Minutes of Meeting	
EUROCAE WG-96 / RTCA SC-236 Joint Plenary # 2	
Standards for Wireless Avionics Intra-Communication (WAIC) Systems	
within 4200 - 4400 MHz	

Date	*Tuesday December 6th through Thursday December 8th 2016*
Place	*U.S.A., College Station Texas*
Venue	*Texas A&M University*
Host	*AVSI*
Contact Persons EUROCAE RTCA	*Adrian Cioranu* Adrian.Cioranu@eurocae.net *Phone: +33 1 40 92 79 31* *And* *Rebecca Morrison* rmorrison@rtca.org *+1 202-330-0654*

AGENDA

1. Welcome/Administrative Duties
2. IPR / Membership Call-Out and Introductions
3. Acceptance of Meeting Minutes for the First Joint Plenary of SC-236/WG-96
4. Recap of Sub-working Group Structure and Scope Statements
5. Review of Schedule for Sub-working groups
6. Break-out into Initial Working Groups
7. Reports of the Plans for the Working Groups
8. New Business Discussions
9. Review of Action Items
10. Plan for next meeting
11. Adjourn.

Attachments:
- Attachment A : Attendance List
- Attachment B : Action List (SC-236-WG96 WAIC) - status 2016-12
- Attachment C : SC236_WG96_EUROCAE_RTCA.pdf
- Attachment D : Presentation FL (swg3_16_12_06)
- Attachment E : Presentation FL (swg3_16_12_08)
- Attachment F : Robin Davies WAIC Boundaries.docx

Appendices:
- Appendix 1: Coexistence scenario
- Appendix 2: Proposed Channelization Plan
- Appendix 3: Sub-Working Groups topics (Updated 6.Dec 2016)

Minutes of Meeting: 06. December

Agenda Item 1 - Welcome

Welcome from Chairmen of RTCA-SC236 Michael Franceschini (MRF), Robin Davies (RD) (Chairman of WG-96) and Secretary Peter Anders (PA).

Rebecca (RTCA) welcomes the group as well to the Joint Plenary # 2 and thanks David Redman for hosting this plenary session.

List of attendances is attached (Attachment A attendance sheet SC236-WG96 plenary 2).

Agenda Item 2 IPR / Membership Call-Out and Introductions

Rebecca and Paul Siegmund (designated FAA representative in SC236) provide the information on IPR, etc. (see attached presentation Attachment C SC236_WG96_EUROCAE_RTCA.pdf).

Agenda Item 3 - Acceptance of Meeting Minutes for the First Joint Plenary of SC-236/WG-96

Two minor editorial changes were asked for by Mike (page 1, and item 3c). It was changed "on-line" and uploaded to the RTCA web site by Rebecca. After this step, the MoM of the First Joint Plenary of SC-236/WG-96 was accepted and considered as being approved.

Agenda Item 4 – Recap of Sub-working Group Structure and Scope Statements
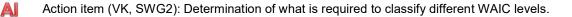
SWG1 - Coordinator: Sanjay Bajekal (SB):

Sanjay was not available to report at this point (he joined the Plenary in the afternoon of day 2). MRF reported instead: One WebEx was done by SWG1, focusing on basic structure of future MOPS; Recommendation to "split" the two classes of use cases – internal WAIC (internal fuselage); and external WAIC aspects of coexistence; may lead to two separate sections in the MOPS (for internal and external).

Note: For "external" aspects - see discussion with William Geoghagan (NATCA) on aircraft-to-aircraft separations and standards of distances.

SWG2 – Valentin Kretzschmar (VK): temporary lead for this SWG:

Refer to the list of SWG2 items – Items in brackets [ ] are still in discussion; to be decided whether they need to be included in the MOPS or not (items d,e,f).

AI Action item (VK, SWG2): Determination of what is required to classify different WAIC levels.

SWG3 Falk Lindner (FL) :

One WebEx was done on SGW level. Following key messages: Modelling of "security chain" is important; Focus on interfaces (towards access points; and towards aircraft function); Taking into consideration existing RTCA/EUROCAE standards elaborated by WG-72.

FL refers to a presentation he has prepared for the SC236 in order to summarize the work results of WG72, which may address the MOPS for WAIC as well.

