shall not cause harmful interference to, nor claim protection from, systems of the aeronautical radionavigation service operating in this frequency band;

3 that WAIC systems operating in the frequency band 4 200-4 400 MHz shall comply with the Standards and Recommended Practices published in Annex 10 to the Convention on International Civil Aviation;

4 that No. **43.1** shall not apply for WAIC systems,

instructs the Secretary-General

to bring this resolution to the attention of ICAO,

invites the International Civil Aviation Organization

to take into account Recommendation ITU-R M.2085 in the course of development of SARPs for WAIC systems.

Key points of the Resolution

1. WAIC is defined as stations on-board a single aircraft and supporting safe operation of aircraft
2. WAIC must give protection and precedence to radio altimeters
3. WAIC must comply with ICAO SARPS – hence SARPS must be first developed

AFE 76 & 76s1: Preparing WAIC Standards

- New AFE to define protocol requirements was proposed as early as June 2008
  - Most members hesitant to commit resources
  - Prefer to waiting until new allocation is quite certain
  - Proposal revisited regularly every year
- AFE 76 kicked-off in August 2014
  - Key PMC experts 99% sure there would be an allocation for WAIC
  - Membership largely overlapping with AFE 73
  - Joint AFE 73/76 telecons and workshops as a matter of convenience
- Goals
  - Define a set of protocol requirements for WAIC
  - Enable future development of “internationally recognized international aeronautical standards”

Final AFE 73 membership

Airbus
Boeing
BAE Systems
Embraer
Honeywell
UTC

AFE 76 members

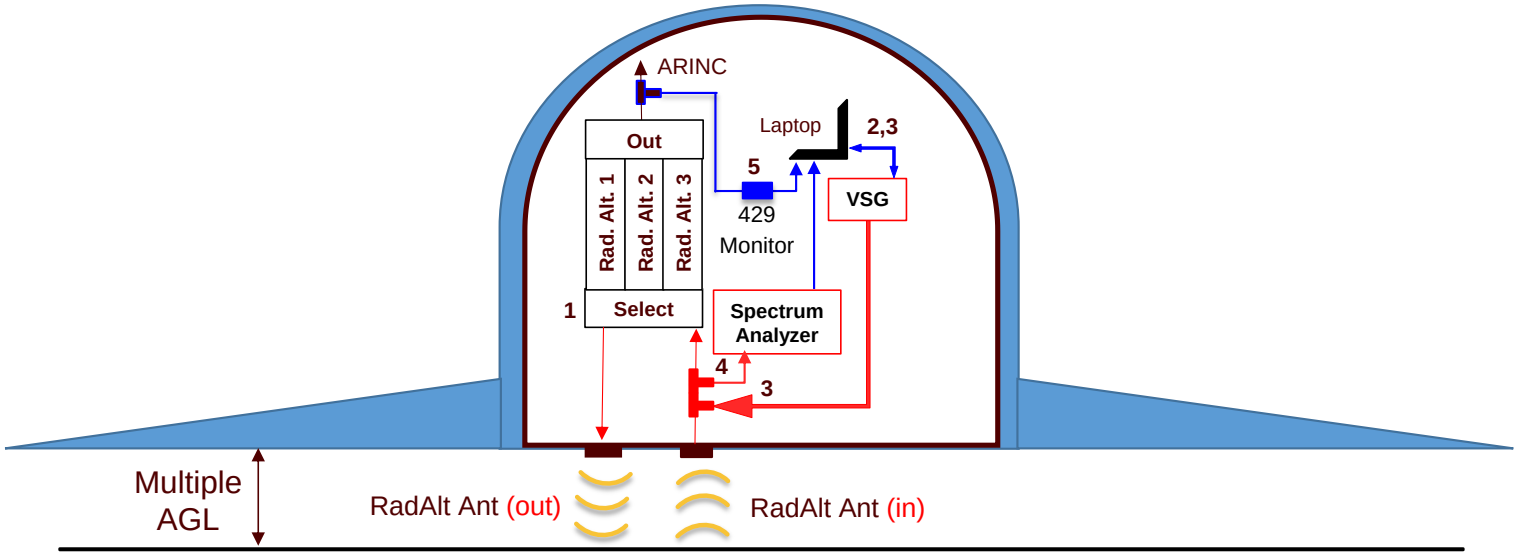
Airbus
Boeing
Embraer
Honeywell
UTC
GE Aviation
HARCO
Rockwell Collins
NASA

