

# Wireless Avionics Intra-Communications (WAIC) Overview and Applications



## Passive Wireless Sensor Technology Workshop 2015

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# Outline

- Introduction - AVSI
- What is WAIC?
- Why WAIC?
- AVSI WAIC Projects - How WAIC?
- Status / Next Steps



# The Aerospace Vehicle Systems Institute



AVSI is an industry-centric applied research cooperative and part of the Texas A&M University System that facilitates pre-competitive collaborative research.



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- BAE Systems
- Rafael D. S.
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**Current membership includes a cross-section of aerospace industry stakeholders, including aircraft producers, system suppliers, regulatory bodies, government and trade organizations, and academia.**

# What is Wireless Avionics Intra-Communications (WAIC)?

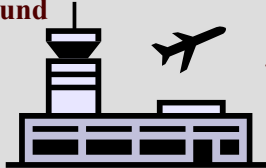
- **WAIC is:**
  - Radiocommunication between two or more points on a single aircraft.
  - Integrated wireless and/or installed components to the aircraft.
  - Part of a closed, exclusive network required for operation of the aircraft.
  - Only for safety-related applications.
  - Based on short range 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

**Communications  
with Ground**



**Operational  
Communications**



**Internet  
Connectivity**

## WAIC Systems:

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



**Proximity  
Sensors**



**Landing Gear  
Sensors**

# Motivation: Why WAIC?

## ***WAIC and Next Generation of Aircraft***

- Aircraft and the RF environment in which they operate are evolving.
- In striving to utilize wireless capabilities, aircraft are on the verge of important technological and design transformations.
- WAIC represents the aviation industry's effort to realize the benefits of wireless technologies for the future generation of aircraft for safety-related functions.
- **Goal is to add operational efficiencies and reduce the overall weight of systems; and include the ability to obtain more data from the aircraft systems and surfaces during all phases of flight.**
- **The objective is to enhance efficiency and reliability while maintaining or improving current required levels of safety.**
- The intent is to NOT mandate equipage changes or to require additional costs to airlines.



# Importance of WAIC to Airlines

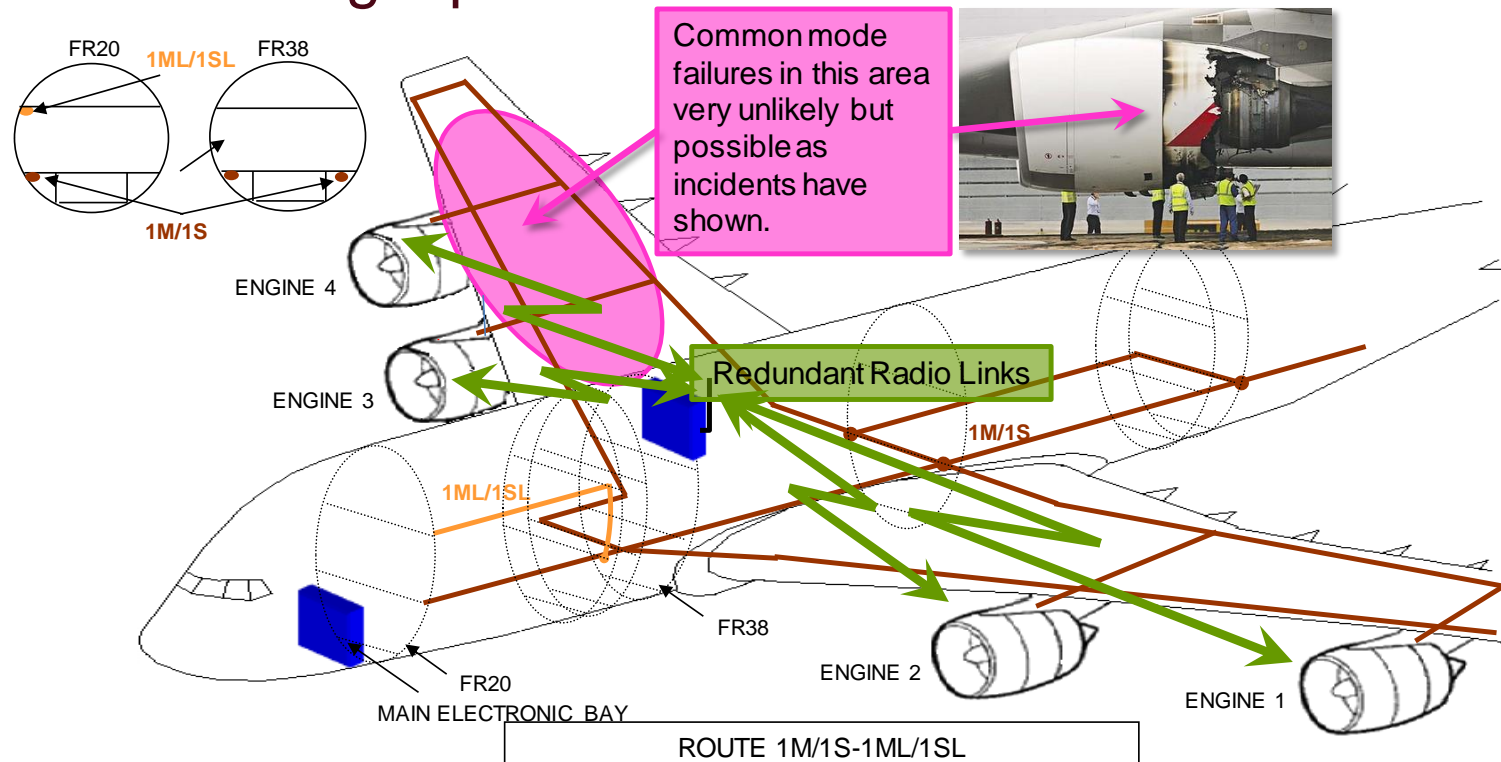
- **Safety Improvements:**
  - Provide dissimilar redundancy
  - Fewer wires means a reduction in connector pin failures, lower risk of cracked insulation & broken conductors.
  - Mesh networking could provide redundancy in emergencies.
- **Environmental Benefits:**
  - Reduced wiring and associated aircraft weight enables less fuel burn.
- **Increased Reliability**
  - Reduce amount of aging wiring
  - Simplify and reduce life-cycle cost of airplane wiring
  - Ability to obtain more data from aircraft systems and surfaces
  - Add new sensors and controls without additional wire routing
- **Provide operational efficiencies and associated cost savings.**
  - To monitor systems and surfaces that currently cannot be monitored without taking the aircraft out of service.
  - Enhance reconfigurability





