RTCA Paper No. 094-24/SC159-1116 Washington, 9 August 2024

EUR 254-24 / WG62-149 Saint-Denis, 9 August 2024

Summary of the One Hundred and Sixteenth Meeting

Special Committee 159 (SC-159)

Navigation Equipment Using the Global Navigation Satellite System (GNSS)

And

Seventieth Meeting

EUROCAE Working Group 62 (WG-62)

GNSS

The one hundred and sixteenth meeting of SC-159 was held on March 22, 2024, virtually, from 9:00 a.m.to 3:00 p.m., Eastern Daylight Time. The meeting was held jointly with the seventieth meeting of EUROCAE WG-62 (GNSS). The attendees were the following:

NAME	COMPANY
Christopher Hegarty (Co-Chairman)	The MITRE Corporation
George Ligler (Co-Chairman)	GTL Associates
Wes Googe (Secretary)	American Airlines
Mikael Mabilleau (WG-62 Secretary)	EUSPA
Hamza Abduselam (GAR)	Federal Aviation Administration (FAA)
Karan Hofmann (Program Director)	RTCA
Mark Watson (Technical Programme Manager)	EUROCAE

NAME	COMPANY
Alessandro Adinolfi	ANAC-Brazil
Ken Alexander	Federal Aviation Administration (FAA)
Javier Andres-Diaz	ENAIRE
John Ashley	The MITRE Corporation
Laurent Azoulai	Airbus
John Barry	Federal Aviation Administration (FAA)
Jeremy Bennington	Spirent
Jason Burns	Federal Aviation Administration (FAA)
Natali Caccioppoli	EUROCONTROL
Stefano Caizzoue	DLR
Ettore Canestri	EUSPA
Tim Cashin	The MITRE Corporation
Christina Clausnitzer	Federal Aviation Administration (FAA)

Rich Clute	ZETA Associates
Jed Dennis	FAA/NAVTAC
Mark Dickinson	Federal Aviation Administration (FAA)
Yi Ding	Esterline CMC Electronics
David Duchet	EUOCONTROL
Andrew Elliot	US Air Force/ US Space Force
Bob Erlandson	NISC III
Swen Ericson	ZETA Associates
Philippe Estival	DSNA
John Foley	Garmin Ltd.
Joseph Gillespie	Federal Aviation Administration (FAA)
Anna Guegan	EUROCAE
Matt Harris	The Boeing Company
Toru Ishita	Japan Radio Air Navigation Systems Association
Sun Jian	COMAC
Sai Kalyanaraman	Collins Aerospace
Vignesh Krishnan	Honeywell International
Linda Lavik	INDRA
Rebecca Lawler	United Airlines
Tieshuai Li	COMAC
Andreas Lipp	EUROCONTROL
Fan Liu	Federal Aviation Administration (FAA)
Matthew M. Lug	US Air Force
Christophe Macabiau	Ecole Nationale de l'Aviation Civile
Jeff Myers	Federal Aviation Administration (FAA)
Tim Murphy	The Boeing Company
Hamdi Nasser	Federal Aviation Administration (FAA)
Yukihide Omori	Japan Radio Air Navigation Systems Association
Christophe Ouzeau	Collins Aerospace
John Owen	Defence Science Technology Laboratory (DSTL)
Doug Phifer	Federal Aviation Administration (FAA)
Ding Qun	CETC Northwest Group., Ltd.
Madhusudhana Rao	Honeywell
Susumu Saito	Electronic Navigation Research Institute (ENRI)
Jaron Samson	EASA
Alex Sissoev	AeroAntenna
Matteo Sgammini	European Commission
John Studenny	CMC Electronics
Francois Tranchet	Airbus
Hans Trautenberg	EASA
Daniel Viotti	EMBRAER
Timo Warns	Airbus
Joel Wichgers	Collins Aerospace
Jim Williams	JHW Unmanned Solutions
Hu Yaying	COMAC
Zhang Ziwu	COMAC

AGENDA

1. Introductory Remarks: RTCA, GAR and Co-Chairs

2. Approval of Summaries of Previous Meetings
   a. One Hundred Fifteenth Meeting for SC-159 and Sixtieth-Eighth Meeting for WG-62 held October 22, 2023 (RTCA Paper No 003-24/SC159-1114 / EUROCAE Reference Number 007-24/WG 62-144)
   b. Sixty-Ninth Meeting for WG-62 (jointly with SC-159 WG-2) held January 29- February 2, 2024 (EUR 045-24/WG62-146)

3. DO-292A Status

4. Final Review and Comment (FRAC) activities
   a. DO-373A (WG-7) FRAC Update

5. Review Working Group (WG) Progress and Identify Issues for Resolution

   a. BeiDou (WG-62 SG-1) Activity Update
   b. GPS/WAAS (WG-2 and EUROCAE WG-62) to include update on related ICAO/Navigation Systems Panel Activities
   c. GPS/Precision Landing Guidance (WG- 4), to include update on related ICAO/Navigation Systems Panel Activities
   d. GPS/Interference (WG-6), to include update on related ICAO/Navigation Systems Panel Activities
   e. GPS/Antennas (WG-7)

6. Discussion of Terms of Reference Updates

7. Action Item Review

8. Assignment/Review of Future Work

9. Other Business

10. Date and Place of Next Meeting

11. Adjourn

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* Hamza Abduselam, Federal Aviation Administration (FAA), was the Government Authorized Representative for this meeting.

