

Wireless Avionics Intra-Communications (WAIC)

Overview and Applications

Agenda Item 1.17 : Status of Securing
a Spectrum Allocation for Wireless
On-Board Safety Services, and on
implementing a regulatory
framework and architecture



Future of Instrumentation & Internet Workshop

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A cooperative of companies, academia and government agencies focused on collaborating on R&D projects, investigating emerging technologies and influencing standards and policies to promote cost effective systems development and certification.

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 ($< 100\text{m}$).
 - 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.

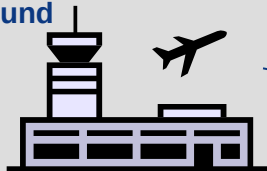
ITU-R Report M.2283 contains technical characteristics and operational objectives for WAIC systems (update to M.2197)

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
Communication
s



Internet
Connectivity

WAIC Systems:

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



Proximity
Sensors



Engine
Sensors



Landing Gear
Sensors

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.

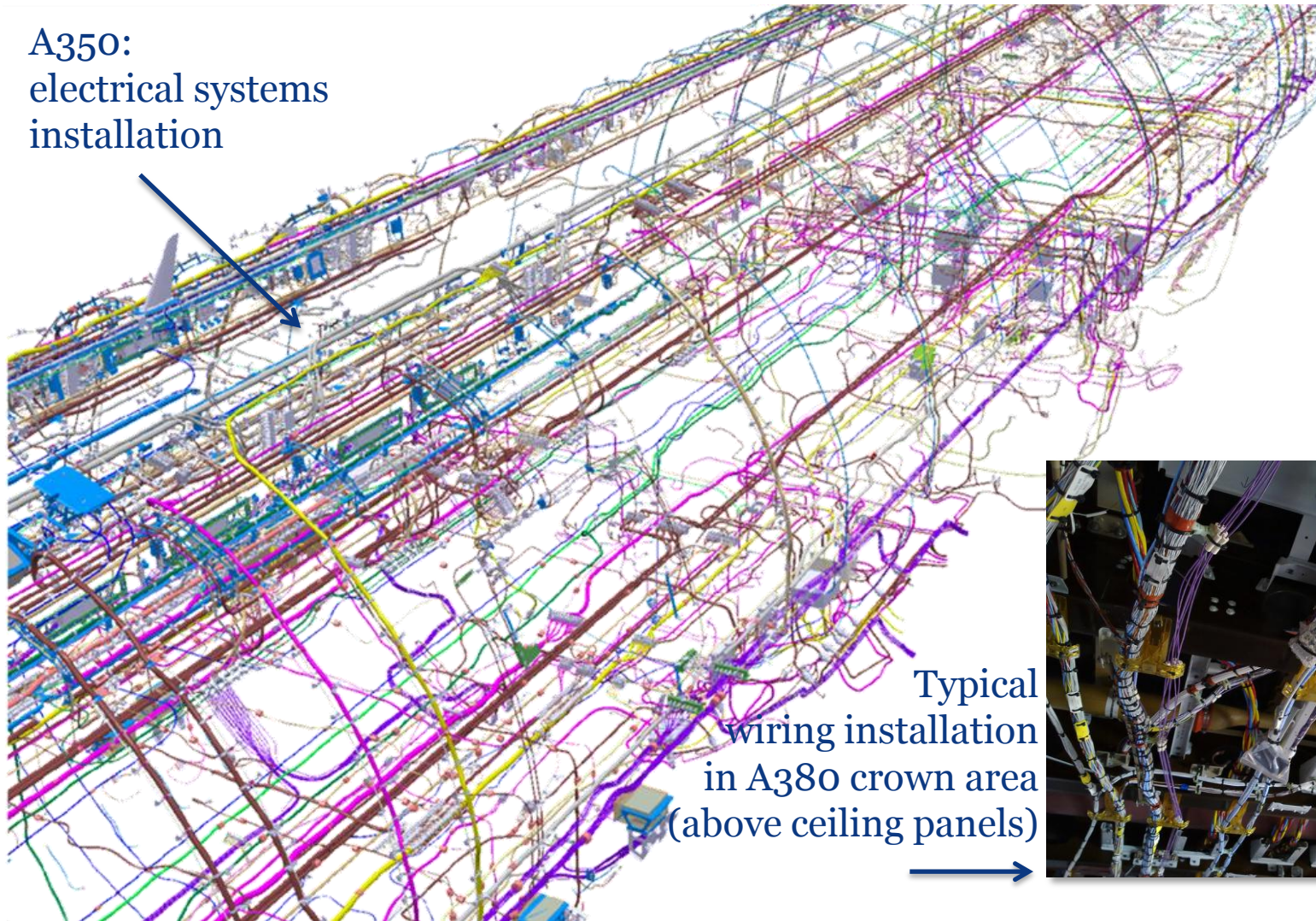
Importance of WAIC to Airlines



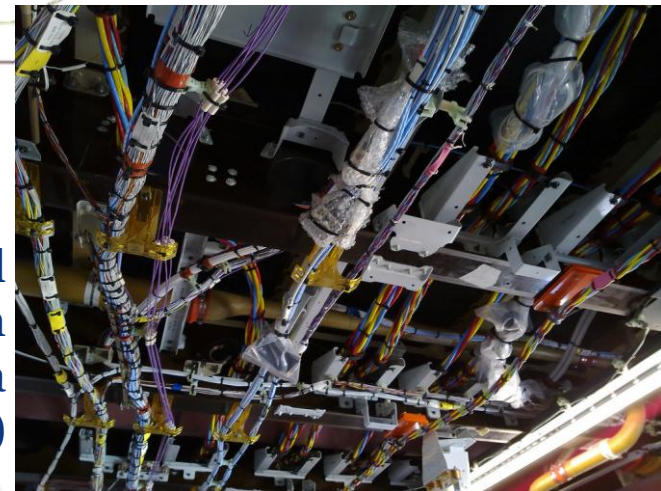
- **Safety Improvements:**
 - Provide dissimilar redundancy
 - Fewer wires means a reduction in connector pin failures, lower risk of cracked insulation & broken conductors.
 - Mesh networking could provide redundancy in emergencies.
- **Environmental Benefits:**
 - Reduced wiring and associated aircraft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

Need for WAIC - Complexity of electrical wiring in modern aircraft

A350:
electrical systems
installation



Typical
wiring installation
in A380 crown area
(above ceiling panels)



Need for WAIC - Complexity of electrical wiring in modern aircraft

- **Electrical wiring:**
some statistics for the example of the A380-800
 - Total wire count: ~100 000
 - Total wire length: 470 km
 - Total weight of wires: 5 700 kg
 - About 30% of additional weight to fix the harness to the structure