- Current AFE 76 period of performance is through 12/31/2016
- Supplement 1 will be requested to support ICAO, RTCA, EUROCAE processes and to define more detailed protocol requirements

AFE 76s1: Current Status

- Simultaneous promotion and support of regulatory framework that will enable certification through RTCA, EUROCAE, and ICAO
  - As directed by the WRC15 resolution, and requested by ToR (facilitate TSOs)
  - RTCA SC236/EUROCAE WG96 Joint comittee activated & working on MOPS
  - ICAO FSMP job cards (WAIC + RadAlt) approved
- Extensive Laboratory testing of Radio Altimeter interference susceptibility is in progress at Texas A&M (flight testing at NASA)
  - Good initial results for simple signals: Expect accuracy to remain in MOPS/ED-30 limits (without WAIC directional antenna controls)
  - refining detailed characterization: multiple signals, time/bandwidth dependencies
  - All RadAlt models (5) currently in service for air transport are in testbed
- Measuring Interference Path losses between aircraft, various locations
  - Scenarios generated to define isolation between aircraft WAIC node, RadAlts
- Continuing modeling and analysis to develop the characteristics and requirements on WAIC nodes and networks, including RadAlt impacts
- Completed AFE 76 docs: Concept of Operations, Protocol Requirements

Initial Flight Testing with NASA



- Laboratory testing using optical delay lines to simulate range will be primarily used for WAIC protocol development
- Initial flight testing at Armstrong Flight Research Center planned (early 2018) will validate the laboratory testing and provide data needed to guide regulatory standards development
- Additional flight testing goals identified using WAIC prototypes under follow-on project (in 2018?)

AVSI Radio Altimeter Lab Test Status

HONEYWELL ALA 52B

	WAIC Waveforms											
	Single Carrier			Dual Carrier MSK			Single Channel OFDM			Dual Channel OFDM		
AGL	4.24 GHz	4.3 GHz	4.36 GHz	4.24 GHz	4.3 GHz	4.36 GHz	4.24 GHz	4.3 GHz	4.36 GHz	4.24 GHz	4.3 GHz	4.36 GHz
500 ft.		[			[			[			[	
1500 ft.		[			[			[			[	
3000 ft.		[			[			[			[	
5000 ft.		[			[			[			[	
8000 ft.		[			[			[			[	

THALES ERT 530

	WAIC Waveforms											
	Single Carrier			Dual Carrier MSK			Single Channel OFDM			Dual Channel OFDM		
AGL	4.24 GHz	4.3 GHz	4.36 GHz	4.24 GHz	4.3 GHz	4.36 GHz	4.24 GHz	4.3 GHz	4.36 GHz	4.24 GHz	4.3 GHz	4.36 GHz
500 ft.		[			[			[			[	
1500 ft.												
3000 ft.												
5000 ft.												
8000 ft.												

THALES ERT 550

	WAIC Waveforms											
	Single Carrier			Dual Carrier MSK			Single Channel OFDM			Dual Channel OFDM		
AGL	4.24 GHz	4.3 GHz	4.36 GHz	4.24 GHz	4.3 GHz	4.36 GHz	4.24 GHz	4.3 GHz	4.36 GHz	4.24 GHz	4.3 GHz	4.36 GHz
500 ft.		[			[			[			[	
1500 ft.		[			[			[			[	
3000 ft.												
5000 ft.												
8000 ft.												

ROCKWELL COLLINS LRA 900

	WAIC Waveforms											
	Single Carrier			Dual Carrier MSK			Single Channel OFDM			Dual Channel OFDM		
AGL	4.24 GHz	4.3 GHz	4.36 GHz	4.24 GHz	4.3 GHz	4.36 GHz	4.24 GHz	4.3 GHz	4.36 GHz	4.24 GHz	4.3 GHz	4.36 GHz
500 ft.		[			[			[			[	
1500 ft.												
3000 ft.												
5000 ft.												
8000 ft.												