Agenda Item 1. Introductory Remarks: RTCA, GAR and Co-Chairs

- SC-159 Co-Chairman Dr. Chris Hegarty called the Plenary to order and welcomed everyone to the meeting.This Plenary meeting was convened as the regularly scheduled Spring biannual meeting. He hoped that all was well and was looking forward to hearing all the reports. Dr. Hegarty then introduced the SC-159 leadership team. Then Dr. Hegarty asked those in the room to introduce themselves. He then asked for those on the web to introduce themselves and their company affiliation. Dr. Hegarty then went back to Mrs. Hofmann and Mr. Watson, Technical Programme Manager of EUROCAE to review the guiding policies for this joint RTCA/EUROCAE Plenary.
- Karan Hofmann, SC-159 Program Director at RTCA, noted that that meetings are conducted in strict accordance with U.S. anti- trust laws. She discussed RTCA's proprietary references policy and committee participation membership policy. She then reemphasized the importance of proprietary property as it is coming up increasingly. Mrs. Hofmann noted that this Plenary meeting is open to the public, and that notice of the meeting was published online and that members of the public may present written or oral statements with the permission of the committee chairmen and program director.
- Mark Watson, Technical Programme Manager of EUROCAE, discussed EUROCAE's Intellectual Property Rights and Membership policies as well as General Data Protection and Privacy regulations. He also reminded all that Russia was still excluded from participating in EUROCAE activities. He commented that if any participants online were from Russia, they would be asked to leave the meeting.
- Then Dr. Hegarty asked if the leadership of WG-62, Mikael Mabilleau, secretary of WG-62, had any opening comments for the group to which he replied no. He also asked Hamza Abduselam, SC-159 GAR, if he had any comments. He offered no opening comments.

Agenda Item 2. Approval of Summaries of Previous Meetings

a) The summary for the 115th meeting of SC-159 and Sixty Eighth Meeting for WG-62 held on October 22, 2023 (RTCA Paper No. 003-24/SC159-1114 / EUROCAE Reference Number 007-24/WG62-144), was presented to the meeting. Meeting attendees were asked to review the summary and provide any comments to RTCA. **Dr. Hegarty asked the group if there were any changes needed for the minutes as submitted. There were no comments from the group, so Dr. Hegarty dispositioned that the minutes were approved.**

b) The summary for the 69th meeting of WG-62 (and SC-159 WG-2) held on January 29 – February 2, 2024 (EUR 045-24/WG62-146), was previously circulated and posted to AerOpus. **Mikael Mabilleau (WG-62 secretary) commented that this last meeting had been held in Prague. He then asked if there were any comments on the summary. There were none so Mr. Mabilleau considered them approved.**

Then Dr. Hegarty considered all summaries approved and then turned to Agenda item 3.

Agenda Item 3. DO-292A Status

DO-292A Update

Dr. Kalyanaraman indicated that the work group had been updating the DO-292A document with 80% of the comments addressed so far. Dr. Kalyanaraman plans to have the document ready to present to the PMC this June for approval. Then he plans to bring it back to WG6. Mrs. Hofmann reminded the group that the PMC has to have the document in hand by May 27th for review before their meeting. This means that it would have to be in Mrs. Hofmann's hands by May 1st. The Dr. Kalyanaraman continued discussion into agenda item 4.

Agenda Item 4. Final Review and Comment (FRAC) activities

Item 4a DO-373A (WG7) FRAC Update

Dr. Kalyanaraman explained that he had introduced the DO-373A discussion with SC-159 WG7. They updated their plan and have marked up the document. Dr. Kalyanaraman will provide this document to Mrs. Hofmann today so it can be prepared for FRAC. He plans on WG7 reviewing this before it is released for FRAC. **Dr. Hegarty then asked if the Committee had approved this document entering into FRAC? Dr. Kalyanaraman then indicated that the committee had previously approved DO-373A entering into FRAC (27 October 2023 Plenary).**

Agenda Item 5. Review Working Group (WG) Progress and Identify Issues for Resolution

Item 5a Beidou (WG-62 SG-1) Activity Update

Dr. Hegarty asked Dr. Kalyanaraman if the Beidou presentation given the previous day would be covered by the WG7 report later in the meeting. Dr. Kalyanaraman indicated that it would so Dr. Hegarty skipped this agenda item for the time being and moved to 5b.

Item 5b. Beidou (WG-2 and EUROCAE WG-62) to include update on related ICAO/Navigation Systems Panel activities

Laurent Azoulai (Co-Chair) introduced his Co-Chair, John Studenny from CMC electronics, and began his portion of the briefing. He first started by remarking that Denis Bouvet had left the team due to a job change but he was still supporting the work when able.