This presentation summarizes the work done by other entities, e.g. PS-WOBAN, and provides an overview of the expected work to be done for the MOPS.

For full presentation refer to document:

http://workspace.rtca.org/apps/org/workgroup/swg3/download.php/24721

Following items, related to the presentation, have been discussed:

Question MRF: "Are the security topics as part of the WAIC system certification of the aircraft "?

Answer by FL: It has to be broken down, up to certain level security belongs to the WAIC.

SR: The MOPS should guarantee a minimum of cyber security. If the application needs additional security measures, it may implement on top of the WAIC level.

(Further discussion of Cyber Security approach – refer to Day 3 below).

SWG4 Paul Sigmund:

No activities so far.

General Discussion on SWG progress:

The plenary generally agrees that SC236 should primarily focus on the "coexistence" scenario of different WAIC and other neighbor radios (RA).

To support the determination of aircraft-to-aircraft scenario, Mr. William Geoghagan (NATCA) explained in detail the current standards of aircraft and radar separation concepts. There is of course a consideration of different flight phases (e.g. separation in flight -1000 feet; taxiing, taxi ways,..). He referred to a FAA ORDER that contains current standards for "Separation" concepts: FAA ORDER JO 7110.65W (Dec 2015). Rebecca made this document available to the Group via the RTCA website documents folder.

Notice: Please use the document for the purpose of SC236 only.

The plenary raised the following question: Considering a Network Management function is needed, what about then to secure it? However, first a decision must be taken, whether a network management shall be part of the MOPS.

Plenary agrees that for complex WAIC system a network management function will be necessary, however for simpler systems it might not be required. Plenary suggests adding options to the MOPS, e.g. if the system is considered as complex then there is a need a management function. However, this still not answered the question – because now the Group needs to determine what is complex, and what is non-complex?

PA suggests avoid writing a lot of options in the MOPS: Instead, the Group should define a *MINIMUM* set of security requirements only.

Plenary raises its concern about not yet known security threads. Developing a system capable to counter attacks of known threads at present time is not the issue, but new threats that may come up in the future? How to consider future developments?

PA: Suggestion to include a MOPS requirement to include "Updating" capabilities for any device, which would allow the system to adopt new security software patches at any time when needed. The EUROCAE WG-96 PS/WOBAN addresses this issue already (refer to 3.4.4.4 Instructions for Continued Airworthiness regarding Cyber Security).

Remark VK: WAIC shall guarantee the cyber security of the WAIC network AND the wired networks (back-connections) it is connected to. How much of this shall be addressed within the MOPS? This should be discussed in SWG3 further on. FL makes a note to do so.

MFT asks if for the risk assessment includes the assumption that attackers do have a full knowledge of the system architecture/characteristics. That would increase the thread level significantly.

FL answers: The likelihood of having someone who knows everything about the system is very low, and should be dealt with as such for the security assessment. If the likelihood is very low, this scenario could be neglected.

Agenda Item 5 Break-out into Initial Working Groups

The SC236 decided not to "break-out" into the sub-working groups; but stay together and work on the main topics related to SWG1. In addition, most of the plenary participants belong to more than one SWG and there are not enough attendees for splitting into SWG2, 3, 4.

A draft paper, created by MRF, was developed by the Plenary to gather "coexistence scenario constrains". Plenary will try to list all the possible scenarios in which coexistence might be an issue, including:

•   WAIC to WAIC (same Aircraft),

•   WAIC to WAIC (between Aircraft),

•   WAIC to RadAlt,

•   RadAlt to WAIC.

All items covered by MRF are compiled in the draft paper "coexistence scenario" (Appendix 01).

Day 2

Review of coexistence scenarios developed on Day 1.

Some coexistence cases between internal WAIC networks from one A/C to another A/C could be removed. They are not relevant, or are redundant in nature (results - see Appendix 1).

US mentioned that discussing about all scenarios is not necessary (in MOPS): For the relevant scenarios only, there will be potential interference and the MOPS shall define how to cope with it.

DR does not agree. He answers that ICAO, FAA etc. may ask about all scenarios, and so we may need to have an answer to each and every scenario.

RD proposes it could be better to just provide a common solution (how to cope with interferences in general) and then try to apply this common solution to all possible scenarios (tailoring).