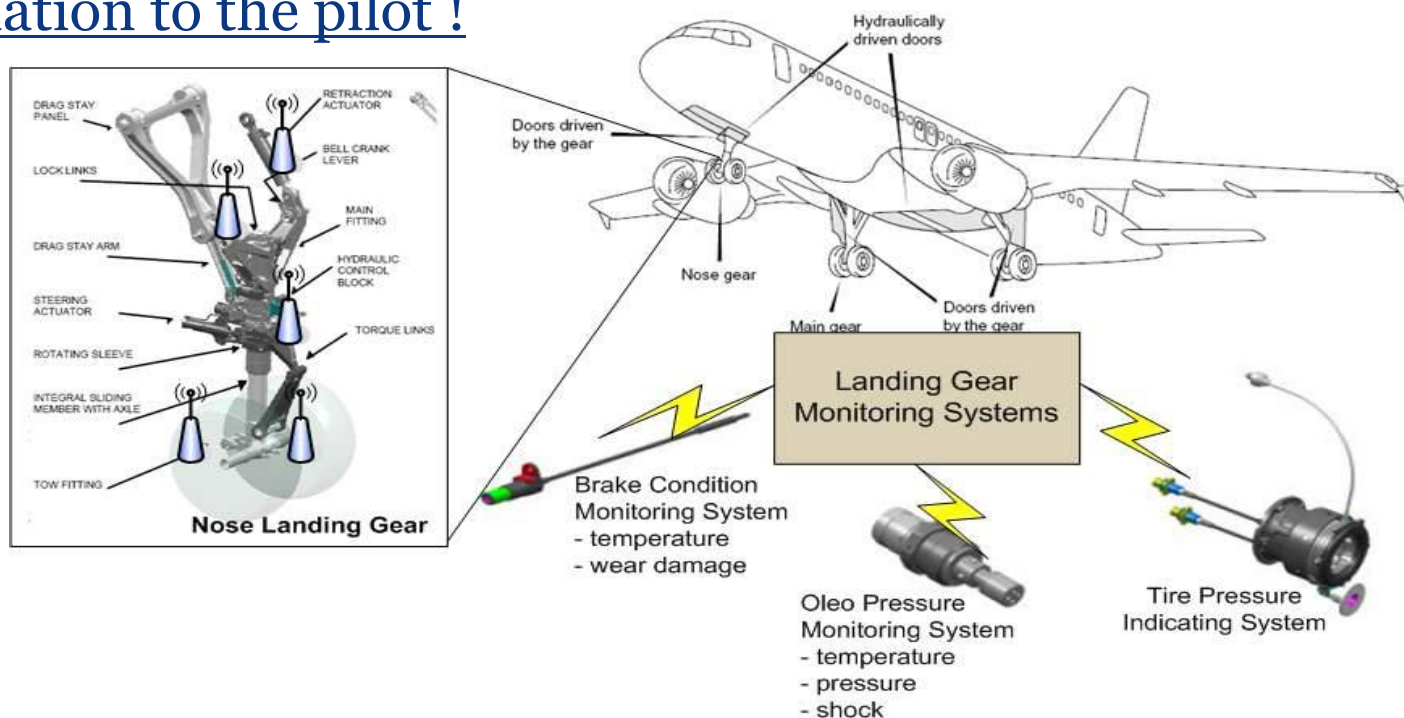
About 30% of electrical wires are potential candidates for a wireless substitute!

Monitoring moving and rotating parts

Example: Landing Gear Monitoring

- Brake condition monitoring
- Oleo pressure monitoring
- Tire pressure Indicating

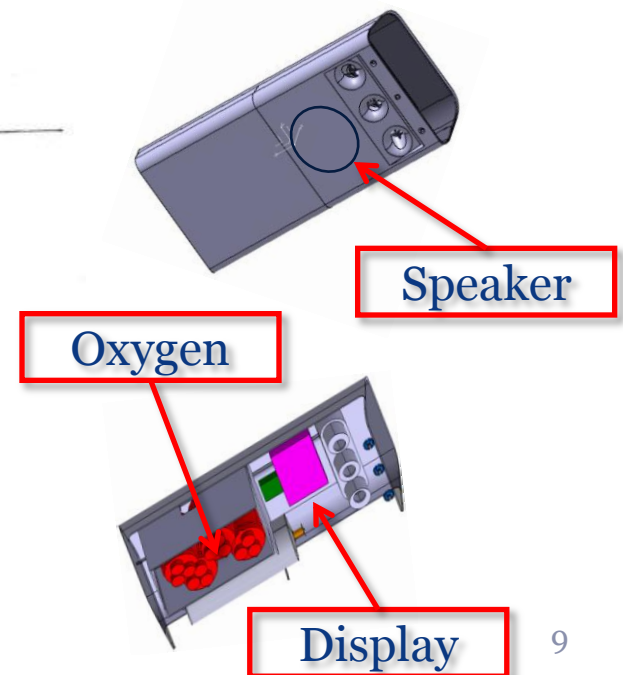
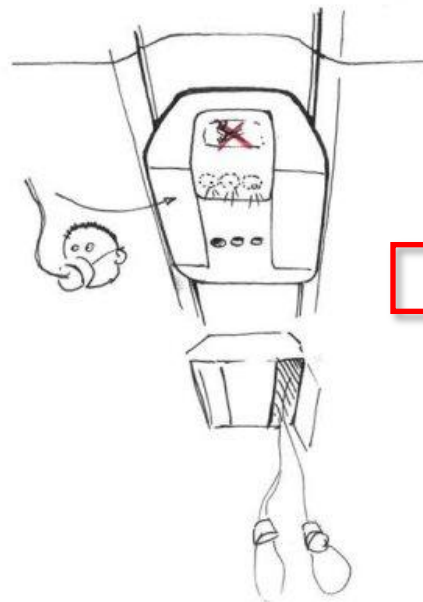
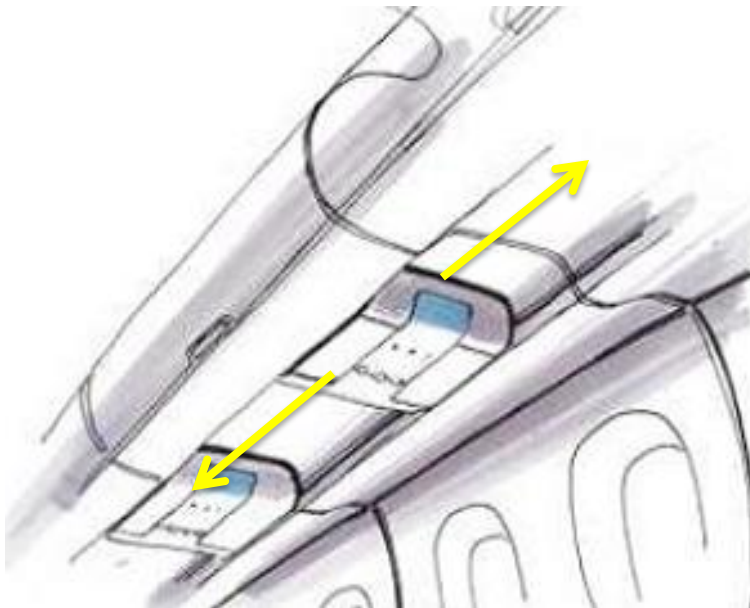
All functions above deliver real-time safety-related system status information to the pilot !



Need for WAIC - Reconfigurability

Example: Wireless Supply Unit

- Release of oxygen masks and trigger of oxygen flow
- Passenger Address Function (audio announcement)
- Display providing safety information to the passenger
- Needs to feature flexible installation locations for allowing fast reconfiguration of seat layout



Wireless can enhance reliability (1/2)