Summary: Papers List & Discussion items

- **Joint WG-2/WG-4/EUROCAE WG-62 meetings in run mode**
  - **2 times in Europe, 2 times in US,**
  - **3-hours teleconferences (the Author's group) from SC-159 & WG-62 on a regular basis**
  - **Editor's group in place responsible for the master document and integration of evolutions, publish an update on a regular basis to perform advanced review and processing of comments:**
    - **Fan Liu, FAA, Lead Editor**
    - **Christophe Ouzeau, Collins Aerospace**
    - **François Tranchet, Airbus Defense & Space**
    - **John Foley, Garmin**

Before moving to the next slide, Mr. Mabilleau asked if there needed to be a discussion about WG-62 conducting non plenary meetings. He explained that when they have meetings with no plenary, we have brought back to this plenary issues for this plenary to review or approve. We strive to follow the process as Mrs. Hofmann has described it. Mrs. Hofmann asked if Hamza Abduselam, as the GAR, participates in these meetings? Mr. Abduselam responded that he does participate but a discussion we can discuss if there is a need to conduct a mini plenary to get approval through the RTCA process. Dr. Hegarty indicated that Dr. Ligler and he did not want to add any more work but if there were a need for a special plenary, they would certainly help to accommodate this need. Dr. Ligler also agreed. He indicated that if WG-62 needed to highlight some particular thing then we can work the same process mentioned. All agreed and the presentation continued.

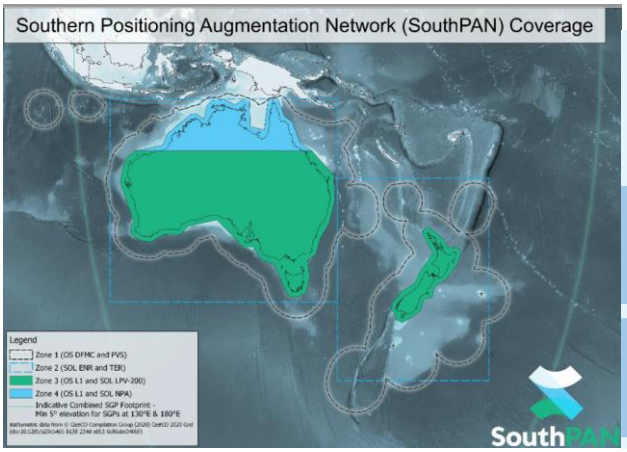
Summary: Papers List & Discussion items (Cont)

- **Overview of papers: A summary with some highlights is provided in this briefing and reflects the discussions. For details, please refer to the papers that will be distributed soon after the meeting.**
  - **2.a South PAN Status (Simon Reynolds)**

- **6.a Propose requirements for carrier phase accuracy/carrier phase uncertainty to be used by the Inertials if not covered in DO-384 or future revision of it (Vignesh Krishnan)**
- **7.a ED-259B/D0-401 maintenance (Fan Liu)**
- **7.b Spoofing: A New Spoofing Work Plan for DO-401/ED-259 from John Studenny, WG-2 Co-Chair**
- **7.c Spoofing paper from John Studenny comments review from Airbus**
- **7.d Spoofing: Spirent interference test means presentation (Andrew Hart)**
- **7.e Spoofing: Jammertest (Norwegian Communications Authority)**
- **7.f Spoofing: Spoofing issues analysis & recommendations: proposed changes to appendix W (John Studenny)**
- **7.h Spoofing: Testing of civil aviation receiver(s) in presence of jamming and spoofing with JRC ISPRA (Christophe Macabiau)**
- **7.i ARAIM: ARAIM Constellation Hypothesis Validity testing presentation (John Studenny)**
- **7.j ARAIM: Presentation / review of the current draft App K on ISM processing (Peter Gardner)**
- **7.k ARAIM: GAL ISD/ISM inputs to Appendix K (Mikael Mabilleau)**
- **7.l ARAIM: Updates / changes to the ARAIM requirements (Jed Dennis)**
- **7.m ARAIM: proposed changes to enable use of GPS L5-I5 for ARAIM/FDE (AI-66/8, AI-66/10, and AI-66/23) (Jed Dennis)**
- **7.n ARAIM: Smoothing requirements under ARAIM (Mikael Mabilleau)**
- **7.o OSNMA Receiver Guidelines briefing (Ettore Canestri)**
- **7.p MUGG project (perimeter of ED-259 req and test procedures covered) (Christophe Ouzeau)**
- **7.q 5° mask angle in SBAS L1 - AI-66/25 (Mikael Mabilleau)**
- **7.r Single frequency GPS L5, GAL E1, GAL E5 measurement accuracy requirements (AI-66/12) (John Foley)**
- **7.s Proposal to simplify/streamline the measurement accuracy test cases related to the CW interference test cases (John Foley)**
- **7.t EGNOS DFMC Demonstrator (FranÇois Tranchet, Thomas Fuhrman)**
- **7.v SBAS MT25/32 Time of Applicability (Timo Warns)**
- **7.w Key management architecture & concepts (Jed Dennis)**

- **7.x ARAIM Algorithm in the MOPS (Hamza)**

2.a South PAN Status (Simon Reynolds)



SouthPAN services

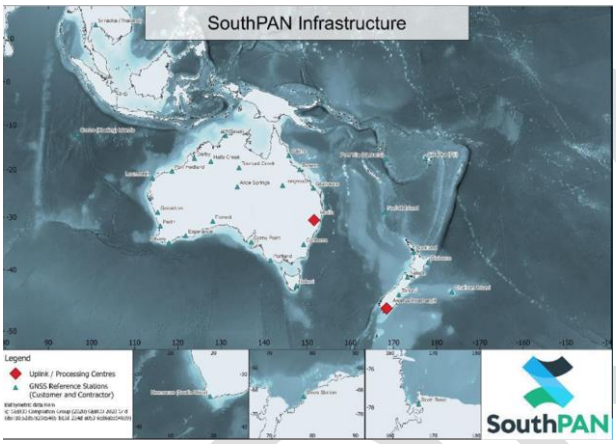
The Southern Positioning Augmentation Network (SouthPAN) is an ICAO-compliant SBAS currently in operation for non-aviation users (Annex 10 & DO-229F for L1 SBAS, Annex 10 Amdt. 93 & ED-259A for DFMC SBAS) (SPID=8, PRN=122)