MRF mentions that it might make sense to just try to identify the worst-case scenarios (e.g. identify how many aircraft can couple to a victim aircraft). If these could be addressed, other scenarios would be a subset.

For the case of parallel located aircraft, the Plenary assumes that only WAIC-to-WAIC interference is relevant. Interference from RadAlt to WAIC could be neglected.

There will be scattering measurements done to verify we achieve 120dB (IPL verified) from RadAlt (in aircraft 1) to WAIC (in aircraft 2).

MRF added a color code to the various coexistence scenarios. Color legend:

•   Green: Not a concern

•   Blue: Rather unlikely

•   Brown: Concern

•   Red: Worst case.

Additional Notes:

- Flight at altitude coexistence scenario is only "RadAlt to WAIC": In this scenario WAIC to WAIC is very unlikely.
- PS: Pre-flight failures must be avoided as well. Although probably not safety critical, a failure during pre-flight could result in a delayed flight. This event should be avoided.

-LUNCH BREAK-

SB joins the plenary and takes the lead, as the topic is related to SWG1 (SB is the coordinator).

SB asks if there would be a hypothetically case that was worse than "two WAIC systems in the same aircraft"? After some discussion, the Plenary concluded, there is no worse case than two non-cooperative systems installed in the same aircraft.

Plenary agrees to focus on cooperative forms and non-cooperative forms of coexistence.

There is a need to define cooperative and non-cooperative systems. Plenary agrees on new action for SWG1: Definition of cooperative WAIC systems and non-cooperative WAIC systems.

An update of the task list for SWG seems to be necessary. Plenary goes through the points in the Sub-working group topics list. (Appendix 3).

SWG1 / point 1 deals with Coexistence and Non-interference. Following sub-items were adapted:

- 1.c WAIC-to-WAIC interference between aircraft. Non-cooperative (1.c.i) added
- 1.d Out of band / unintentional interference: The MOPS would deal with the spectral mask and we will include an out of band tolerance threshold.
- 1.e Coexistence scenarios: xxx
- 1.f Generate aggregate interference environment (in-band detail, out-of band TBD): Tests are postponed to the beginning of January. A second campaign might be necessary for measuring the shielding in the aircraft (on board and off board). A campaign for some measurements for IPL between various points in different aircrafts. Point 1.f.1 is covered, 1.f.2 is almost covered and 1.f.3 is empty.
- 1.g Waveform PHY/MAC layers (only for coexistence): MRF mentions that g and l should be moved closer. G and j might be moved together (J. was channelization plan). So now, former J became G.
- 1.i Hi and LOW (burst OTA data rates, data rates ranges….).

Plenary agrees that we have to avoid addressing all possible corner cases, otherwise the MOPS will get too complex. At the same time we have to be careful about excluding things from the scope, ideally we should identify all cases, but only the relevant items should be considered in detail in the MOPS.

Assuming that the most complex coexistence issue is derived from adjacent parallel aircraft and WAIC systems interfering with each other, the plenary suggest adopting following way-forward:

Define an envelope around the aircraft, in which WAIC can be operated. What should be considered outside this envelope? Answer: WAIC should not be reachable outside that envelope.

To achieve this "operational envelope" determination, ML proposes to include in the MOPS a requirement which limits the field strength outside the aircraft at a certain distance. This would avoid pointing antennas directly towards outside the aircraft, or using omnidirectional antennas in the wingtips (for instance).

The question was asked "*are field strength or power limitation requirements sufficient to avoid interference with other aircraft WAIC systems*"?

Some members thought that field strength control would not provide enough mitigation to ensure coexistence. Additional means might be necessary, e.g. such as special coding techniques.

In order to test and develop the idea of using "*Field strength*" as a reliable measure to ensure coexistence, MRF suggests focusing on WAIC-to-WAIC and especially for the more demanding installation locations e.g. on a Landing Gear (LG) leg and in the cabin (window issues). So it might be interesting to focus on interferences between different aircraft for the following cases:

- from LG to other LG,
- from LG to cabin (different aircraft),
- from cabin to LG (single aircraft) and
- from cabin to cabin (This one might cover the worst case in terms of WAIC to WAIC interference).

Discussion ongoing about the scenario "landing gear from aircraft 1 interfering with cabin in aircraft 2": Assuming a 30m distance between both elements we can consider around -69dB free space attenuation, which might be enough.