Example: Dissimilar redundancy

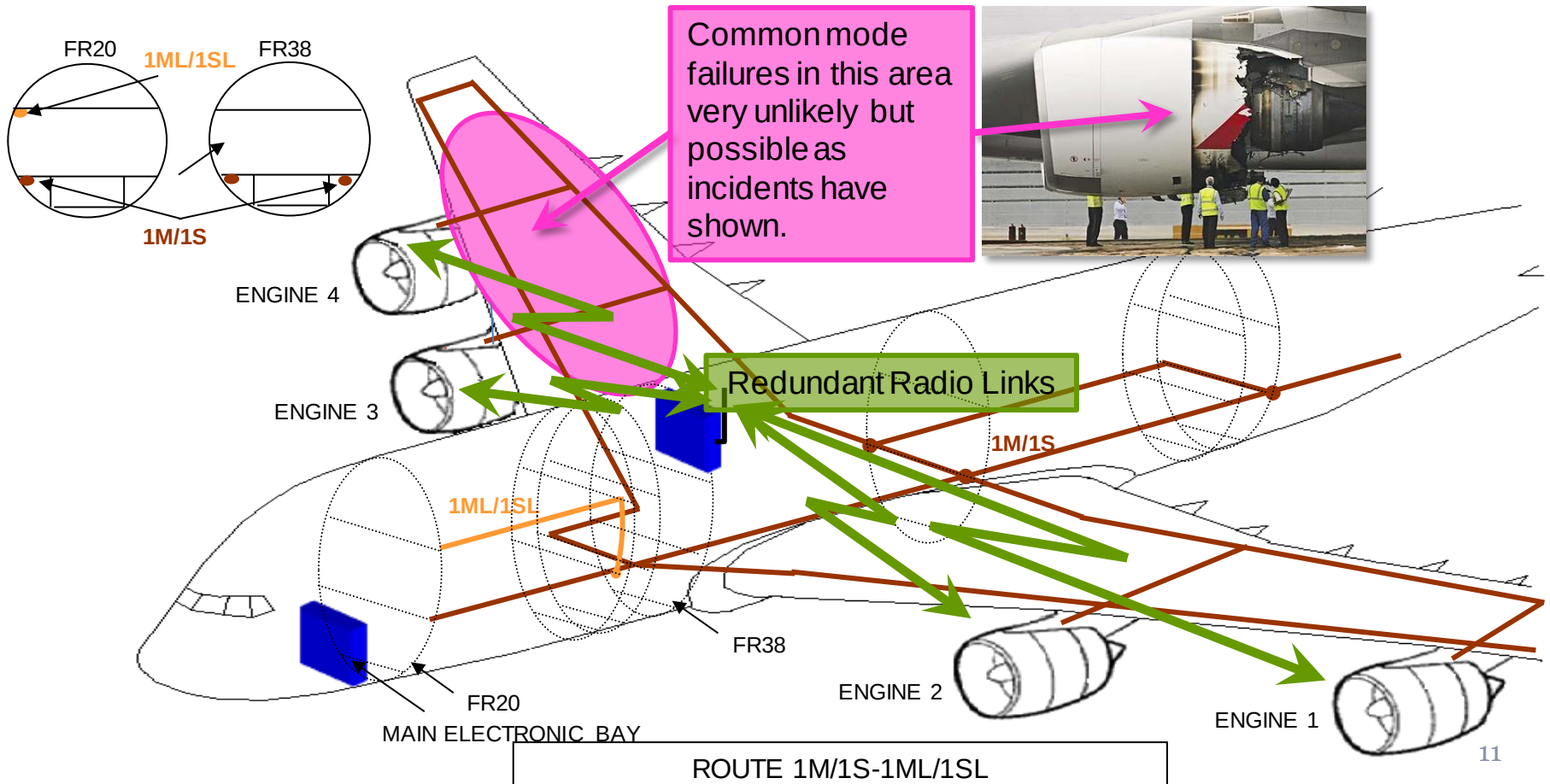
- Aircraft wiring features usually twice or triple redundancy
- Redundant wiring routes in different areas within the aircraft structure mitigate risk of single points of failure, caused by defect wiring (e.g. corrosion, chafing of isolation or loose contact) or cut wires (e.g. through particles intruding aircraft structure as in case of an engine blast)
- Wiring routes are segregated to the farthest possible extend allowed by the aircraft geometry

A wireless connection provides a dissimilar redundancy if wires are disconnected.

Need for WAIC - Dissimilar Redundancy

Example: Redundant communication paths (cont'd)

- Route segregation, combined with redundant radio links, provides dissimilar redundancy and mitigates risk of single points of failure



Agenda Item 1.17 – Resolution 423

resolves

that WRC-15 consider, based on the results of ITU-R studies, possible regulatory actions, including appropriate aeronautical allocations, to support the implementation of WAIC systems, while taking into account spectrum requirements for WAIC and protection requirements for systems operating in accordance with existing allocations,

invites ITU-R

- 1 to conduct, in time for WRC-15, the necessary studies to determine the spectrum requirements needed to support WAIC systems;
- 2 to conduct sharing and compatibility studies, based on the results of *invites ITU-R 1*, to determine appropriate frequency bands and regulatory actions;
- 3 when conducting studies in accordance with *invites ITU-R 2*, to consider:
 - i) frequency bands within existing worldwide aeronautical mobile service, aeronautical mobile (R) service and aeronautical radionavigation service allocations;
 - ii) additional frequency bands above 15.7 GHz for aeronautical services if spectrum requirements cannot be met in frequency bands studied under *invites ITU-R 3i*),

Examples of 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

Application	Type of benefit	High Rate -Outside		Period of operation	New or existing						
Avionics comm. bus	Application	Type of benefit	Low Rate - Outside		Period of operation	New or existing application					
	Application	Type of benefit	Low Rate - Outside		No. of nodes simultaneously operational	Period of operation	New or existing application				
Structural sensors	Air data sensors	Ice detection	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		
	FADEC aircraft interface	Landing gear (proximity) sensors	Cabin pressure	Wire reduction	0.8	0.8	11	Park, taxi, takeoff, cruise, landing	Existing		
External imagery sensors (cameras etc.)	Engine prognostic sensors	Landing gear sensors (tire pressure, brake temperature, hard landing detection)	Engine sensors	Wire reduction, maintenance enhancement	Low Rate - Inside				108	Park, taxi, takeoff, cruise, landing	Existing and new
	Flight deck and cabin crew voice	Landing gear sensors (wheel speed feedback, skid control, position feedback, steering)	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		
	Flight deck and cabin crew still imagery	Flight control sensors, position feedback and parameter	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		
	Flight deck and cabin crew motion video	Additional prognostic sensors, aircraft	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		
	Total	Flight -Operations related digital data	Engine sensors	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	
		Cargo compartment data	Cabin	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		
Structural sensors		Structural	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			

Low data rate inside category applications

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	0.8	0.8	11	Park, taxi, takeoff, cruise, landing	Existing
Engine sensors	Wire reduction, maintenance enhancement	0.8	0.8	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		

Low data rate outside category applications

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
Ice detection	Operational and safety enhancement	0.5	0.5	20	Park, taxi, takeoff, cruise, landing	Existing and new
Landing gear (proximity) sensors	Wire reduction, flexibility enhancement	0.2	0.2	30	Park, taxi, takeoff, cruise, landing	Existing
Landing gear sensors, tire pressure, tire and brake temperature and hard landing detection	Wire reduction, flexibility and operational enhancement	1.0	1.0	100	Park, taxi, takeoff, landing	Existing
Landing gear sensors, wheel speed for anti-skid control and position feedback for steering	Wire reduction, flexibility and operational enhancement	5.5	5.5	40	Park, taxi, takeoff, landing	Existing
Flight control system sensors, position feedback and control parameters	Wire reduction, flexibility enhancement	8.0	8.0	60	Park, taxi, takeoff, cruise, landing	Existing
Additional proximity sensors, aircraft doors	Wiring reduction, flexibility enhancement	0.2	0.02	50	Park, taxi, takeoff, cruise, landing	Existing
Engine sensors	Engine performance, wire reduction, flexibility enhancement	0.8	0.8	32	Park, taxi, takeoff, cruise, landing	Existing and new
Cargo compartment data	Wire reduction, operational enhancement	0.5	0.05	25	Park, taxi, takeoff, cruise, landing, taxi	Existing
Structural sensors	Wire reduction, flexibility enhancement, safety enhancement	0.5	0.3	40	Ground, takeoff, cruise, landing, taxi	New
Totals:		884.1*	855.9*	397		