L1 SBAS Open Service
- Augments GPS L1 C/A
- Better than 3m (H) and 4m (V)

DFMC SBAS Open Service
- Augments GPS L1 C/A + L5, and Galileo E1 + E5a
- Better than 1.5m (H) and 2.5m (V)

PPP via SouthPAN
- Augments GPS L1 C/A + L5, and Galileo E1 + E5a
- Better than 0.375m (H) and 0.525m (V), with 80 min convergence

1. Early Open Service performance will improve as SouthPAN is deployed
2. Safety-of-Life Services are in development, expected 2028



- South Pan compliant with ICAO SBAS L1 and DFMC
- SOL expected in 2028 but not planned to become certified

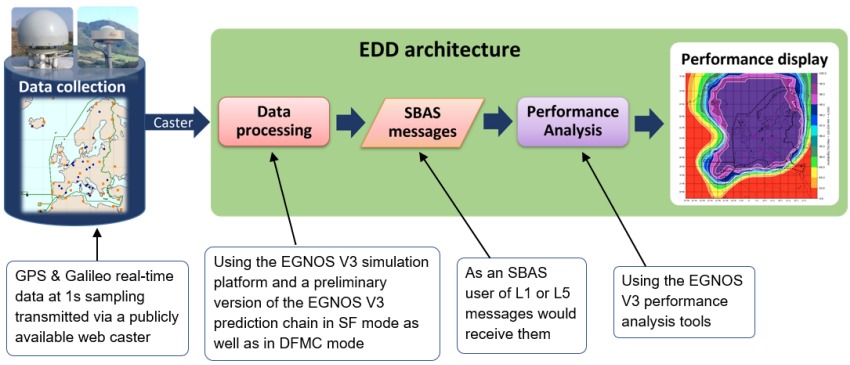
7.t EGNOS DFMC Demonstrator (Thomas Fuhrmann, François Tranchet)

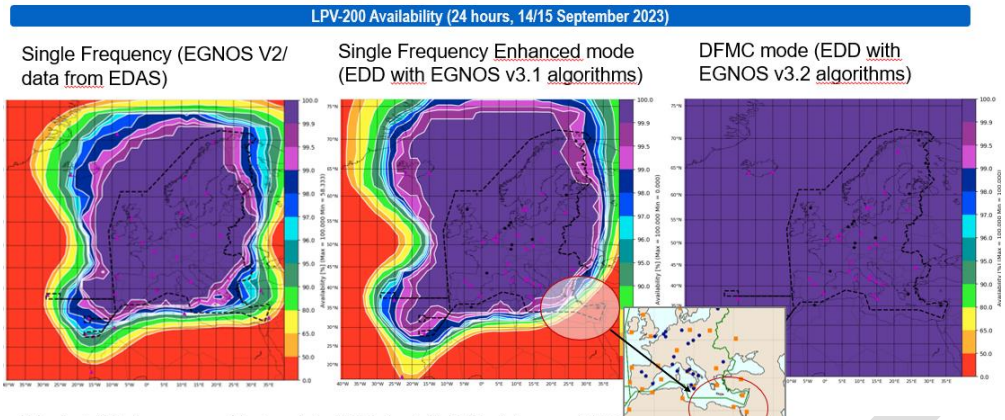
EDD Architecture

Objective of EDD

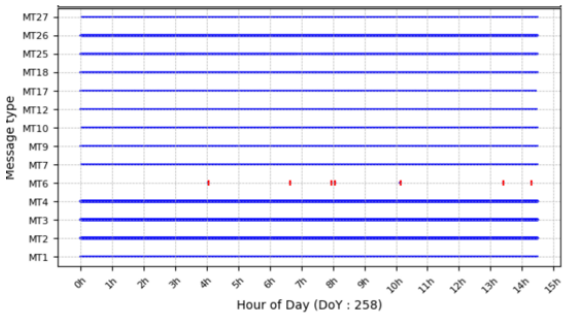
First live demonstration of EGNOS V3 on real GNSS data over Europe:

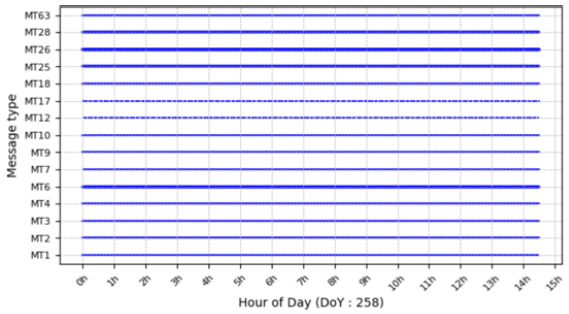
- ✓ Representative of EGNOS future system (except for the monitoring station network)
- ✓ Representative of ED-259
- ✓ Processing data from public GNSS stations with EGNOS V3 assets
- ✓ Confirm expected DFMC performance improvements versus Single Frequency Single Constellation