Copy from the drawing wall:

The -69 dB comes from a calculation done by SB. Pr=Pt+Gt+Gr+Ls
Pt=5dBm/MHz
Gt=Gr=0
Ls=-74 dB (30 m of path)

An approach might be to include a request for airframers in the MOPS, that they have to demonstrate protection of -69 dB (IRP) for interference events. They could design the aircraft accordingly. That might isolate the external from the internal system. PA suggests avoiding of requirements or specifications with respect to the general aircraft design as protection or compliance means. This would radically reduce the acceptance of the MOPS as a basic specification for implementing WAIC systems. Worse case determination shall be done based on current existing A/C design standards, including HIRF standards.

Other informal observation: For this discussion the terms "internal WAIC system" and "external WAIC system" have been used. Plenary agrees that a definition is needed in the MOPS for both of the terms.

Day 3:

Plenary continues discussing the calculation assumptions done on Day 2. It was assumed a 30m path length (LG to cabin) is adequate. WG mentioned, a Gulfstream is a smaller aircraft, but can reach an internal link of 15m (which is considered as the longest path inside a cabin). This would result finally in a LG to cabin path shorter than 30m. Question: Would this distance represent our worst case? Should this being the basic of the MOPS?

To answer these questions, it might be necessary to decide another question first: Should we write requirements for the WAIC system integrator, for the equipment developer, for the airframer? Or for all of them?

The equipment developer is surely a consuming stakeholder of the MOPS, but there could also be additional parts addressing the installation and the final compliance demonstration to be done at A/C level.

PA refers to an existing MOPS that contains similar levels of information for different stakeholders: The ED112A – This MOPS has been established primarily for Crash recorders (as a basic for equipment TSO), but ED112A addresses also A/C interfaces, installation constraints, flight test conditions, etc. This "pattern" may also be used for the WAIC/MOPS.

MRF tries to summarize the coexistence discussion so far:

Two main points, we have a virtual bubble around the aircraft we are not allowed to escape from, and we have to be sure that the systems inside that bubble are capable of working. At the same time, we also need to be sure that the systems inside the bubble can work with each other, even if from different manufacturers.

Should we define that equipment from different suppliers are going to be **cooperative** with each other, or should we leave it open. No agreement achieved at this point.

However, it is agreed that coming up with "categories of service" might be a good approach. Then, we would be able to define requirements for each "category".

Going into "classes of services" definitions might be a good approach. However, defining C/I limits for each class of service could be a bit tricky since different systems might need different C/I values to work.

US suggests, what we need to put in the MOPS are mechanisms to verify certain requirements but not go into defining "Packet Loss ratios", or "C/I minimums", etc. The MOPS should be to ensure coexistence only.

MRF: if that is the goal, it could be done with ICAO Annex 10 only. The MOPS shall go further.

PS: The TOR says that the MOPS should be the basis for a TSO, in addition to ensuring coexistence.

US: Challenging again the question, is the future TSO be at equipment level or a system level?

PS: We don't decided yet.

MRF: TSOs are typically done for box level, however, for this system there are questions that cannot be answered at the box level, only at the system level.

VK: Can we define it now?

MRF: We do not know how to decide. There is no standard procedure for this decision making.

RD: Maybe we should draw a system and define then what we want to specify.

MRF: Since we don't know what need to specify, we have to do all and then taking out what is not relevant. Therefore, we may start with a full system level analysis and then decide what is up to the equipment developer, and what remains required for system developer/integrator.

For instance, we might not be able to achieve coexistence on a link level. Then we need to go one level higher (system / network management level).

SB: If you cannot guarantee performance at a link level, maybe WAIC is not the solution at all.

MRF: If we cannot solve the problem of coexistence at component level then we have to go at network (system) level, which becomes part of the MOPS.

The group asks for suggestion of the FAA:

PS: The FAA cannot answer this question. Some aspects are going to be answered by equipment manufacturers and others by system level. The MOPS could have different options.