High data rate inside category applications

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
Avionics comm. bus	Wire reduction, flexibility enhancement, safety enhancement	500	500	15	Park, taxi, takeoff, cruise, landing	Existing
Air data sensors	Wire reduction, maintenance enhancement	100	100	8	Park, taxi,, takeoff, cruise, landing	Existing
FADEC aircraft interface	Wire reduction, maintenance enhancement	12.5	12.5	10	Park, taxi, takeoff, cruise, landing	Existing
Engine prognostic sensors	Wire reduction, operational enhancement	4 800	80	30	Park, taxi, takeoff, cruise, landing	New
Flight deck and cabin crew voice	Wire reduction, untethered operation, operational enhancement	16	16	10	Park, taxi takeoff, cruise, landing	Existing and new
Flight deck and cabin crew still imagery	Wire reduction, flexibility enhancement safety enhancement	1 600	1 600	2*	Park, taxi, takeoff, cruise, landing	New
Flight deck and cabin crew motion video	Wire reduction, flexibility enhancement safety enhancement	1 000	1 000	4**	Park, taxi, takeoff, cruise, landing	New
Flight -Operations related digital data	Wire reduction, flexibility enhancement	1 000	100	2	Park, taxi, takeoff, cruise, landing	New
Total figures:		161 785***	18 385***	81		

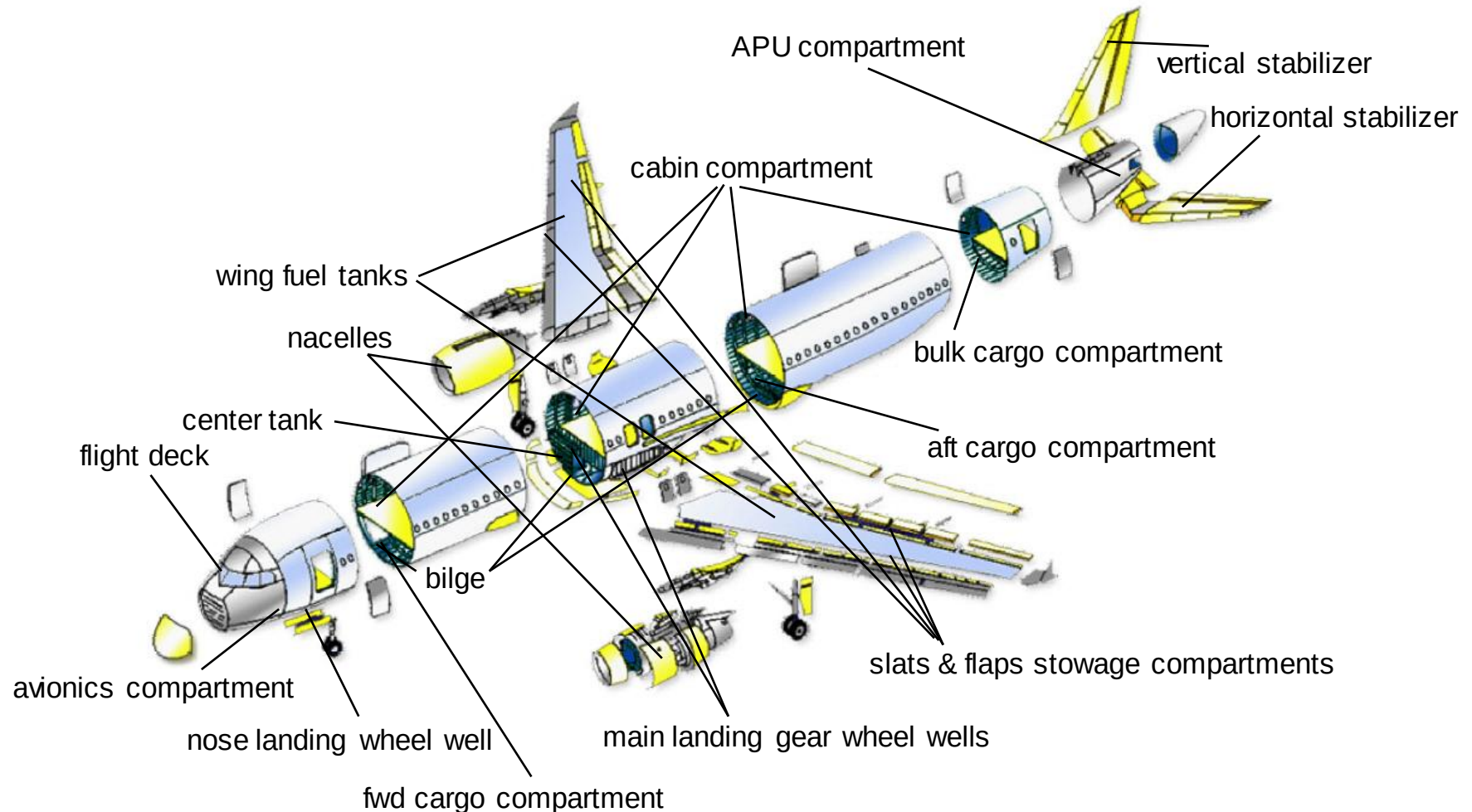
Application	Type of benefit	Net peak data rate per data-link/ (kbps)	Net average data rate per data-link/ (kbps)	No. of nodes simultaneously operational	Period of operation	New or existing application
Avionics comm. bus	Wire reduction, flexibility enhancement, safety enhancement	500	500	15	Park, taxi, takeoff, cruise, landing	Existing
Structural sensors	Wire reduction, flexibility enhancement, safety enhancement	45	45	40	Park, taxi, takeoff, cruise, landing	New
External imaging sensors (cameras, etc.)	Wire reduction, flexibility enhancement, safety enhancement	1 000	1 000	3	Park, taxi, takeoff, landing, taxi	Existing
Total figures:		12 300*	12 300*	58		

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

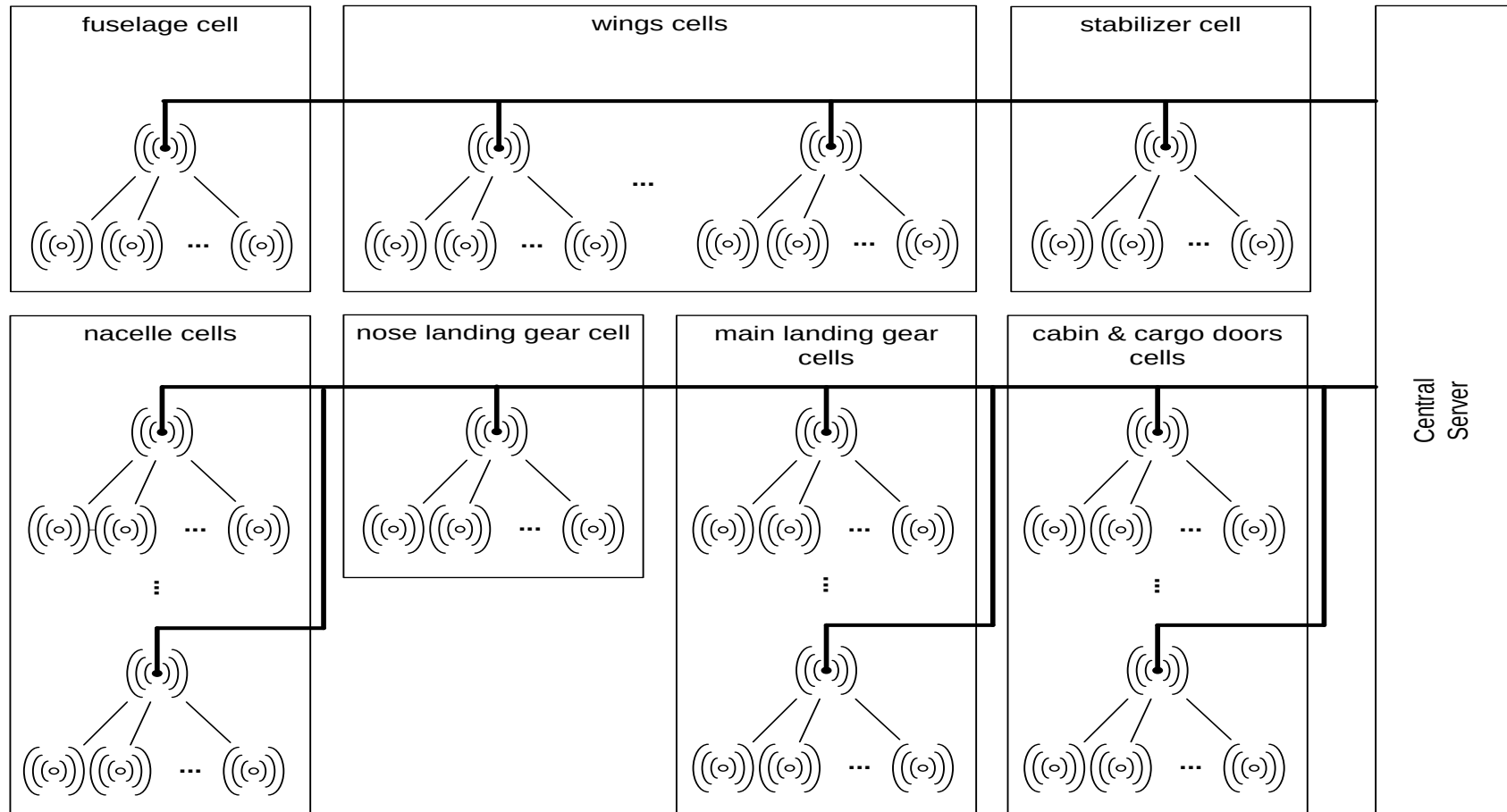
**145 MHz Total Spectrum Allocation Needed
(Before Band Sharing)**