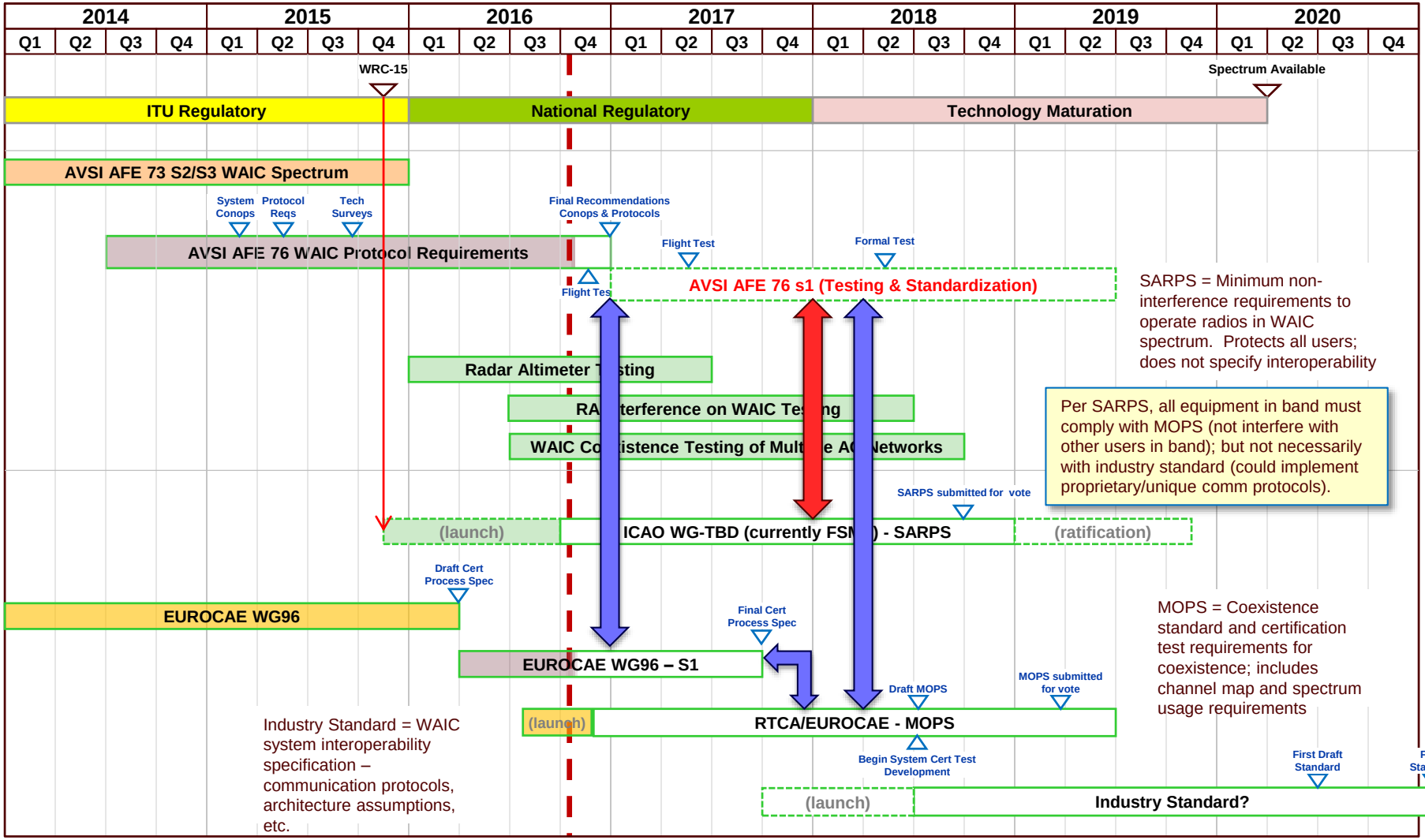
ROCKWELL COLLINS LRA 2100

	WAIC Waveforms											
	Single Carrier			Dual Carrier MSK			Single Channel OFDM			Dual Channel OFDM		
AGL	4.24 GHz	4.3 GHz	4.36 GHz	4.24 GHz	4.3 GHz	4.36 GHz	4.24 GHz	4.3 GHz	4.36 GHz	4.24 GHz	4.3 GHz	4.36 GHz
500 ft.		[			[			[			[	
1500 ft.												
3000 ft.												
5000 ft.												
8000 ft.												