Message Type bandwidth analysis - SF





EGNOS V2:
- Fast Corrections via MT2, M3 and MT4 every 6s
- LTC Broadcast via MT25 with velocity code=0
- Less frequent Iono delay corrections in MT26
- MT27

EGNOS V3:
- Fast corrections set to 0 in MT2, 3 and 4 every 60s
- LTC Broadcast via MT25 with velocity code=1
- More frequent ionospheric delay corrections on MT26
- MT28

- EMS file generated could be shared with manufacturers
- Could be good to distribute the data to receiver manufacturers for testing as backward compatibility

7.a ED-259B Maintenance (Fan Liu)

- Review of introduced modifications
- Introductions of data and time as minimum requirements
- Leap second and week number rollover evet test should be added
- Need to add multiple test cases to test corner cases
- Question raised about MT42 useful of having time (with integrity). If yes, it coud be Useful for spoofing detection.
- Do we need a valid flag for UTC and velocity with two options separated or combined Into the navigation alert. Objective is to inform spoofing. We need a threshold. Do we need an integrity bound on this? Or only accuracy like today=> Need users of GNSS to express their needs

- An external trusted source of timing could be useful
- Nav alert in the MOPS doesn't lead necessarilty to time and velocity being out of Tolerance
- We logged an action to look at the need to have integrity and spoofing detection on Veocity, Date, Time and Altitude separately

Review of actions resolved

- **7.q 5° mask angle in SBAS L1 - AI-66/25 (Mikael Mabilleau)**
  - AI-66/25 SBAS iono residual error model is valid for mask angle greater than 5°
  - 3.1.1.6.1.4 DMS 263 and 264
  - Add another condition GPS satellite elevation is greater than or equal to 5°
- **7.m ARAIM: proposed changes to enable use of GPS L5-I5 for ARAIM/FDE (AI-66/8, AI-66/10, and AI-66/23) (Jed Dennis)**
  - Proposal to use L5-I5 ranging for ARAIM for ED-259 whereas not authorized to be used
  - Reviewed of the comments from the FRAC and the proposed changes including the equations impacts
  - Benefits unclear with more tests plus the need to define sigma noise. During the first OC of ED-259, requirement was removed because the robustness to interference was poor.
  - A note is added to provide rationale to not use L5-I5 under DMS237
- **7.n ARAIM: Smoothing requirements under ARAIM (Mikael Mabilleau)**
- Agreed to have smoothing requirements for H-ARAIM/FDE, thus proposed new requirements
- Decision agreed by the group and requirements to be developed in the MOPS including for RAIM/FDE.
- **7.r Single frequency GPS L5, GAL E1, GAL E5 measurement accuracy requirements (AI-66/12) (John Foley)**
- Absence of requirements for sigma noise accuracy for Gal E1, E5 and GPS L5.
- Do we need tighter requirements for INS integration for unsmoothed PR ? Need to coordinate with INS manufacturers on 2.1 m.
- Proposal for sigma noise PR smoothed.

- Smoothed GPS L1 σ_{noise} = 0.15m
- Smoothed GPS L5 σ_{noise} = 0.20m
- Smoothed GAL E1 σ_{noise} = 0.15m
- Smoothed GAL E5 σ_{noise} = 0.20m

Group agreed to the 0.15 meter threshold.

However, scaling up to 0.20 meters for L5 may not be appropriate, to be discussed at Author's Group

ARAIM discussion topics

- **7.l ARAIM: Updates / changes to the ARAIM requirements (Jed Dennis)**
  - Jed suggests to modify requirement to introduce RAIM STA and STB instead of HARAIM and in the future V-ARAIM
  - STB will be introduced concurrently with ICAO SARPs
  - Need to define somewhere STA and STB and precise that FDE is always applicable in the document
  - Will be integrated in the draft MOPS
- **7.j ARAIM: Presentation / review of the current draft App K on ISM processing (Peter Gardner)**
- **7.k ARAIM: GAL ISD/ISM inputs to Appendix K (Mikael Mabilleau)**

•Definition of GPS ISD and protocols for processing ISM

•ISM processing flowchart & ISD values are stable and consistent with ICDs and with ICAO SARPs

•Presentation of Galileo ISD information to feed App K

•Commentts and questions are encouraged

- Requirements must be developed based on the appendix K
- **7.x DFMC MOPS ARAIM Algorithm (Hamza Abduselam)**

•Proposal to include in an appendix the algorithms from the ADD was agreed by the group

•Benefits one stop shop but not to be followed necessarily

•Wording will precise that it is an example and not an AMC that would force a manufacturer to apply exactly these algorithms

- Need to show to regulator all the assumptions and performance are met. And test procedures (offline test) must be complete

7.p MUGG project (Christophe Ouzeau)

MUGG PROJECT OBJECTIVES

Main objectives

- Project funded by EUSPA
- Development of a SBAS DFMC Receiver for aviation SoL with minimum maturity level for flight tests (i.e. TRL 7):
  - DFMC SBAS Receiver definition
  - DFMC SBAS Receiver development, integration and tests
- Implementation of part of the ED-259 functions starting from P/L baseline (next slide), including H-ARAIM
- Support the DFMC standardization activities (ED-259/DO-401)