Major components of a typical passenger aircraft and location of compartments



Compartments Accommodate a Cellular System Topology

Generic network topology of a network of WAIC installed outside of the aircraft structure

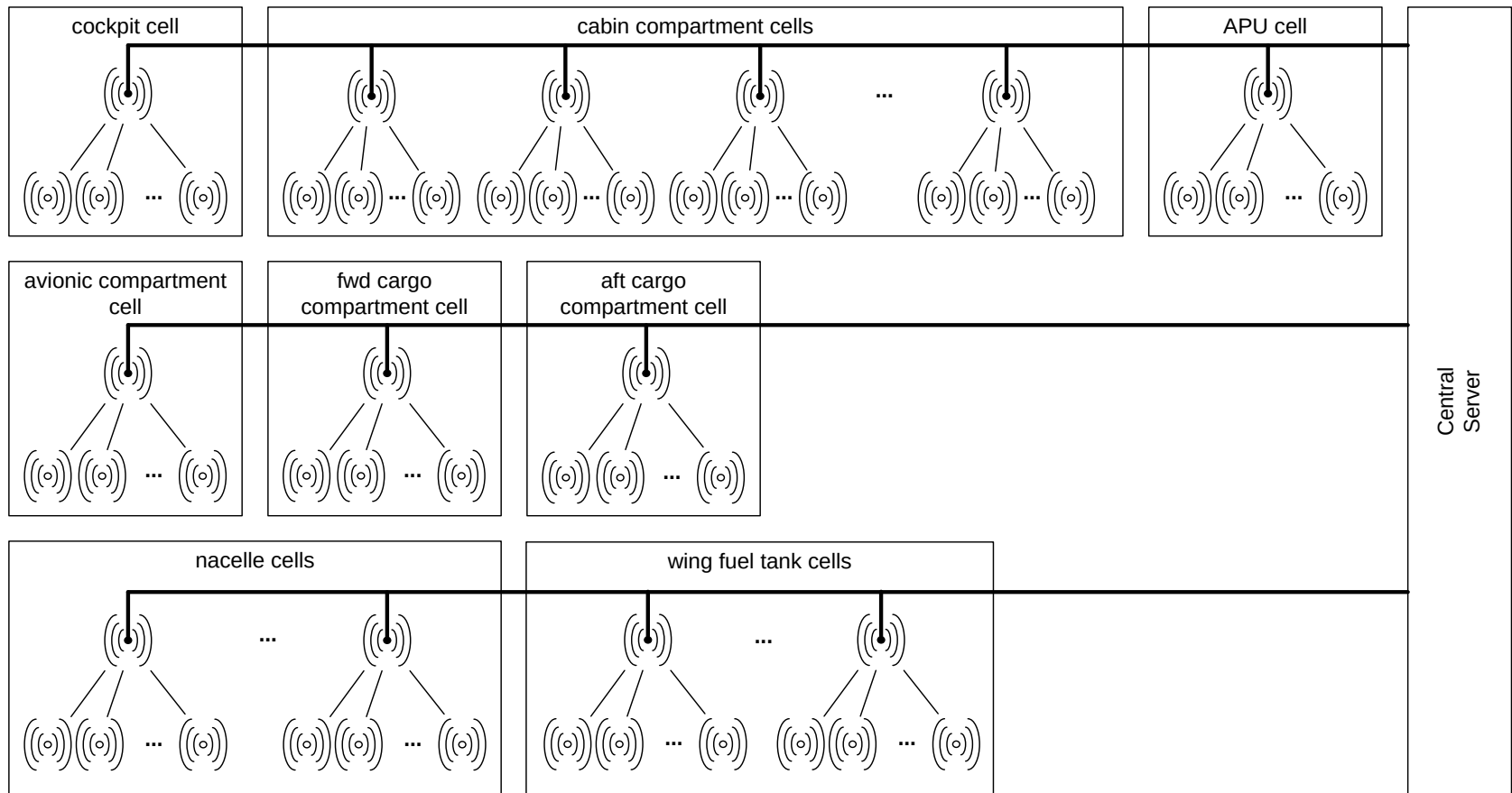


Legend:

 Gateway node
  End node
 — Wireless link
 — Wired link

Multi-hop relaying may be employed within each cell.
VIAs between isolated nodes in sub-cells may be used to unify it.

Generic network topology of a network of WAIC systems installed within compartments inside the aircraft structure



Legend:

 Gateway node
  End node
 — Wireless link
 — Wired link

WAIC Technical Characteristics

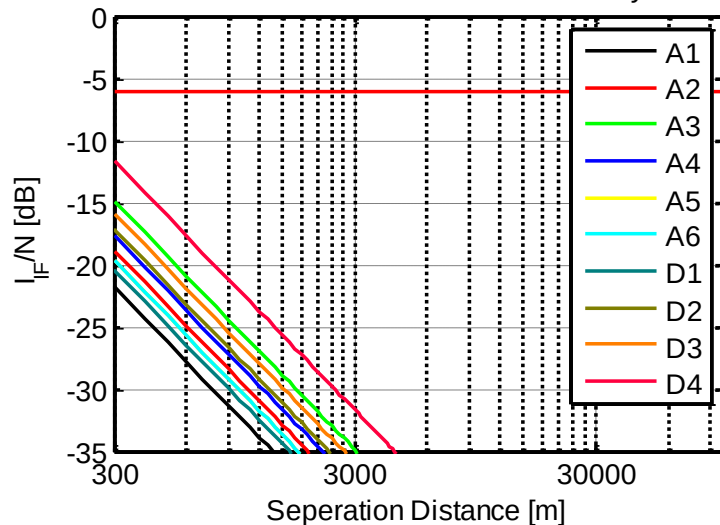
	Low data rate systems	High data rate systems	Units
Total net average data rate per aircraft	1.25	30.7	Mbps
Total net peak data rate per aircraft	2.3	174.1	Mbps
Overall spectrum requirements	51 ¹	94 ¹	MHz
Spectrum requirements per aircraft	35 ²	53 ²	MHz
number and location of simultaneously active transmitters 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