We might be trying to solve too many problems at once, which make it difficult to identify the core issue. Our goal should be to help the applicant to characterize the issue and tackle it. We may not be able to put under the same umbrella a real-time sensor system and a system controlling the fasten-seatbelts-signs. How specific this document needs to be will depend on the group members themselves. For instance, if they want to "buy" a TSO-box from the catalog, that box needs to have a specific approved performance, tested under pre-determined (environmental) conditions. But it may include notified limitations or restrictions for installations, integrity, MTBF, use cases, etc. It cannot be required by TSO that such boxes, developed by different vendors (UTC, Honeywell, etc), will communicate with each other. Boxes may be designed to only communicate together, if they are designed by the same company (e.g. UTC-box1 <-> UTC-box2). However, a basic requirement is that boxes from different manufacturers must not interfere with each other (including from one aircraft to another). In other words, they must coexist without disturbance. Again, a TSO may come with installation limitations and/or engineering instructions to guarantee that the system works as desired. We have the decision to make about how much of that we want to define within the MOPS.

MRF: there will be bandwidth allocation constrains (at least on ground) so aircrafts must be able to coexist with each other on ground. This may imply "application trimming" (application will have less WAIC communication on ground).

SB: one option is to limit the bubble to a few meters outside the aircraft. And then say, if the bubble gets the full size, WAIC of this aircraft gets 100% of the available channel. If the bubble must be bigger, then you get less, e.g. 50%, of the channel and so on.

PS: Application trimming can also be achieved by selecting applications that are not necessary on ground, for example, it is not necessary to get tire pressure all the time, and so it can "share" its allocation with another time-uncritical application.

<u>**LUNCH BREAK**</u>

RD presents a diagram he created as a response on the discussion before lunch (refer to Attachment F : Robin Davies WAIC Boundaries.pdf). Some explanations of the diagram:

- A1 stands for Aircraft1, XA external A, IA internal A.

We assume intra-aircraft coordination between two (or more) WAIC networks. "Coordination" means they are able to communicate in order coordinate their conditions for coexistence. This would only be possible if the two (or more) networks following the same communication standard/protocol.

Next question is: Is A/C to A/C coordination required? Majority of the Group says: No! "Coordination" would require a minimum capability of communication. But, communication outside the aircraft via WAIC is not permitted by current ICAO policy (WAIC).

MRF proposes to establish a "channelization plan". Basic assumption is to nominate a 5 MHz channel as a primitive. That means we get 40 MHz channel (within 4200 - 4400 MHz). MRF started online a draft "channelization plan", which will be sent to attach it in the minutes (see Appendix 2).

After a short break, RM takes the lead for a presentation about RTCA policies:

- Rule of access to DOs/EDs documents: If you are not a member of RTCA you can't get a copy of a DO.
- Right now, the Cyber-security documents from RTCA and Eurocae are different, so they apply different policies. Both RTCA and Eurocae are working in a joint document right now, which should come out by the end of 2017. Therefore, referencing to former documents might be tricky since they are not fully compatible (should be avoided).

Change to SWG-3 topics:

FL to present some architecture extracted from WG-96 PS (refer to Attachment E : Presentation FL swg3_16_12_08:

The focus of is the link of node to node connection.

MRF asks if the link between WAIC node and the A/C system has to be considered as well?

FL: Opinion is that it is not part of the WAIC system. Rational: The interface between the WAIC node and the A/C system (let's say a sensor) is part of the application. Therefore, it is for the application to manage erroneous information and to protect its information in a robust way.

We have to keep in mind that at some point, the wireless sensor is likely to be tampered. PS requires that if this could be happened it has to be justified that there will be no effect at aircraft level. We have to prevent that someone would be able to inject "bad data" into the A/C system. Protections needed!

FL: For physical security we can possibly refer to existing measures and guidance. Physical security will be dealt with applying existing standards.

PS: there is a rule (best practices actually). Physical protection is an installation constraint more than a requirement for the MOPS.

PA: "Physical protection" is addressed by the EURCAE/PS for WOBAN. This part in the WOBAN-PS is adapted from an EASA CRI (F65), which addresses this issue.

Al ACTION: EASA CRI -F65 on physical protection - Access for the group (PA to ask KH)

FL presents the slide "Threat Categorization STRIDE", showing basic security threats and security controls. The first step would be to apply this model STRIDE to the WAIC medium, and then identify weak points and then solutions for protection.

Group starts filling in the table presented by FL. It will be continued by SWG3. It is stored in:
http://workspace.rtca.org/apps/org/workgroup/swg3/download.php/24722

"Spoofing" is defined in this table as an action to gain access to the system; however a more traditional approach is to consider spoofing as the injection of non-valid data.