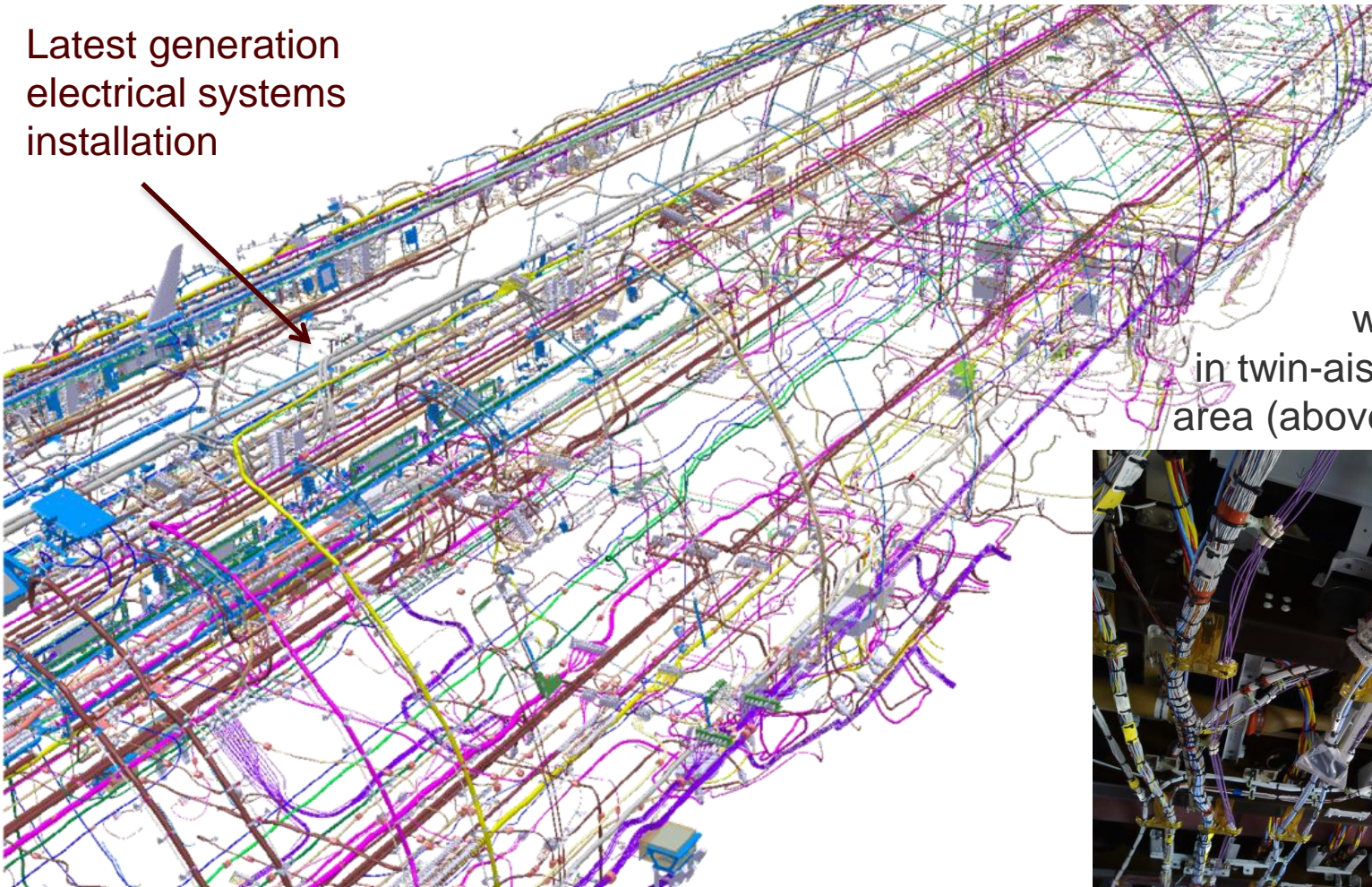
# Need for WAIC - Dissimilar Redundancy

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

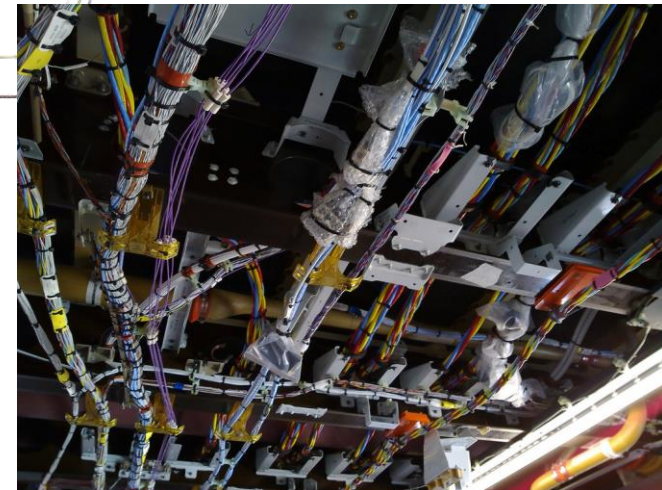


# Need for WAIC - Complexity of electrical wiring in modern aircraft

Latest generation  
electrical systems  
installation



Typical  
wiring installation  
in twin-aisle aircraft crown  
area (above ceiling panels)





# The AVSI WAIC Team



Core Participants		Supporting Participants	