Non-Interference Case Analysis Synopsis

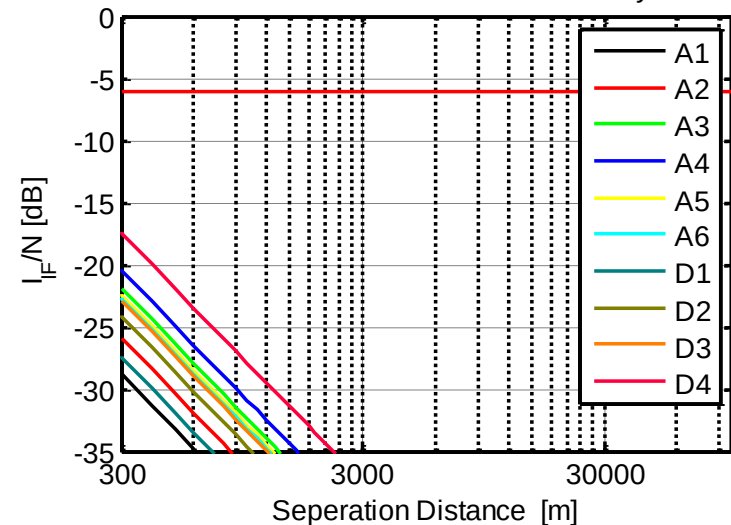
Receive Transmit	FMCW RadAlt	Pulsed RadAlt	WAIC Low Rate (802.15.4 baseline)	WAIC High Rate (802.11 a/g baseline)
FMCW RadAlt	<i>N/A</i>	<i>N/A</i>	Will need <9 dB S/I: I_{eff} lower over symbol by >>360° phase roll	No impact at any I/S: FEC coding recovers loss of 2-4 OFDM bins
Pulsed RadAlt	<i>N/A</i>	<i>N/A</i>	No impact at any I/S: 4-ary data symbols can tolerate losing 5 chips of 32 w/o error	No impact at any I/S: FEC coding recovers raw errors from <10% of OFDM symbols
WAIC Internal * Low & High	Meets WP5B – 6 dB I/N, all scenarios; Aircraft Shielding	Meets WP5B – 6 dB I/N, all scenarios; Aircraft Shielding	• Separate Low Rate (2.6 MHz) and High Rate (20 MHz) channels. • Estimate 15 low & 12 high rate channels • TDMA access scheme may share portions of frequency channel timelines between compartments by coordinating orthogonal time slot allocations (when compartment utilizations are <<100%) • Channelization Plan may also exploit isolation between compartments for channel time slot re-use (in same time slot) (mainly considered for High Rate channels)	
WAIC External * Low & High	• Meets -6 dB I/N, All scenarios • Directional Antennae for critical cases	• Meets -6 dB I/N, All scenarios • Directional Antennae for critical cases		

WAIC Desensitization of RadAlt is harshest factor

Receiver desensitizations criterion for HI systems

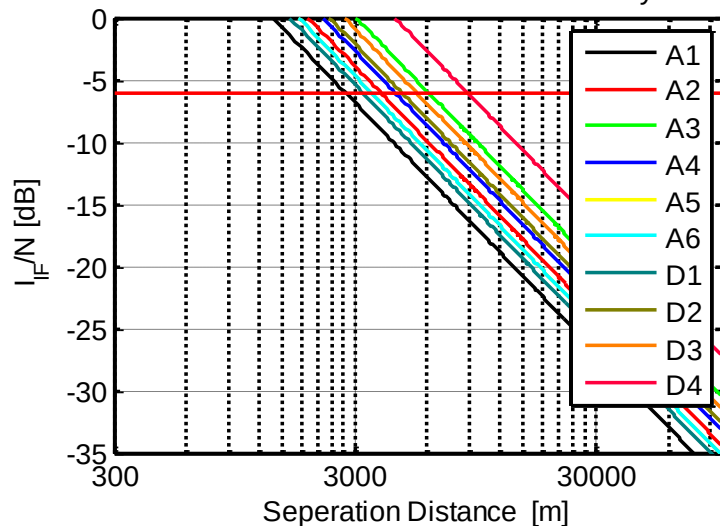


Receiver desensitizations criterion for LI systems

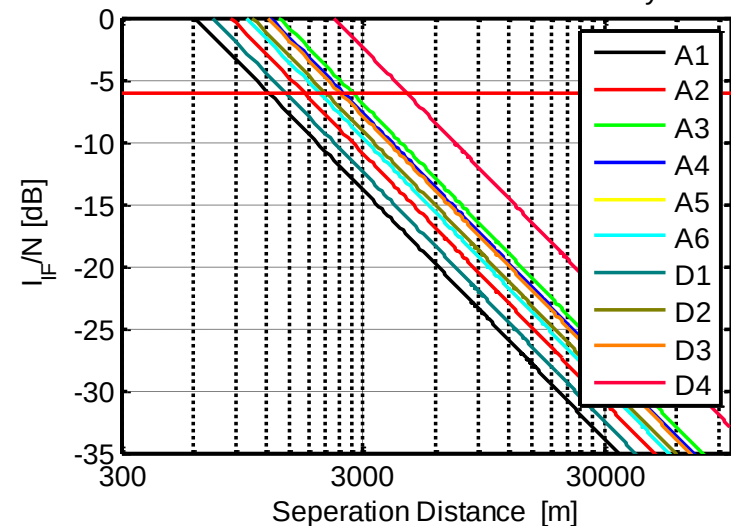


Internal WAIC systems meet -6 dB I/N non-interference criteria

Receiver desensitizations criterion for HO systems



Receiver desensitizations criterion for LO systems



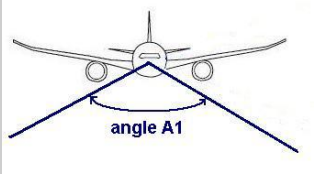
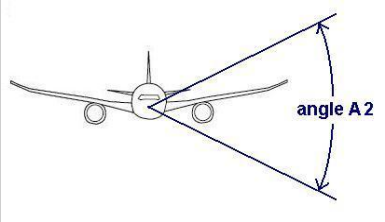
Note: HO/LO as shown using generic Omni antenna construct & full power

Technical Information

- **Aircraft Shielding:**
 - Very complex issue: depends on installation location of transmitter and receiver.
 - Fuselage attenuation is a directional property of the aircraft.
 - Statistically, the most common orientation between an aircraft and point on the ground is significantly higher than the average over all of the viewing angles (can exceed 30 dB).
 - Even outside systems experience partial shielding – depending on location.

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

Aircraft Shielding

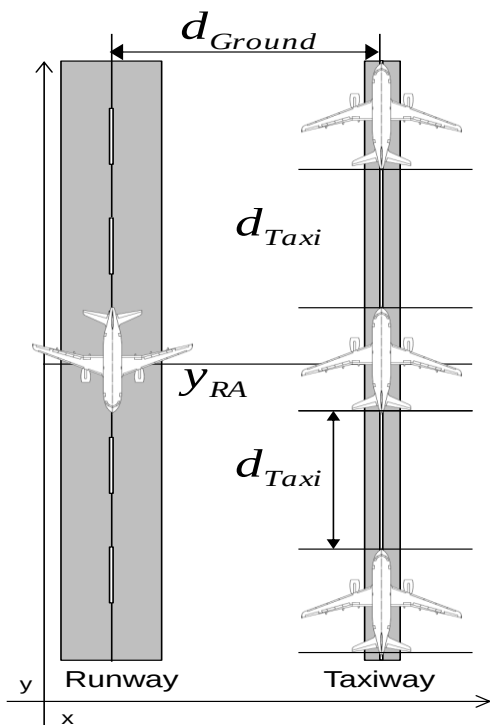
Case	Viewing Angle	Configuration	Typical attenuation
1	viewed from A1 	a) transmitters within cabin	25dB
		b) transmitters installed in lower lobe of aircraft fuselage	35dB
2	viewed from A2 	a) transmitters within cabin	10dB
		b) transmitters installed in lower lobe of aircraft fuselage	30dB
3	All angles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