Synopsis of WAIC Industry Development Activities

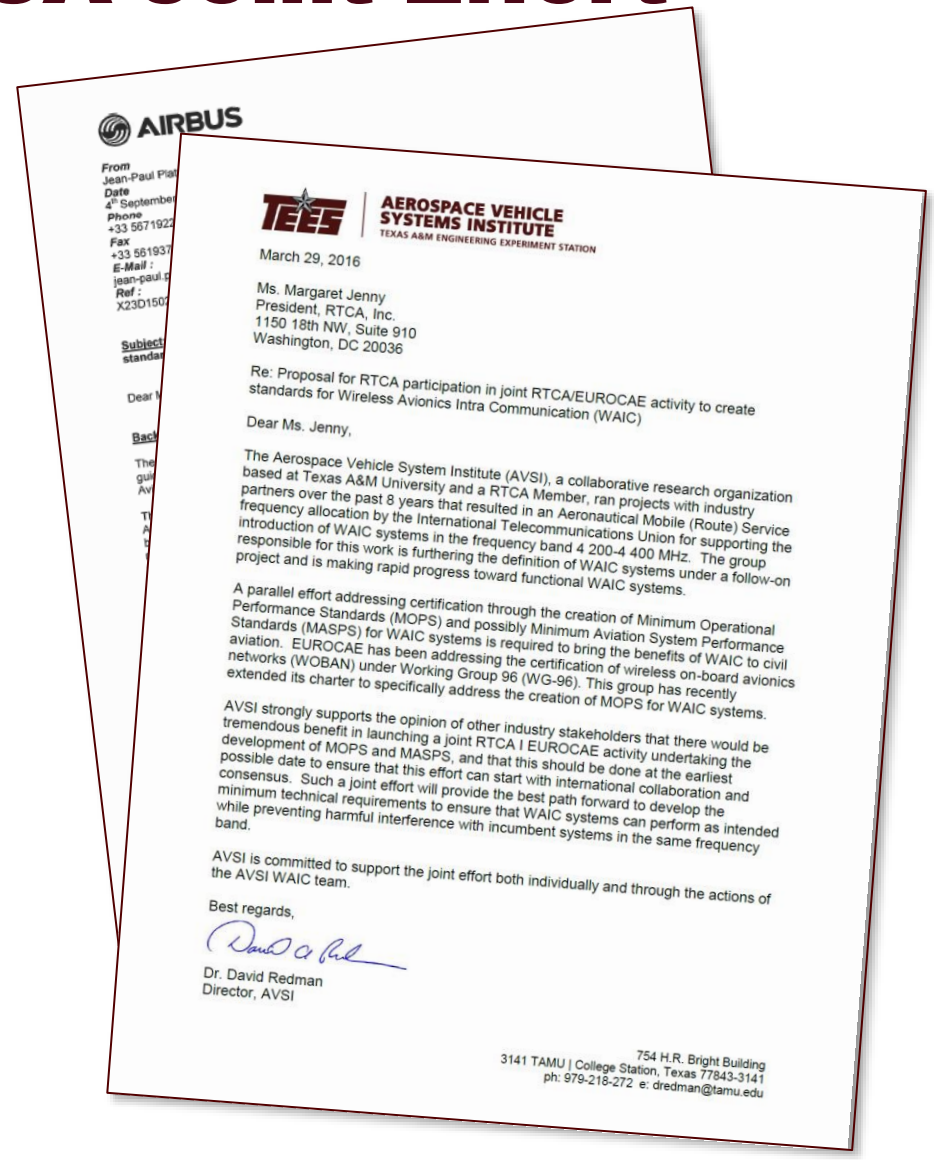
- Develop co-existence rules and necessary MAC/network protocols
  - Minimize WAIC ←→ Radar Altimeter interference impacts (FMCW & pulsed)
  - Maximize WAIC performance in presence of (up to 3-on, 12 max) RadAlts
  - Minimize WAIC ←→ WAIC interference between adjacent aircraft
- AVSI AFE-76 s1: perform RadAlt testing (TAMU & NASA)
  - Define protocol requirements, CONOPS.
  - Support RTCA & ICAO with technical analysis & test data, (MATLAB) modeling
- RTCA SC-236/EuroCae WG-96: Develop WAIC MOPS
  - Performance requirements for intra-aircraft co-existence & on-board performance (but not an interoperability *standard;* only compatibility between aircraft is needed)
  - Technical details for inter-aircraft co-existence (beyond SARPs)
  - MRF/Honeywell Chairing both committees (need more members)
- ICAO: Develop WAIC & RadAlt SARPs – FSMP job cards
  - As directed by the ITU resolution, develop a WAIC Standards and Recommended Practices (SARPs) Document to govern use
  - SARPs will be limited to governing *inter-aircraft coexistence requirements with specs*; reference MOPS for technical details (need MOPS in place!!?)
  - Will present full RadAlt test data results to FSMP WG meetings