Airbus	Uwe Schwark, Thomas Meyerhoff, Peter Berwing	BAE Systems	Robin Davies
Boeing	Joe Cramer, Kim Kolb, Scott Marston, Dave Kirkland	Bombardier	Fidele Mopfouma
Embraer	Fernando Luiz, Aristides Cintra	GE Aviation	Luke Bolton
Honeywell	Michael Franceschini	Gulfstream	Simón Colmenares
UTC	Radek Zakrzewski, Christopher Fitzhugh	Sikorsky	Brian McCabe
		Texas A&M	Scott Miller, Greg Huff

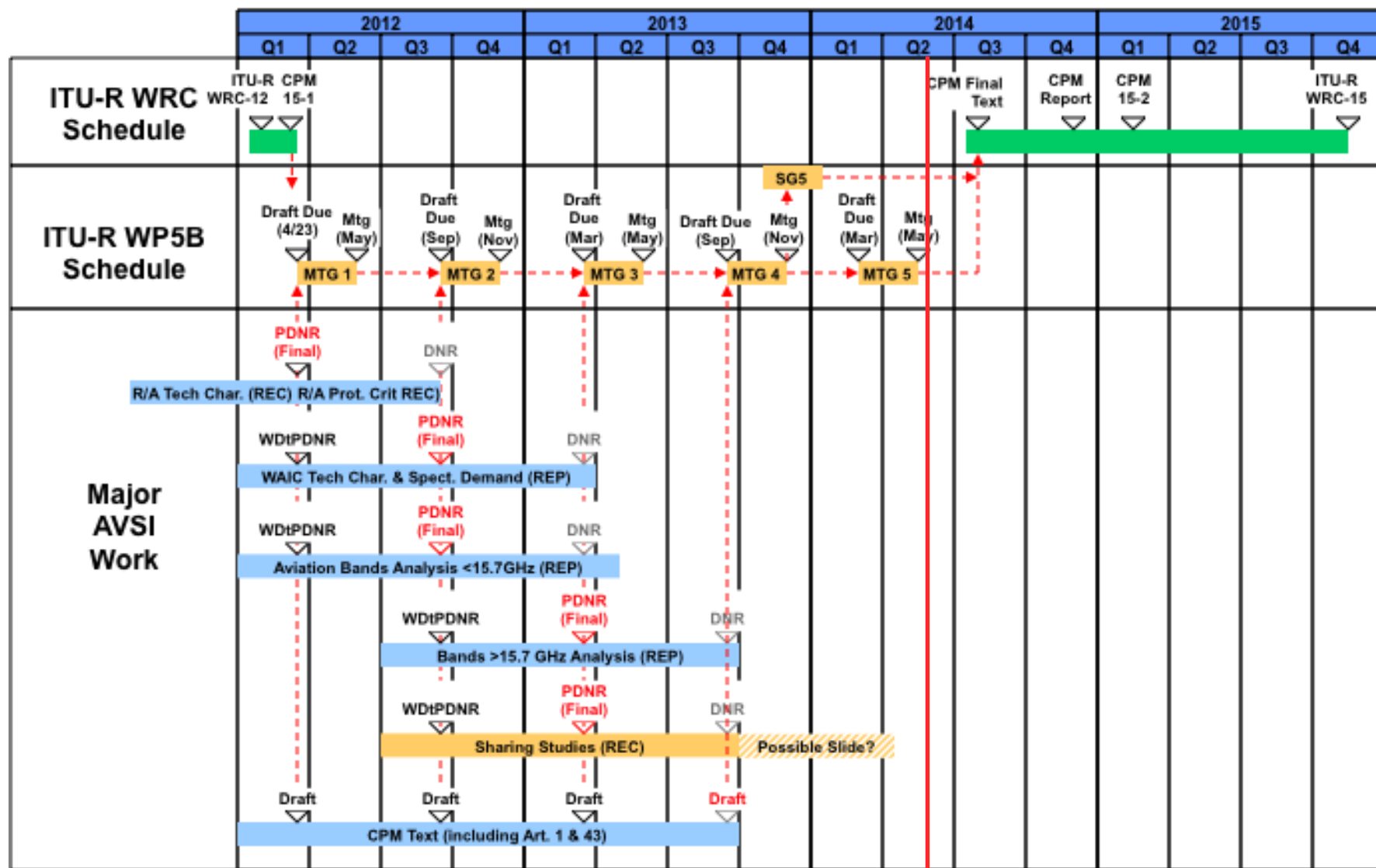
# AVSI Provided Existing Forum for Rapid Program Start