Aircraft Component Shielding

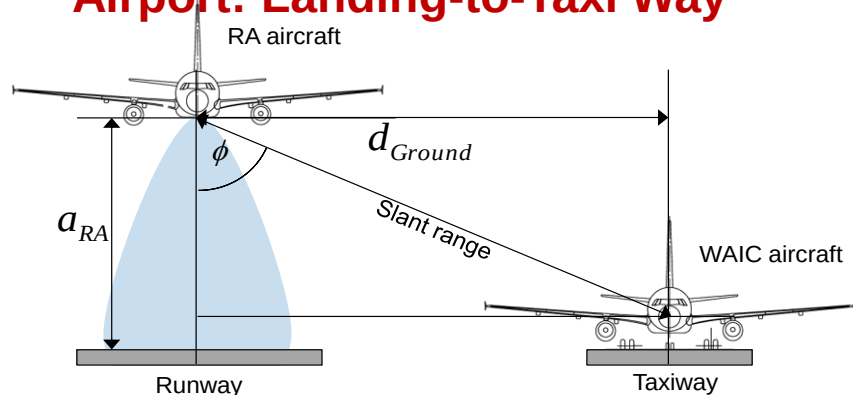
WAIC transmit antenna location	Assumed aircraft structural shielding / dB		
	'+/- 60° rel. to yaw axis	+/- 30° rel. to pitch axis	all other angles
flight deck	25	10	35
cabin compartment	25	10	35
avionics compartment	35	35	35
fwd and aft cargo compartment, center tank, bilge	35	30	35
bulk cargo compartment	35	30	35
wing fuel tank	35	35	35
horizontal stabilizer	35	35	35
nacelles	35	35	35

WAIC transmit antenna location	Assumed aircraft structural shielding / dB		
	'+/- 60° rel. to yaw axis	+/- 30° rel. to pitch axis	all other angles
nose (lower shell only)	0	5	0
center (upper shell)	5	0	0
center (lower shell)	0	0	0
tail (upper shell only)	5	0	0
left wing (upper shell only)	5	5	0
right wing (upper shell only)	5	5	0

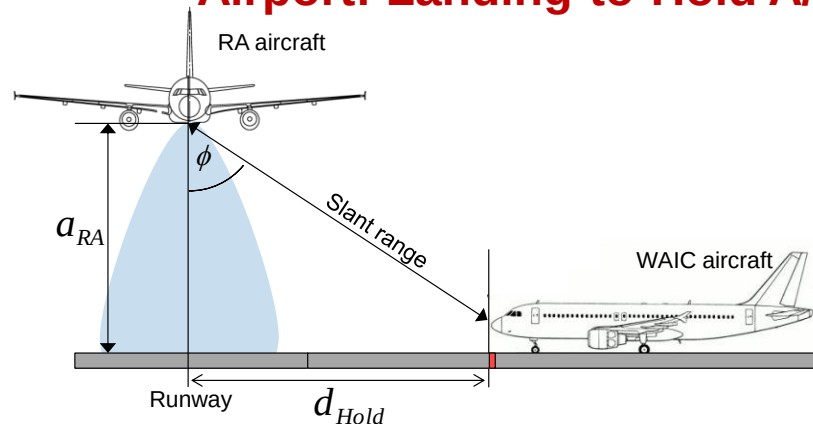
Critical External WAIC-RadAlt Scenarios (3)



Airport: Landing-to-Taxi Way

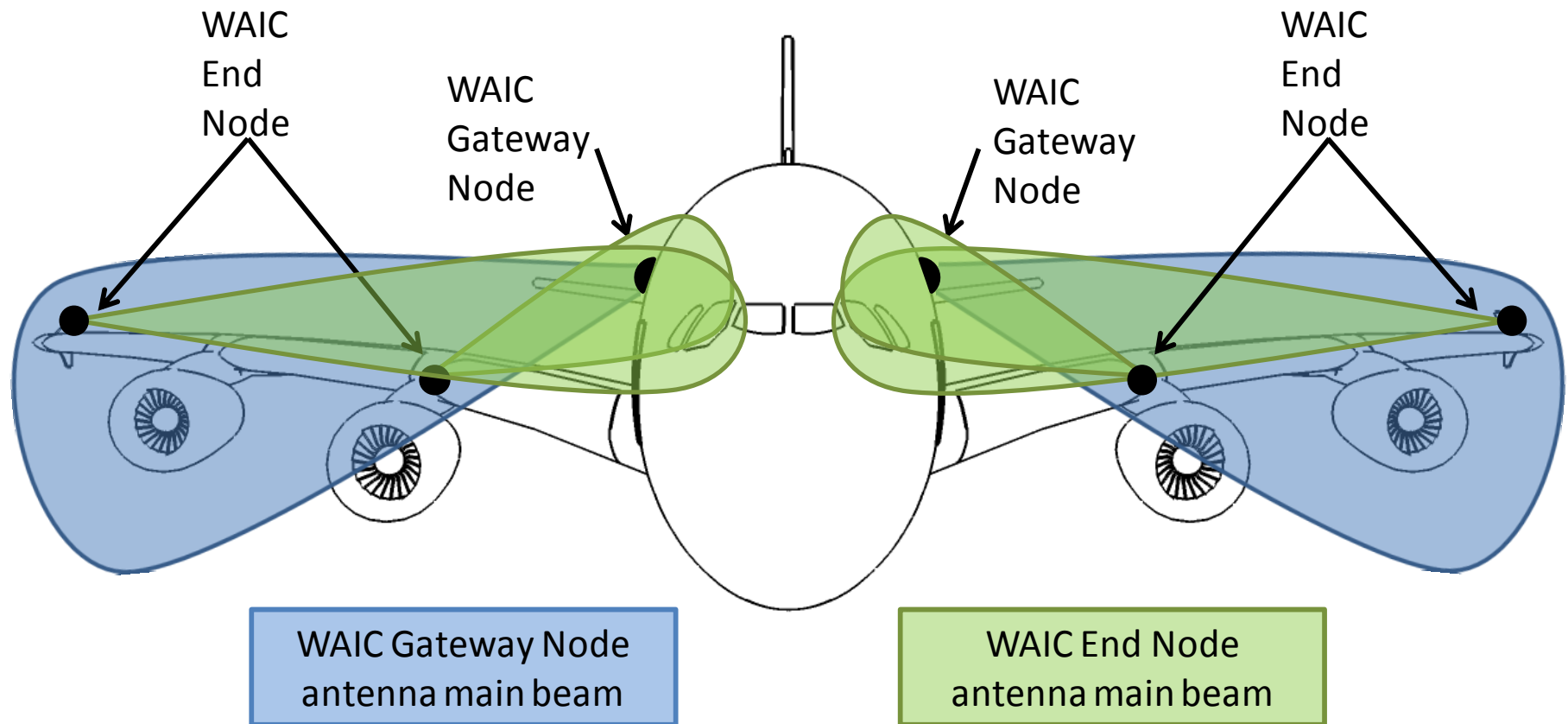


Airport: Landing-to-Hold A/C



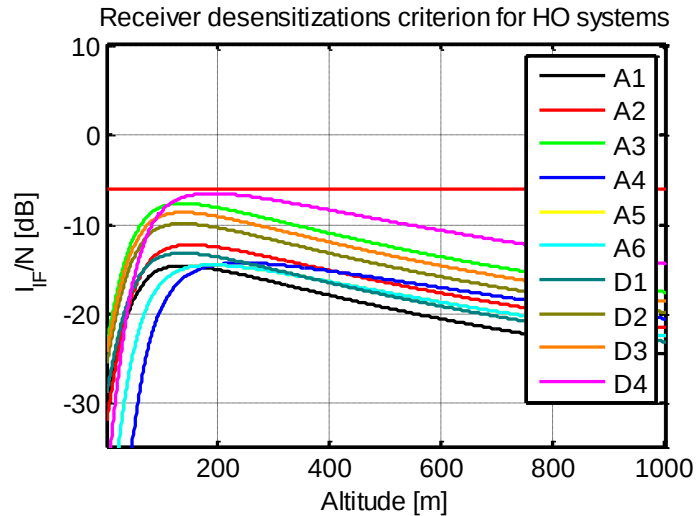
**En-Route:
Proximity Fly-By**

WAIC External Systems Shape the Radiation Pattern Using Directional Antennas to Reduce Interference Effects