WAIC Roadmap – Industry Standards



EUROCAE / RTCA Joint Effort

- EUROCAE and RTCA have formed a joint committee to develop a Minimum Operational Performance Specification (MOPS).
- EUROCAE extended the charter of Working Group 96 (WG-96) to develop a WAIC MOPS.
- AVSI WAIC member companies urged the US FAA to initiate a new Special Committee to develop a WAIC MOPS.
- RTCA established a Special Committee (SC-236) to develop the MOPS within two years.
- Terms of Reference establish these as a joint effort to cover both Europe and the US with a single document.
- **NOTE: interoperability between aircraft is not necessary, only compatibility for co-existence**



AIRBUS

AEROSPACE VEHICLE SYSTEMS INSTITUTE
TEXAS A&M ENGINEERING EXPERIMENT STATION

March 29, 2016

Ms. Margaret Jenny
President, RTCA, Inc.
1150 18th NW, Suite 910
Washington, DC 20036

Re: Proposal for RTCA participation in joint RTCA/EUROCAE activity to create standards for Wireless Avionics Intra Communication (WAIC)

Dear Ms. Jenny,

The Aerospace Vehicle System Institute (AVSI), a collaborative research organization based at Texas A&M University and a RTCA Member, ran projects with industry partners over the past 8 years that resulted in an Aeronautical Mobile (Route) Service frequency allocation by the International Telecommunications Union for supporting the introduction of WAIC systems in the frequency band 4 200-4 400 MHz. The group responsible for this work is furthering the definition of WAIC systems under a follow-on project and is making rapid progress toward functional WAIC systems.

A parallel effort addressing certification through the creation of Minimum Operational Performance Standards (MOPS) and possibly Minimum Aviation System Performance Standards (MASPS) for WAIC systems is required to bring the benefits of WAIC to civil aviation. EUROCAE has been addressing the certification of wireless on-board avionics networks (WOBAN) under Working Group 96 (WG-96). This group has recently extended its charter to specifically address the creation of MOPS for WAIC systems.

AVSI strongly supports the opinion of other industry stakeholders that there would be tremendous benefit in launching a joint RTCA I EUROCAE activity undertaking the development of MOPS and MASPS, and that this should be done at the earliest possible date to ensure that this effort can start with international collaboration and consensus. Such a joint effort will provide the best path forward to develop the minimum technical requirements to ensure that WAIC systems can perform as intended while preventing harmful interference with incumbent systems in the same frequency band.

AVSI is committed to support the joint effort both individually and through the actions of the AVSI WAIC team.

Best regards,

Dr. David Redman
Director, AVSI

754 H.R. Bright Building
3141 TAMU | College Station, Texas 77843-3141
ph: 979-218-272 e: dredman@tamu.edu

RTCA SC236 / EUROCAE WG96 Joint Effort

- **Active since August 2016 (Sept joint) – *MRF chair***
  - ToR objective is to generate MOPS that can be invoked by TSO
- **Formed 4 focused Sub-Working Groups**
  - SWG 1 – Coexistence and Signals in Space – all RF issues
    - Transmit spectral masks and power limits, receiver protections and performance
    - RA & WAIC – intra- & inter- a/c; Protocols for sharing T/BW occupancy
  - SWG 2 – Networking – architectures and performance
    - Minimum node functional requirements to become member of a network
    - Recommends: Classes of service, topologies, traffic models for test cases
  - SWG 3 – Cybersecurity – mechanisms & ops procedures
    - Initial security system & continued airworthiness (SC-216/WG72 docs)
    - Encryption, key generation/management; jamming a serious concern
  - SWG 4 – Physical & environmental issues (& installation)
    - Node functions tested to performance level by environmental dependency
    - TSO calls out functions, not equipment (LRU) types (*up to manufacturer*)
- **Lingering question: how deep does system spec go?**
  - Want to be application agnostic, but system performance is tied to application needs (thus classes of service categorization)
    - Need protocols requirements for application usage (API) ?
  - Generate network test cases (traffic model, topology…) ??