- Previous AVSI wireless avionics feasibility study identified need for dedicated spectrum for WAIC
- International spectrum usage governed by the International Telecommunications Union – Radiocommunications (ITR-R) organization under the United Nations
  - World Radio Conference (WRC) is quadrennial, thus there is an 8 year process to achieve a spectrum allocation

## Launch AVSI WAIC Project

- AVSI team secured a WAIC Agenda Item (1.17) at WRC-12, which directed studies for consideration at WRC-15
- Studies considered band width and location requirements and band sharing for envisioned WAIC applications

# ITU-R Radio Regulations Process



# **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

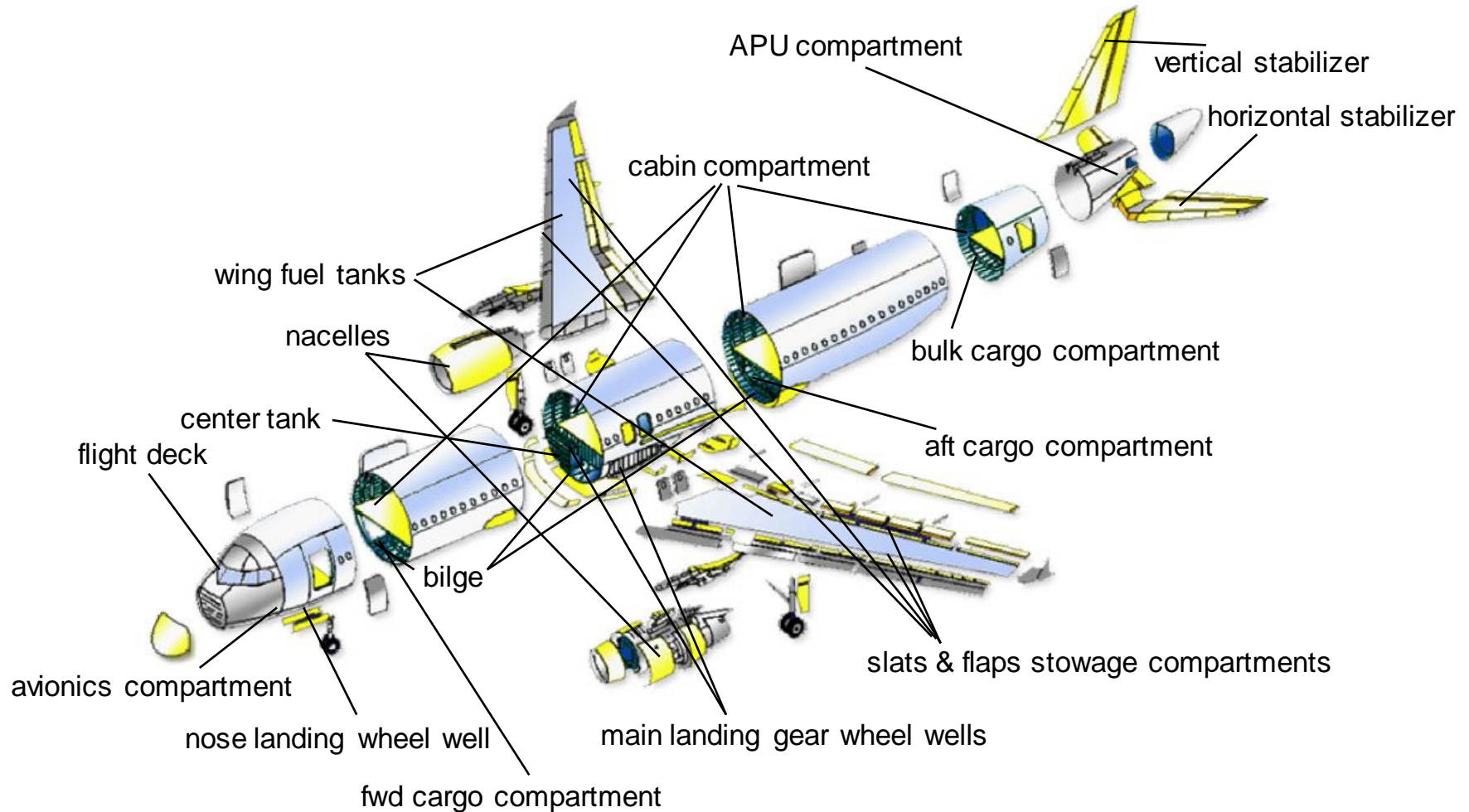
# WAIC spectrum requirements for all application categories

WAIC application category	Application data rate in kbps ( $P_{\text{eff}}$ )	Protocol overhead factor ( $\alpha$ )	Channelization overhead factor ( $\beta$ )	Multiple-aircraft factor ( $m$ )	Modulation efficiency in bps per Hz ( $\eta$ )	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