If encryption is used, who is going to do the security-key management for the systems? Is it going to be the operator, the aircraft manufacturer, etc. How to deal in the MOPS? It is still to be proposed by SWG3.

END of the discussion of SWG3.

The chairman MRF proposes to review the agenda of the meeting:

The following agenda items have been covered by discussion above:
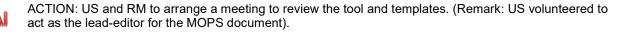   5. Review of Schedule for Sub-working groups
     6. Break-out into Initial Working Groups
     7. Reports of the Plans for the Working Groups

Some tasks are due by the next plenary:
- SWG1 and SWG3 plan to have some WebEx meetings.
- SWG-2 and SWG-4 have no schedule, shall be done until next plenary.

Agenda Item 10 New Business Discussions

New RTCA tool for document editing:

Al ACTION: US and RM to arrange a meeting to review the tool and templates. (Remark: US volunteered to act as the lead-editor for the MOPS document).

Agenda Item 9 - Review of Action Items

The up-to-date Action items list is part of this MoM (see excel file/Attachment B), including recording of the new action items mentioned above:

3 new Action Items created during joint plenary meeting #2 (AI 14…16)

2 actions remained open from previous meetings (AI 7, 11).

All working group members are requested to check the status of the Actions items list. Please comment if any inconsistencies are listed.

Agenda Item 10 - Plan for next meeting

Next meeting will be on 28.02. to 2.March, in Washington(DC) USA. RTCA will host this next meeting.

Next meetings (after this one) have been scheduled (for 2017).

Review of detailed schedule (excel file by RM).

Agenda item 11 Adjourn

================ End of the third Day / End of Meeting ============================

Complied by Peter Anders
Secretary of SC-236/WG-96

Approved by Michael Franceschini
Chairmen of Joint SC-236/WG-96 (MOPS for WAIC)

Appendix 1 : Coexistence Scenario Constraints

External WAIC System Concerns
- *WAIC to WAIC*
- *WAIC to Altimeter*
- *Altimeter to WAIC*
- Landing Scenario (1 a/c in air, other(s) on ground- including to taxiway – full runway length)
  - Vertical separation, slant offset
  - Hold a/c is closer to runway than taxiway (a/c nose is 225ft from runway centerline)
  - a/c in air can be from 0 to 100 ft altitude at runway end (50 ft typical)
    - based on 3 degree descent, 2000 ft max touchdown zone limit (>2000???)
    - yields ~ 30 degree max angle for window offset
- Taxi Scenario (weight on wheels)
  - Nose to tail
    - Minimum separation - NONE
  - Passing (wingtips)
    - Same direction
      - By airport design (taxiway separation – chart supplement)
      - Check ICAO annex 14 with aerodrome design
      - FAA AC150/000-13a = airport design
    - Opposite directions
    - Perpendicular crossing (wingtip to nose)
- Terminal (at Gate/ in alley)
  - Any orientation
  - Up to airline operations (wing walkers)
- Flight at altitude
  - Vertical coupling
    - Separation distance – 1000 ft minimium
    - but can be less below FL180 with visual separation
  - Horizontal coupling (including through window)
- In-flight: parallel approaches (2 a/c in air)
  - Standard separation
    - Longitudinal, latitudinal
  - Loss of separation (acceptable separation standards)
- Parallel Take-off
- Parallel – I takeoff, 1 landing

Runways 75 ft wide; air carrier runways 150 ft (225 ft separation); Taxiways are 75 ft wide