The MUGG prototype is tested applying the latest ED-259 Rev A scenarios and test procedures under the requirements coverage

ED-259 Rev A Appendix C interferences environment are currently injected in the tests

At standardization level, any outcome is shared on the scenarios/tests feasibility covered by MUGG

Project phase	MUGG-1	MUGG-2	Total
System Test Procedures	194	320	514
System Analyses	13	6	19
System Inspections	4	10	14

505/514 System Test Procedures are automated : 98.249%

The MUGG prototype covers the following functionalities (non-exhaustive list), up to ED-259A v0.18:

- Core constellations: GPS and Galileo
- Integrity mode supported: L1 SBAS, DFMC SBAS, H-ARAIM and RAIM
- SBAS L1 SF GEO ranging
- FAS L5 – Output LPV deviations in SBAS L5 approach mode

MUGG-2 ED-259 coverage

The MUGG prototype does NOT cover the following functionalities:

- SBAS L5 DF GEO ranging
- Display
- Robustness to spoofing

Number of ED-259A requirements	Number of ED-259A requirements covered by MUGG-2
748	320 (42,8%)
678 (without optional)	308 (45%)
523 (without optional + general human factor/path selection/path definition/navigation displays/alerts/mode switching)	308 (58,9%)

Collins Aerospace

All are feasible with scenarios. Results to be shared.
Some editorial comments to be provided to the editor's group. No hard stopper all tests run.
Logged an action on app C of ED-259 Justification of app C. RTCA of October outcomes of that.
Need to synchronize with WG-6
New req in rev B will be included in coming projects.

At this point in the presentation, Mr Mabilleau added some additional comments to the the MUGG presentation. He stated that that EUSPA had MOPS for validation which were presented last October by Thales while Collins Aerospace did so just recently. This is our contibution to help Validate these proposed MOPS. Dr. Hegarty asked what the acronym "MUGG" means. Mr. Mallibeau Replied, Multi-Mode-GPS+Galileo. At this point Mr. Azoulai turned the presentation over to John Studenny.

7.b Spoofing: A New Spoofing Work Plan for DO-401/ED-259 from John Studenny, WG-2 Co-Chair

- Motivation:
  - Many websites created that report spoofing incidents: Spoofing incident frequency, increased variety, and cleverness of spoofing scenarios/attacks, has greatly increased over the past 5 years. Example: Spoofers can be designed to exploit GNSS receiver weaknesses, there are examples of GNSS requiring a "factory reset" after a spoofing attack.
  - Several websites were created that openly sell spoofing-enabling technology, specifically Software Defined Radio Spoofers.
  - While WG-6 has done an outstanding job of categorizing pre-spoofing RFI and Jamming (DO-235 & DO-292), SC-159 does not have the same level of effort or intensity in categorizing spoofing technologies, spoofing signals and their characteristics, or spoof scenarios aimed at spoofing and that can exploit GNSS receiver weaknesses and/or any spoofing-detection/mitigation augmentations weaknesses (augmentation example: DO-384 has no spoofing requirements).
  - Our Appendix W MOPS, and spoofing test scenario needs a refresh to account for the current and expanding spoofing environment, recognize that spoofers are shifting their strategy beyond simple spoofing towards exploiting GNSS receiver weaknesses. Reason: we have very high "top-level" S1 to S7 narratives that do not go into spoofers, spoofing signal details.
- Our spoofing test scenarios need and overhaul. Need to develop spoofing "stress-tests" aimed at GNSS receiver vulnerabilities including GNSS spoofing augmentations. Reason: that is where real-world spoofing scenarios are headed.
- If there are going to be GNSS augmentations, individual equipment MOPS is likely required, example: CRPAs – we do not have a CRPA MOPS, and it would have made "compatible" with existing FRPA L1/L5 antenna MOPS.

•WG-2 recognizes the need for an overhaul of spoofing signal categorizations, creation of spoofing "stress-test" scenarios, pass/fail criteria, GNSS receiver (and any augmentations) spoofing detection and mitigation capability.
•Do not know how this will impact certification or TSO at this time.
•Ad Hoc Spoofing Working proposed, John Studenny volunteered to chair. Please contact John to join, all are welcome.
Volunteer members to date.

Name	Organization	Email
Jed Dennis	FAA	Joseph.CTR.Dennis@faa.gov
Hamza Abduselam	FAA	Hamza.Abduselam@faa.gov
Fan Liu	FAA	Fan.Liu@faa.gov
Stefano Caizzone	DLR	Stefano.Caizzone@dlr.de
Manuel Cuntz	DLR	Manuel.Cuntz@dlr.de
Andriy Konovaltsev	DLR	Andriy.Konovaltsev@dlr.de
Emilio Pérez Marcos	DLR	Emilio.PerezMarcos@dlr.de
Matt Harris	Boeing	matt.harris@boeing.com
Tim Murphy	Boeing	tim.murphy@boeing.com
Todd Walter	Stanford University	twalter@stanford.edu
Sherman Lo	Stanford University	daedalus@stanford.edu
John Owen	Border Consulting	jirowen@borderconsulting.co.uk

- Proposed Ad-Hoc Spoofing Working Group Mission Statement

Document:

1. The spoofing technologies that create spoofing signals,
2. Categorize and catalogue spoofer configurations specifically antenna configurations and the resulting spoofing signal capabilities,
3. Categorize, catalog, spoofing signal attributes,
4. Develop a catalog of spoofing signals that can enable the development of spoofing scenarios, develop, and write the qualitative spoofing signal descriptions,
5. Using qualitative descriptions, develop quantified signal descriptions and catalog them,
6. Using whatever knowledge of GNSS receiver vulnerabilities and the above spoofing signal catalogue, develop a series of stress-test spoofing scenarios designed to expose any/all known GNSS receiver (and augmentations) vulnerabilities.