**145 MHz Total Spectrum Allocation Needed (Before Band Sharing)**

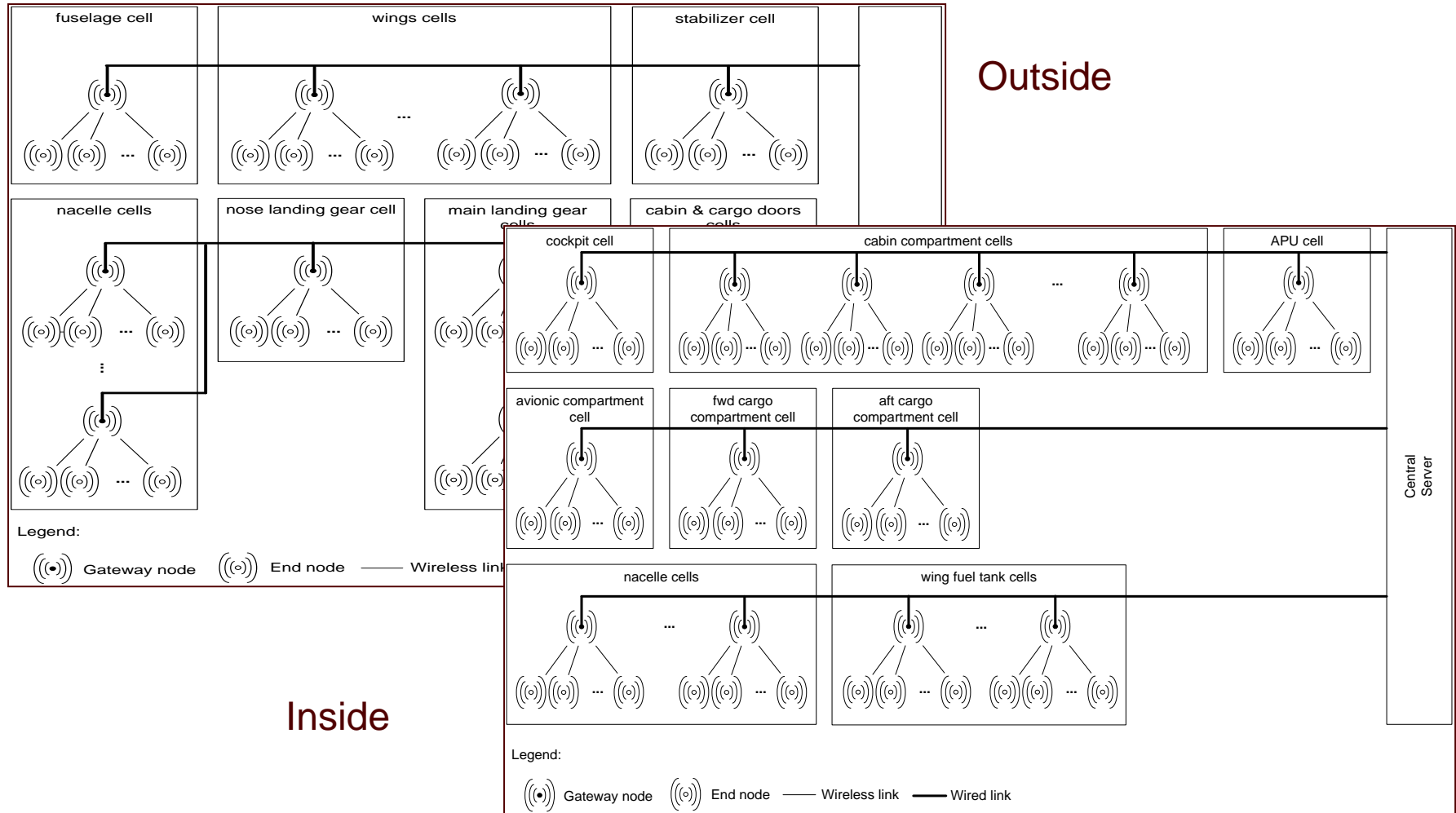


# Major components of a typical passenger aircraft and location of compartments



**Compartments Accommodate a Cellular System Topology**

# The WAIC model consider different network topologies

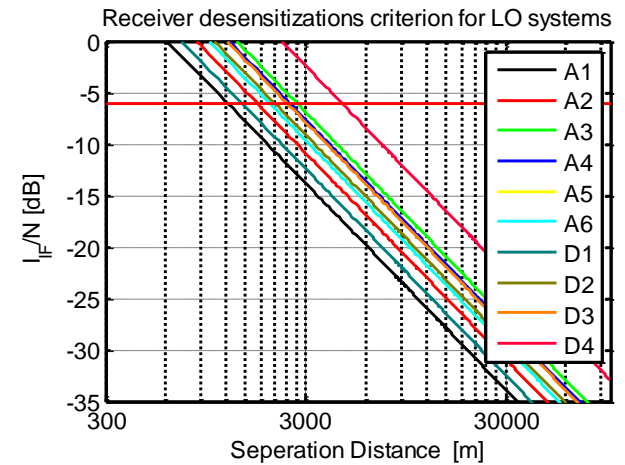
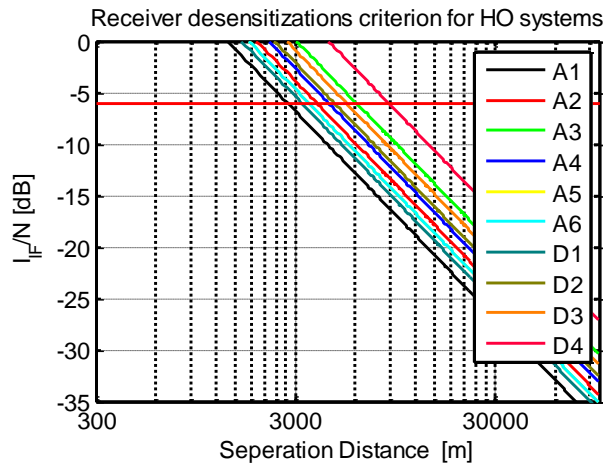
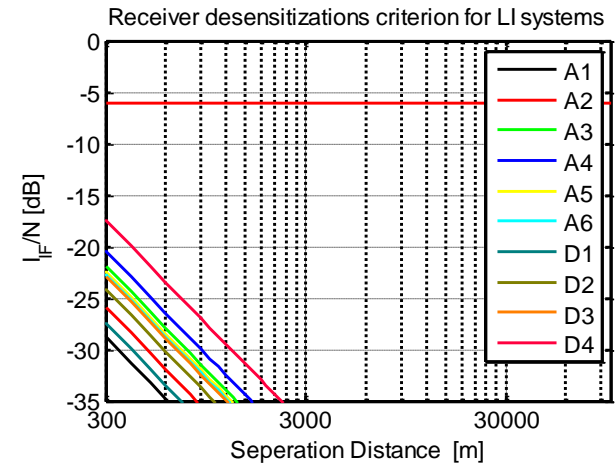
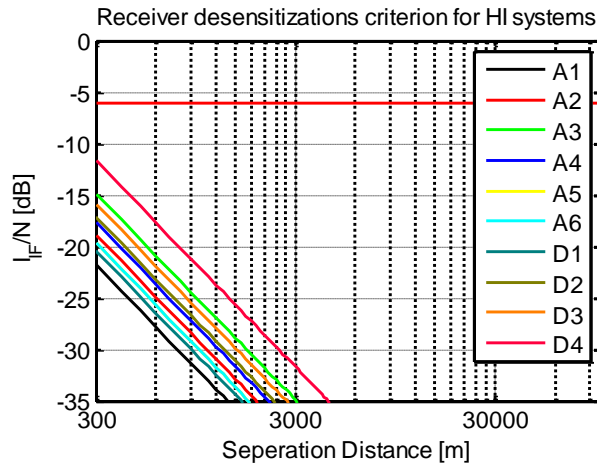


## **Spectrum requirements and practical considerations led to radar altimeter band**

- Considered only Aeronautical allocated bands