Internal WAIC System Concerns
- *Landing Scenario (1 a/c in air, other(s) on ground- including to taxiway – full runway length)*
  - *Vertical separation, - ensures minimal to no window coupling (multipath?) ?*
  - *Low likelihood for internal systems*
- Taxi Scenario (weight on wheels)
  - *Nose to tail*
  - Passing (wingtips) WAIC-to-WAIC only;
    - WAIC-WAIC pre-flight cannot have reportable link outages (alarms, ops delays…)
    - *no altimeter coupling – verify by IPL measurements*
    - Same direction: By airport design (taxiway separation – chart supplement)
      - ICAO annex14 aerodrome design, FAA AC150/000-13a - airport design
    - Opposite directions
    - *Perpendicular crossing (wingtip to nose)*
- Terminal (at Gate/ in alley) WAIC-to-WAIC only; *no altimeter coupling – IPL verify*
  - Orientation dependent - *+/- 45 degrees?*
  - Up to airline operations (wing walkers)
  - Worst case interference, but low severity/safety impact. (Can wait-out for adaption)
- Flight at altitude Altimeter-to-WAIC *(with banking, lateral offset)*
  - *Vertical coupling – full fuselage attenuation –WAIC-altimeter done at ITU*
  - *For WAIC-to-WAIC, need to consider lateral offset + banking (30º max)– may get window coupling*
    - *This is a highly unlikely/rare scenario, and could only last briefly*
  - Horizontal coupling (including window) – 3 mile separation w/o longitudinal (120 dB)
- In-flight: parallel approaches (2 a/c in air) WAIC-WAIC
  - Standard separation distances
    - Latitudinal runway separation – 4300 ft (apt design standard)
      - Simultaneous dependent approaches (no longitudinal separation).
        - Precision Runway Monitoring (faster radar updates)
    - 2500ft->3600ft runway centerline. 1 nmile diagonal separation
    - 3600-4300ft 1.5 nm

- >4300 ft needs 2 nm separation
  - PRM, <4300 centerline, no longitudinal separation. Window-to-window direct
    - *Adjusted to same altitude before glideslope intercept. Parallel from 12nm-5nm out (4 minutes)*
  - Loss of separation (acceptable separation standards)
  - *Check altimeter coupling to interior – seems geometries don't raise a concern*
- Parallel Take-off WAIC-WAIC
  - <2500 ft parallel, no longitudinal separation.
  - *No altimeter inference effects to WAIC*
- Parallel – I takeoff, 1 landing
  - Very brief interference interval - <3 sec

Interference Scenario Analysis: Interior System

Landing Gear to Window Receiver, adjacent a/c; Wingtip to adjacent window included
Wing length only: 100 ft , so 100 ft interference path → 74 dB path loss
      This is actually the wingtip distance; should be 2x wing for Lgear to fuselage
Friend link 50 ft in cabin to window → 68 dB path loss
Interference is at -69 dBm/MHz (using 5 dBm/MHz max Pout 0 dBi antenna. Low data rate.
Friend link has - 63 dBm /MHz → 6 dB S/I (again, this really wingtip interference)
      Landing gear should be 12 dB S\I, based on 200 ft P_i and 50 ft P_{fr}
No multipath or bulk losses included in friend link yet – 20-30 dB margin reasonable
Need to do high data rates also, HO-LI… Also, more severe geometries
But closest a wingtip can get to a fuselage is the shorter wing's length

A320: wingspan 110 ft, cabin width 3.7 m (12 ft), LOA 37.5 m → cabin 30m (100 ft) cabin length, height 12m (top of tail). Window height ~ 6 m (20 ft)
      110 ft P_i and 50 ft P_{fr}, 6 dB S/I; wingtip is 0 dB S/I
Gulfstream 650: wingspan 100 ft, LOA 100 ft, interior 54 ft, height 26 ft
      100 ft P_i and 50 ft P_{fr}, 6 dB S/I; wingtip is 0 dB S/I
CRJ200 wingspan 70 ft, LOA 87 ft (cabin 40 ft). Range ratio is ~1:1

Recommend a 6dB front/back ratio on wingtip antennas, pointing inward.
      Maintains a minimal 6 dB S/I, same as for an omni on the landing gear
Interior receivers need to operate with a 6 dB S/I in-channel
For cockpit windows, no nose-to-tail kissing in taxi line. Maintain 50ft or more.
      Check window coating attenuation for closer fits

Define the S/I and S/N that each class of service can operate at is
      CLoS 1 = 6dB, CLoS 2 = 9 dB….
      Separate link level and net level CLoS. (ie, latency is net level, BER vs SNIR is link level)
Transmit Power control, diversity…
Types of Radios

Marketable evolution: interior systems use simple IPL initially, and a/c meets S/I levels for I indicated. Ex-Ex systems develop more protocols (Longer certification risk), but once developed, can be employed by new internal systems for additional aircraft design freedoms