As part of developing stress-test spoofing scenarios, this group will recommend generic laboratory test setups and possibly a free-air test setup. Our objective is the creation of repeatable and exactly reproducible stress-tests by any knowledgeable, capable engineering group using appropriate generic equipment.

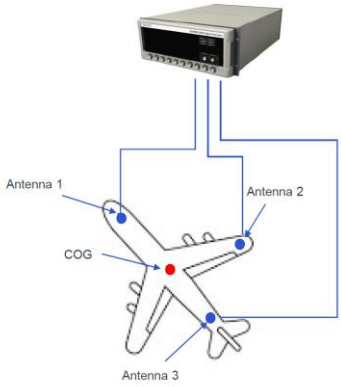
The stress-tests should test various aspects of GNSS receiver vulnerabilities; however, the concept of a minimum set of required stress-tests has yet to be defined, such a definition will also be a part of our task.

The working group's effort should result in the creation of recommend stress-test spoofing scenarios, pass/fail criteria, and a comprehensive spoofing claim table that can be used as an input for certification (TSO) credit.

Andreas Lipp commented that Maintenance personnel may need features of the table to accomplish Maintenance functions on spoofing receivers on aircraft. Others in the meeting offered several places that could provide additonal information for different spoofing scenarios.

7.d Spoofing: Spirent interference test means presentation (Andrew Hart)

- During author's group meeting, spoofing was discussed.
- Question: Can free-air GNSS and spoofing signals (single transmit antenna) be effectively simulated for lab tests? This would have to be a requirement for repeatable and reproducible tests. Do such simulators exist?
- Easily « accessible » Simulator manufacturers were invited to tell the author's group if this is possible.
- Spirent responded and was invited to present answers to this question. In summary, the answer is yes. The diagram on right is from the Spirent presentation.



- Other simulator manufacturers invited but did not respond in time.
- It might be useful to have an "industry day" wherein all known GNSS simulator manufacturers are invited to present their answers.
- It might be useful/would be helpful to invite simulator manufacturers to the Ad Hoc Spoofing Working Group.

7.e Spoofing: Jammertest (Norwegian Communications Authority)

- The Jammertest organization is part of the Norwegian Communications Authority
- Jammertest holds an annual, free-air jamming and spoofing event for aircraft, land and sea vehicles.
- Jammertest uses off-the-shelf, commercial & publically accessible jamming and spoofing equipment to create open-air jamming and spoofing test scenarios.
- Jamertest invited for several reasons:
  - Awareness of jamming spoofing capabilities of not only Jammertest, but what can be done with off-the-shelf equipment
  - Awareness of jamming and spoofing signals and Jammertest's signal plan – it is supposed to mimic real-world jamming and spoofing,
  - Can become a contributor to our new Ad Hoc Spoofing Working Group, request that RTCA make a formal invitation for Jammertest participation to our new Ad-Hoc Spoofing Working Group.

Dr. Hegarty informed the group that MITRE used spoofing equipment to spoof specific GPS equipment. Mr. Tranchet also indicated that Safran was also doing some work that may be presented in the future.

7.f Spoofing: Spoofing issues analysis & recommendations: proposed changes to appendix W (John Studenny)

- Appendix W S1 and S7 spoofing categories require evolution, detailed signal descriptions, with a lead into developing spoofing Stress-tests.
  - •Appendix W with Garmin's (John Foley's) detailed review incorporated was reviewed. Incorporation did not account for Airbus' comments but were presented during the working group meeting.
  - •The re-write of Appendix W is 37 pages of detailed test, it would be difficult to summarized into a one- or two-page slides
    - Spoofer technologies identified
    - Spoofer free-air antenna categories identified
    - 11 signal attributes identified (there may be more)
    - S1 to S7 re-categorized in terms of proposed, new signal categories – the goal is to provide a much more precise, qualitative signal description.
    - Much more precise, qualitative signal descriptions will lead into precise quantitative signal descriptions - a catalogue of signals
  - •Using this catalog, "stress-test" scenarios must be designed to elicit and expose GNSS receiver (and any augmentation) susceptibility to spoofing – be reflective of real-world spoofers, this is future work to be done (Ad Hoc Spoofing Working Group).
    - Need Knowledge of "common" receiver vulnerabilities must be taken into account, spoofing tests designed accordingly. Some vulnerabilities are presented, but not used to develop stress-test scenarios , this is future work to be done (Ad Hoc Spoofing Working Group).

Ken Alexander then expressed concern that publishing the work and solutions found would make it apparent to those bad actors that you now have a solution to what they are trying to accomplish. How do we protect this information for the future. Mr. Studenny indicated that that topic would be discussed in this new WG.