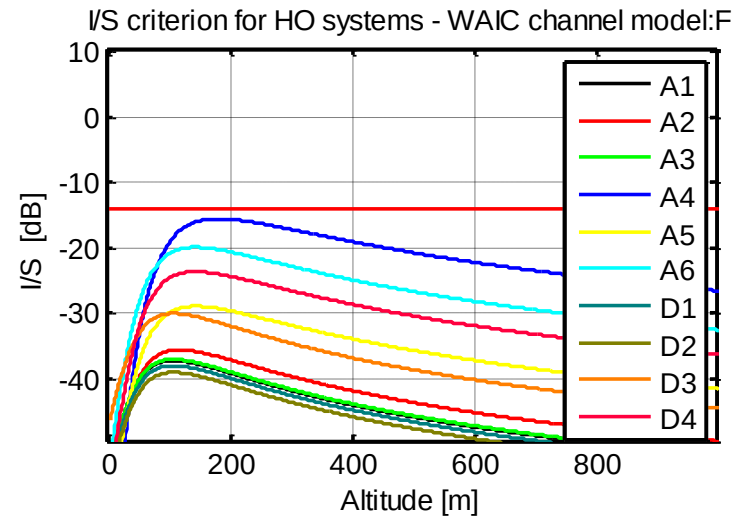


Directional Antenna pattern controls is one potential mitigation technique for external WAIC systems

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

- ITU-T 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)*

Agenda Item 1.17 Status for WRC 2015

- **Output of Conference Preparatory Meeting: SINGLE METHOD, NO OPTIONS CPM text**
 - Consolidated conflicting Methods and Options into a unanimous position for WRC 2015, no opposition
 - **Virtually assures the co-primary AM(R)S spectrum allocation will be approved at WRC-15**
 - **4200-4400 MHz (Radio Altimeter Band)**
- **Recommended Radio Regulations Modifications:**
 - **5.438** Use of the band 4 200-4 400 MHz by the aeronautical radionavigation service is reserved exclusively for radio altimeters installed on board aircraft and for the associated transponders on the ground.
 - **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 [A117-WAIC] (WRC-15).
 - **Reasons:** This footnote makes reference to the following Resolution [A117-WAIC] (WRC-15)

Agenda Item 1.17 – Resolution A117

Resolves

1. that WAIC shall be defined as radiocommunication between two or more aircraft stations located on a single aircraft, supporting the safe operation of the aircraft;
2. that the 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 the WAIC systems operating in the frequency band 4 200-4 400 MHz shall comply with Standards and Recommended Practices published in Annex 10 to the Convention on International Civil Aviation;
4. that No. **43.1** shall not apply

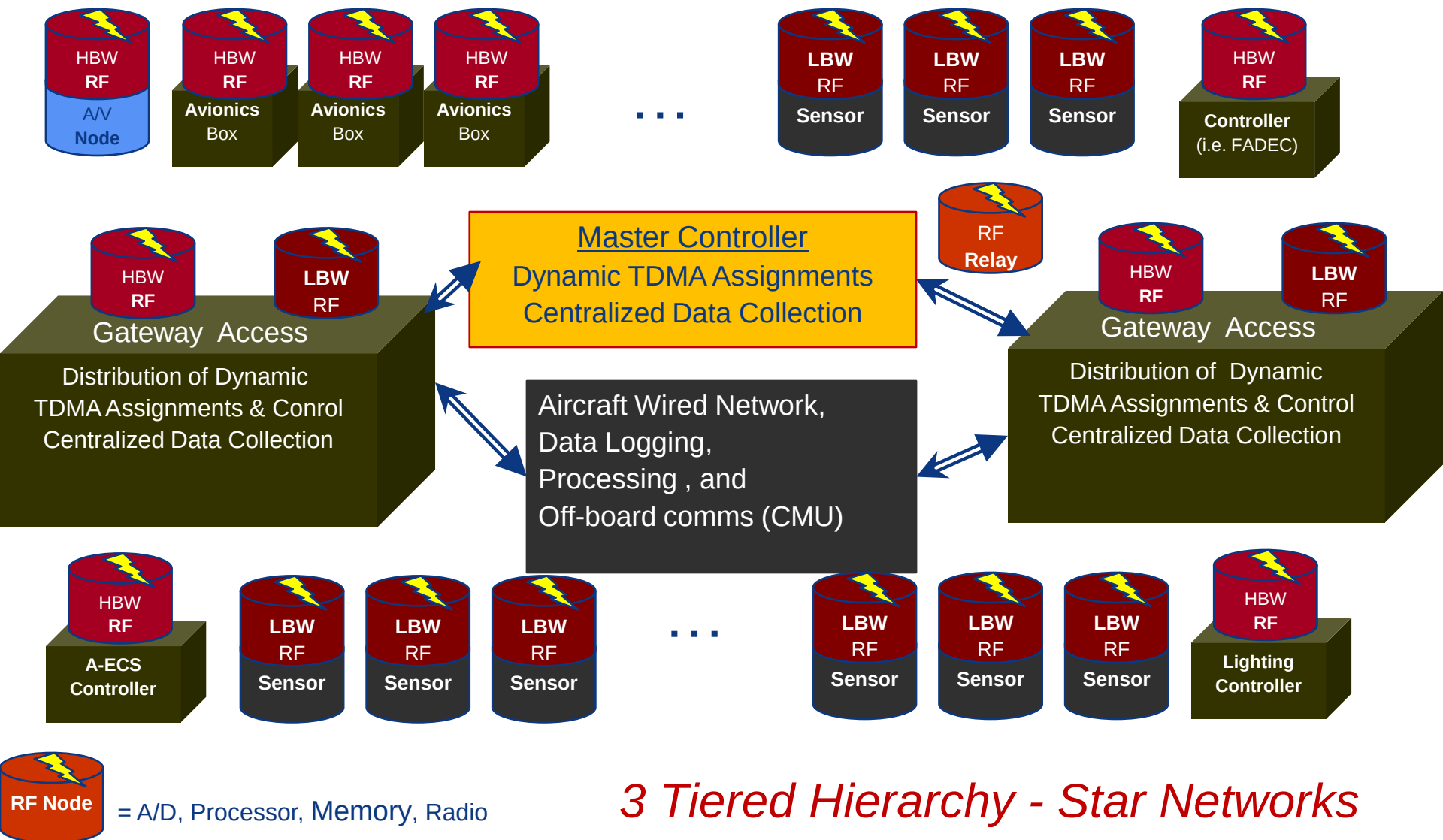
instructs the Secretary-General

- to bring this Resolution to the attention of ICAO,

invites ICAO

- To take into account Recommendation ITU-R M.[WAIC-CONDITIONS] in the course of development of SARPs for WAIC systems.
- **Reasons:** This Resolution provides relevant regulatory provisions to satisfy the agenda item

Nominal Architectural Concept



3 Tiered Hierarchy - Star Networks

Spec supports > 2000 LBW Nodes, >1000 HBW Nodes

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 and WAIC Next Steps

- **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**
 - This will only approve at a high level the ability for WAIC to use (share) the 4200-4400 MHz frequency band
 - Justification and support is adequate secure an allocation
 - 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 will follow WRC2015**
- **ICAO and RTCA framework and technical expertise in generating SARPS, MASPS, and MOPS will steer WAIC towards enabling future aircraft certification efforts**