- The radar altimeter (RA) band 4.2 – 4.4 GHz was promising since there was only one incumbent service
- Two of three major RA manufacturers are AVSI Members
- AVSI team helped defined RA protection criteria
- AVSI team performed band sharing studies to demonstrate WAIC compatibility with incumbent service
- Considered HI, LI, HO, LO application compatibility with both FMCW and Pulsed radar altimeters


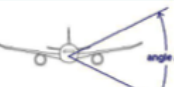
# WAIC Desensitization of RadAlt is harshest factor

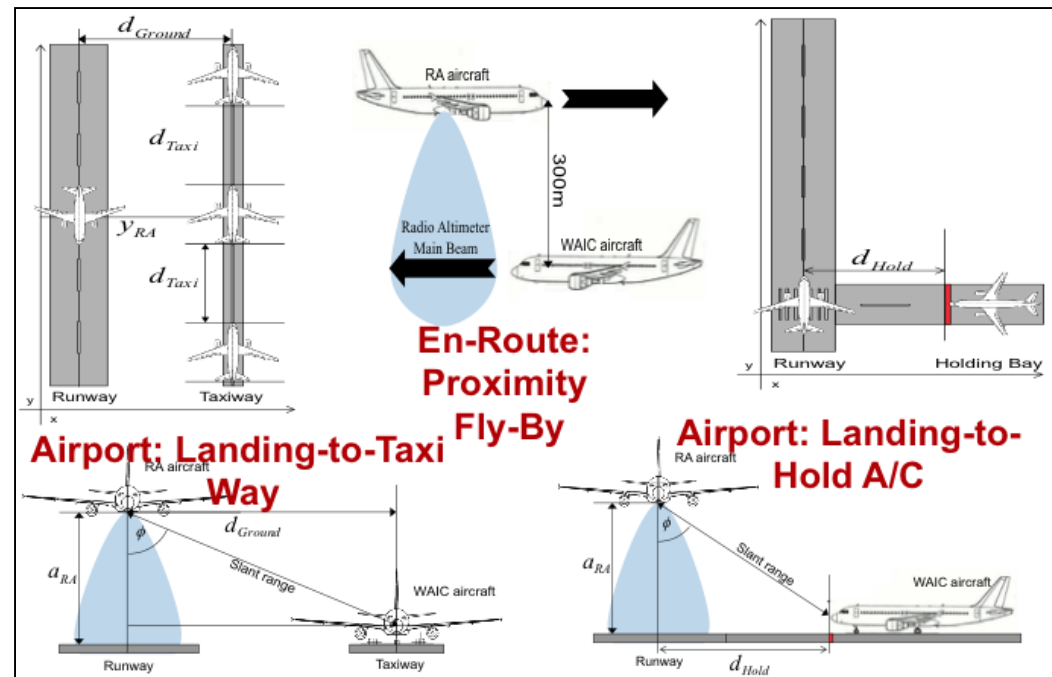
Internal WAIC  
systems meet  
-6 dB I/N non-  
interference  
criteria