Support of ICAO Standards

- As directed by the ITU resolution, the AVSI WAIC team initiated an effort within the International Civil Aviation Organization (ICAO) to develop a WAIC Standards and Recommended Practices (SARPs) Document
  - Also supporting development of a Radio Altimeter SARPs
  - This will require a minimum of 2 years to develop
    - ICAO, like ITU is a treaty organization
- WAIC SARPs will be limited to governing *inter-aircraft coexistence requirements*
  - Includes transmit channelization, spectral masks, and receiver performance/protection characteristics (including out-of-band)
  - Also included non-interference with adjacent aircraft RadAlts
- Detailed performance requirements for intra-aircraft will be covered in the WAIC MOPS and referenced
- Adding adjacent band interference susceptibility testing being added to TAMU testbed to support RadAlt SARPs

WAIC System Design are Evolving

- Transmit spectral mask, psd, and channelization plan agreed to for MOPS
  - Uses 5 MHz channelization, high and low data rates
  - Support original low data rate masks & 5 MHz OFDM
  - 6dBm/MHz psd limit (high+low data rates)
- Working receiver performance issues currently
- Identifying hardware implementation approaches
  - Tailored COTS chipsets, SDR availability in band
  - Considering passive (reflective) designs
  - Exploring energy harvested power, long-life battery
- Developing/modeling PHY/MAC/net protocols in simulations & on prototypes (co-existence emphasis)
- Include cyber-security protections, safety issues

WAIC Technical Characteristics (WRC15)

NOTIONAL – NOT A SPEC STANDARD!!	Low data rate systems	High data rate systems	Units
Total net average data rate per a/c	1.25	30.7	Mbps
Total net peak data rate per aircraft	2.3	174.1	Mbps
Overall spectrum requirements	51 [1]	94 [1]	MHz
Spectrum requirements per aircraft	35 [2]	53 [2]	MHz
number of simultaneously active transmitters per channel	1	1	-
Antenna gain (RX and TX) [3]	0	0	dBi
Max. transmission power [4]	10	50	mW
3-dB emission bandwidth	2.6	16.6	MHz
20-dB emission bandwidth	6	22	MHz
40-dB emission bandwidth	12	60	MHz
Receiver IF-bandwidth	2.6	20	MHz
Thermal noise floor (*kBT*) [5]	–110	–101	dBm
Receiver noise figure	10	10	dB
Receiver noise floor [5]	–100	–91	dBm
Required signal-to-noise ratio [6]	9	14	dB
Receiver sensitivity	–91	–77	dBm
Protection criterion (*I*/*S*)	–9	–14	dB

Conclusions

- The high level the ability for WAIC to use (share) the 4200-4400 MHz frequency band was approved at WRC-15
  - The ITU-R and WRC 2015 effort is the first to identify, analyze, justify and develop/prove WAIC concepts
  - ICAO, ATU, CITEL, APT, CEPT, ASMG, RCC and aviation groups were all supportive.
- RTCA/EUROCAE, ICAO FSMP, and AVSI Team and Committees are making good progress to exploit the WRC 2015 WAIC allocation
- ICAO and RTCA framework and technical expertise in generating SARPS and MOPS will steer WAIC towards facilitating future aircraft certification efforts – enabling TSOs & transmit allocation licenses
- Significant analysis & strawman system design has been done that proves WAIC has the potential to meet aircraft needs, as well as RF community co-existence – but regulations are needed to ensure this
  - Network Protocols and Requirements Definition and System Design and RadAlt interference susceptibility testing are underway on AVSI AFE 76/76s1
- WAIC On-board wireless technology for safety services will benefit airlines & aerospace industry; safety will be enhanced, not compromised

Thank You!

- Questions?
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