CAN aircraft interference bubble be small enough for no additional cooperative measures?
- If so, then that cell has unrestricted frequency use
- If not, then other techniques such as FH, channel management/interference avoidance.. will need to be employed – BUT ONLY FOR THOSE CELLS WITH OVERLAPPING BUBBLES

Appendix 2: Proposed Channelization Plan

Based on 5 MHz channel primitives (3-7?) for coexistence management
Channels 1-40
Subchannels at 1MHz: Channels 1a-1e (or 1a-5 if aggregated from 200 KHz primitives)
Subchannels at 200 KHz: channels 1aa-1ay (or 1a-1y if this is the primitive))
Aggregated Superchannels
     10MHz = channel 1-2   15 MHz = channel 1-3   20 MHz = channel 1-4

LTE bandwidths 1.4, 3, or 5 MHz primitive?? , AeroMACS uses 5 MHz primitive
     802.11a/g is 16.6 MHz, 52 subcarriers of 319 KHz each
          LTE BWs: 1.4MHz, 3, 5, 10, 15, 20MHz. (Occupied **bandwidth**: 1.08MHz, ...)
Do we still need separate High data rate and low data rate subsystems?

Appendix 3: SC-235 Sub-Working groups   Updated Dec-6 2016)

1. **Co-existence and Non-Interference**
   a. RadAlt –WAIC – on ownship
   b. RadAlt – WAIC between aircraft; also, between altimeter effects if appropriate
   c. WAIC-to-WAIC Interference between aircraft
      - Non-cooperative approaches
      - Coexistence approaches: interference avoidance, FH, others. Compatibilities between different techniques. Network/Control Plane implications
   d. Out-of-band / unintentional interference
   e. Co-existence scenarios: landing to taxi/hold; terminal/parked, others??
   f. Generate Aggregate Interference environment (in-band detail, out-of band TBD)
      - Measurement campaign – RadAlt interference susceptibility, ground scattering
      - IPL - analyses + measurement Propagation data (on board)
      - IPL between various points on different aircraft (from interior to …)
   g. Channelization plan *(sub-channelization?)*
   h. Waveform PHY/MAC layers (not for interoperability, only coexistence)
   i. Hi and low [burst OTA data rates, data rate ranges], bandwidths, transmit power, receiver sensitivities, dynamic range….
   j. spectral confinement: transmit and receive spectral masks, in-band
   k. MAC approach: TDMA, CSMA, CDMA, FDMA, hybrid; timing/synchronization (local/*global?*)
   l. [Modulation types, industry standards (IEEE, ISA 100), PDUs…. (guidelines, or firm specs?)]
   m. Antenna patterns, gain…
2. **Network Layer and System Level Issues**
   a. Control plane, centralized vs. local (gateway/subnet) responsibilities
   b. Coexistence management mechanisms (for inter-aircraft coordination) – liaison with SWG1
   c. Integrity, reliability, availability (QoS)
      - Determinism – data is delivered correctly & on time – as intended (within bounds)
   d. [Application layer interface / QoS capability assurances (latency, jitter, BAG, rates…)]
   e. [Compatibility with avionics busses, protocols, interfaces…]
   f. [Net routing topologies – hub/spoke, relay spokes, mesh, peer-peer??]
   g. *Certification Issues – system level guidance? Net Manager as a class of node?*
3. **Security**
   a. Threat assessment, vulnerabilities/probabilities/costs
   b. Airworthiness implications (SC-216/WG-72 liaison)
   c. Encryption approaches
   d. Key management, distribution, compromise recovery…
   e. Anti-tamper, physical protections
4. **Physical and Environmental Requirements**
   a. Bus and component (sensors, digital/analog..) interfaces
   b. Power (prime, battery, energy harvest…)
   c. Installation guidance and constraints
   d. ANTENNA locations, orientations, net far-field pattern after considering lobing (reflections…)
   e. *Certification Issues – system level guidance? Net Manager as a class of node?*
   f. Maintenance, continued airworthiness
   g. Reconfiguration, retrofit
   h. WAIC radio as a device AND radio + application element(s) (e.g. – wireless sensor)
   i. Human protection (RF)
   j. Standards docs (DO-160) HIRF, lightning, EMC, temp/pressure/humidity/vibration, salt. SEU
      - *Identify applicable DO-160 tests to be done under WAIC operating conditions.*