# Aircraft Shielding & Geometry Considerations

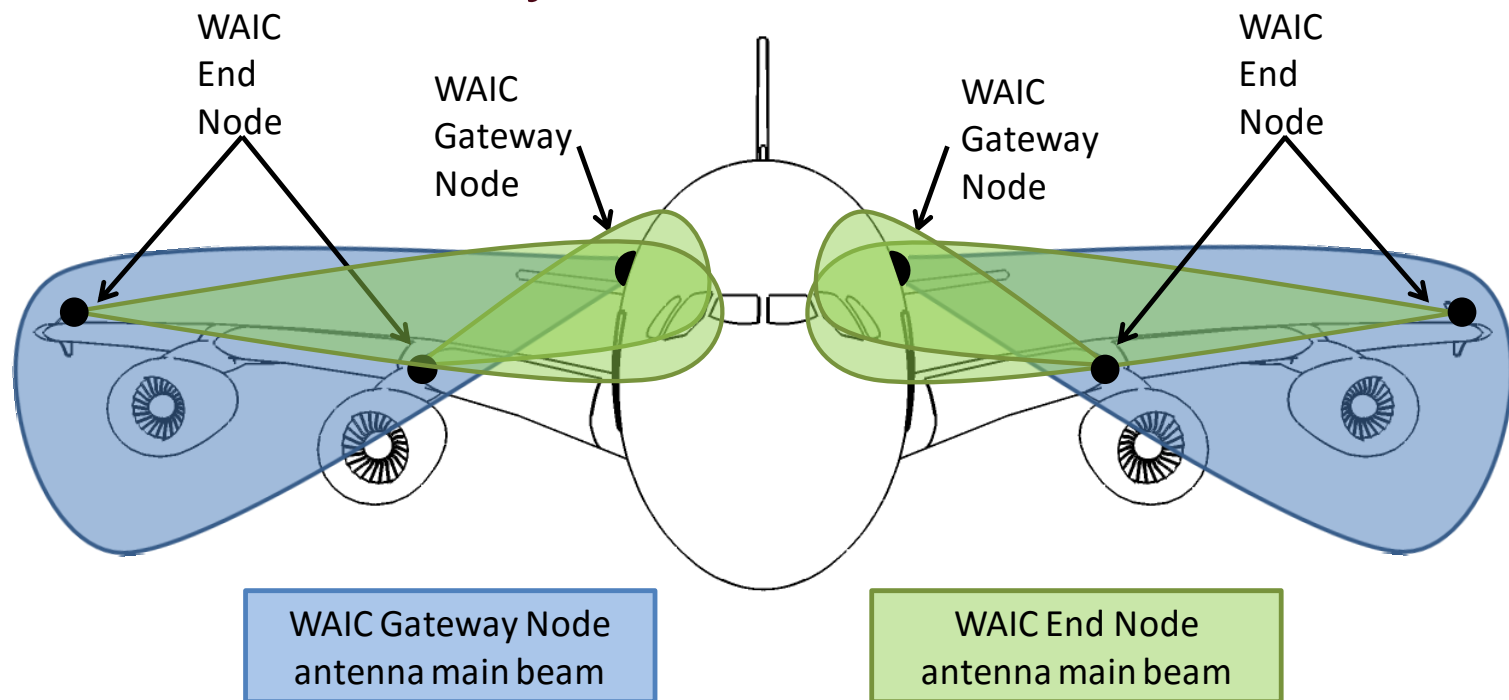
- Additional Path Loss due to Aircraft Shielding crucial to isolating WAIC Internal Systems from the Radio Altimeter without requiring additional mitigation techniques

Case	Viewing Angle	Configuration	Typical attenuation
1	viewed from A1	a) transmitters within cabin	25dB
		b) transmitters installed in lower lobe of aircraft fuselage	35dB
2	viewed from A2	a) transmitters within cabin	10dB
		b) transmitters installed in lower lobe of aircraft fuselage	30dB
3	All angles	Enclosed compartments or aircraft fitted with shielded windows	35dB
4	n/a	Partly shielded external aircraft areas	5dB

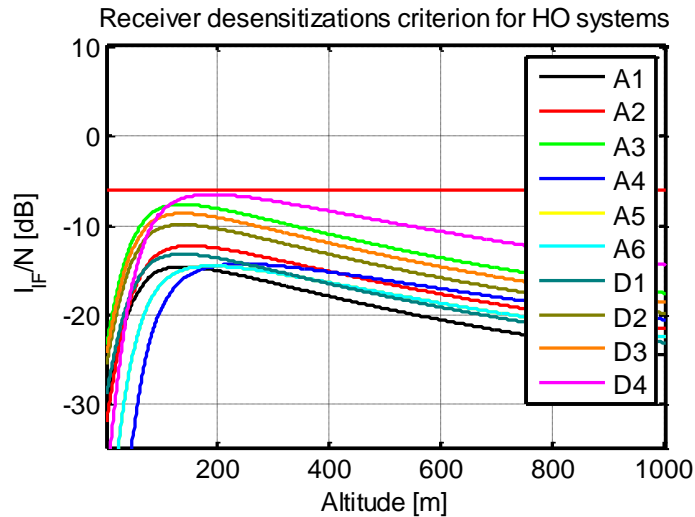


# Using Directional Antennas to Reduce Interference Effects

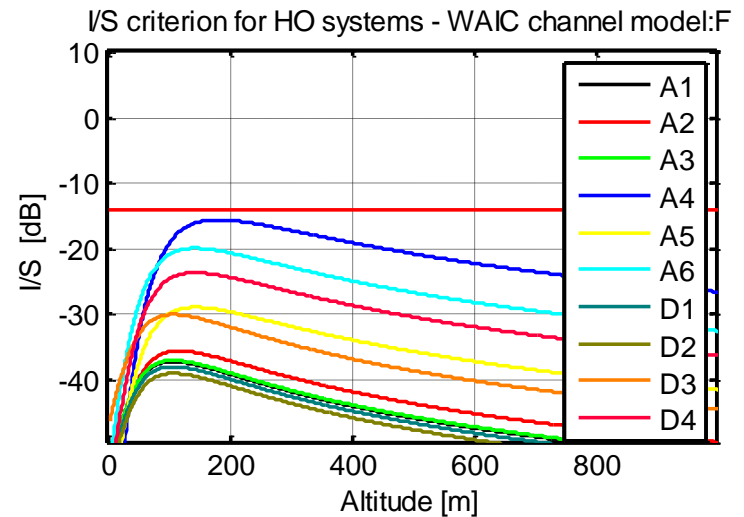
- WAIC External Systems can shape the radiation pattern using directional antenna pattern controls as one potential mitigation technique for external WAIC systems



# WAIC External Systems do not Interfere with RadAlts after Directional Pattern Control



Results of radio altimeter receiver desensitization for the “airport taxiway” scenario



Results for I/S protection criteria for WAIC HO systems for the “airport taxiway” scenario



# 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)*

# SUCCESS AT WRC-15

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ADD

## 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;

#### *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.

# AVSI Team Working on Next Steps

- Beginning design of standardized WAIC protocols to exploit anticipated allocation
  - Further analysis
  - Modeling
  - Prototyping
- Working with International Civil Aviation Organization (ICAO) to define regulatory framework
  - Minimum Operational Performance Spec's (MOPS)
  - Standards and Recommended Practices (SARPS)
  - Minimum Aviation System Performance Standards (MASPS)

2014				2015				2016				2017				2018				2019				2020							
Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4				
				WRC-15 11/2015																				WAIC First Delivery!							
ITU Regulatory								National Regulatory								Technology Maturation															
AVSI AFE 73 S2 WAIC Spectrum																															
								(launch)								ICAO WG-TBD (currently WG-F)															
								Draft Cert Process Spec																SARPS submitted for vote							
EUROCAE WG96																Final Cert Process Spec															
								EUROCAE WG96-S1																							
								System Conops								Protocol Reqs								Tech Surveys							
								Final Recommend.																Draft MOPS: Means to ensure coexistence defined							
								(launch)								RTCA/EUROCAE MOPS															
																Draft MOPS								MOPS submitted for vote							
																Begin System Cert Test Development															
																								First Draft Standard							
																								Final Standard							
								(launch)								(Industry Standard?)															

SARPS = Minimum non-interference requirements to operate radios in WAIC spectrum. Protects all users; does not specify interoperability

Per SARPS, all equipment in band must comply with MOPS (not interfere with other users in band); but not necessarily with industry standard (could implement proprietary/unique comm protocols).

MOPS = Coexistence standard and certification test requirements for coexistence; includes channel map and spectrum usage requirements

Industry Standard = WAIC system interoperability specification – communication protocols, architecture assumptions, etc.

(MOPS and Industry Standard not directly coupled)

# Design Evolution of WAIC Systems

- Extensive Laboratory Testing of Radio Altimeter Sensitivity to Interference
  - Concludes that accuracy remains within required limits
  - Directional antenna controls are not necessary
- MATLAB modeling and simulation of WAIC and Altimeter interactions for protocol development
- Identify hardware implementation approaches
  - Consider COTS chipsets, SDR availability in band
  - Consider passive (reflective) designs for low power
    - Goal is to get to energy harvested power, long-life battery
- Develop PHY/MAC/net protocols on prototypes
- Include security protections, safety issues

# Conclusions

- WAIC On-board wireless technology for safety services will benefit the airlines and aerospace industry.
- Safety will be enhanced, and not compromised.
- ITU, ICAO, ATU, CITEL, APT, CEPT, ASMG, RCC and aviation groups are all supportive and being updated.
- The ITU-R and WRC 2015 effort is the first to identify, analyze, justify and develop/prove WAIC concepts
- The high level the ability for WAIC to use (share) the 4200-4400 MHz frequency band was approved at WRC-15
- 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
- Network Protocols and Requirements Definition and System Design on AVSI AFE 76 are underway following the successful WRC2015
- ICAO and RTCA framework and technical expertise in generating SARPS, MASPS, and MOPS will steer WAIC towards enabling future aircraft certification efforts

# Thank You!

- Questions?
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  - 979-218-2272