7.i ARAIM: ARAIM Constellation Hypothesis Validity testing presentation (John Studenny)

- •New Concept: Constellation Hypothesis Validation Test
  - All RAIM algorithms create subset solutions, at least one has to be fault-free (must be "consistent") – defined by a test threshold derived from the Probability of False Alarm.
  - Subsets are created according to a Constellation Hypothesis (for N satellites in view, up to F satellites are by hypothesis, faulted)
  - The Constellation Hypothesis is the result of many years of observation under NO SPOOFING conditions.
  - Spoofing, or other circumstances, may cause ALL subsets to detect fault (failure of test threshold).

- Result: no ability to exclude faulted satellites
- All bounding calculations (which depend on have at least one fault-free (consistent) subset solution become invalid.
- This state could be caused by partial spoofing wherein some satellite data are authentic, some are spoofing satellite data. The result is navigation solution inconsistency and possible all subsets declared faulted.

- Action:
  - Review MOPS requirements, ensure above condition is tested and if present, ensure RAIM bounding is declared unusable
  - Propose this condition can be used as a possible "partial spoofing" detector since Constellation behavior is not as per established hypothesis.
  - CAUTION: RAIM is NOT a spoofing detector (it never has been, nor will it ever be), but this one condition is useful as an input to a spoofing detection system.

Ken Alexander remarked that RAIM is not spoofing detection. This use of RAIM could cause further problems to a spoofing situation today. Mr. Trautenburg also added to support for not publishing details of this work as we don't have solutions to what is being identified today. Mr. Studenny offered that we need to stay away from the military discussion and just focus on a civilian evaluation of jamming and spoofing that comes down to denial of service.
Mr. Azoulai indicated that Dr. Kalyanaraman and WG6 may have some work planned to support
This spoofing work. Ken Alexander challenged that all problems cannot be solved with the receiver. You need to use other systems to validate spoofing. Did the MOPS speak to INS oscillator performance Within an integrated nav suite? Mr. Studenny replied that there is not one standard today. Inertial manufacturers each may do something different so there is no conclusive answer. Mr. Estival then confirmed
what had already been discussed. For detection of spoofing areas, we do not have any better platforms for detection than that which is on an aircraft. Other ideas were offered but Dr. Hegarty recommended joining his new WG to have further discussions.

Spoofing session summary

- The group agrees that we need to go further on the spoofing mitigation at receiver level
- Proposal to update appendix W with more detailed threat categorization
- Agreement to further pursue improvement of the receiver in terms of resilience, stress testing and characterization of the risk
  - It was already planned but maybe not in line with the evolution dynamics of the threat (in terms of frequency and sophistication)
- Recognize that some sort of « augmentation » can help the receiver to be more resilient (e.g. second antenna, mix with IMU, CRPA) but would need separate effort and will likely require new standards

- While consensus that this effort must be taken, several questions are still open and did not reach consensus
    - When and where to stop in terms of spoofers catalogue knowing how much this evolves rapidly
    - Some chacteristics are not accessible to the public (military types) whereas these are the ones the aircraft are the most exposed nowadays
    - Diverse opinions have been shared on the need to consider « no assumptions at all », indeed It is an equipment MOPS where tests must repeatable in a lab ; versus consider some assumptions for some types of aircraft. Consensus on these aspects must be found in forthcoming meetings
    - Need to reach out to more simulators' manufacturers to offer them the possibility to showcase their products

.

At this point Mr. Azoulai resumed the presenter role for the WG2 presentation.

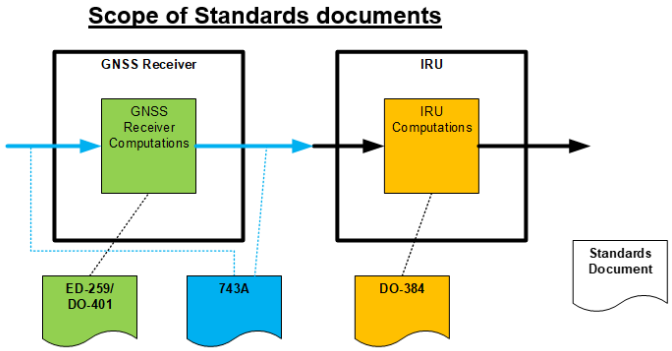
7.h Spoofing: Testing of civil aviation receiver(s) in presence of jamming and spoofing with JRC ISPRA (Christophe Macabiau)

- JRC ISPRA and ENAC conducted tests in June 2023 at ISPRA with a GSS9000 & a TSOC146c Rx
    - Injected signals were: L1/L5+L1 SBAS, collected C-UAS signals, and ground repeater signals+noise
    - Tests similar to ED259/DO401 5.3.6 & 5.3.7 integrity tests
    - About 15 scenarios were run, leading to several observations (No TSOC146c Rx position integrity failure, L1-G1 vs L1 stimulation, long correlation of position errors)
    - Overall, there is a need to do additional tests, next session is 2-4 apr 2024:
    - Need to increase theoretical prediction capabilities (ex: predict which scenarios bound other scenarios)
    - Additional tests are interesting (ex: more tests in spoofing situations)
    - Consolidate information from previous tests on integrity performance (repeat tests, …)
    - Use low SBAS UDREs/GIVEs/DFREs during RFI integrity tests

6.a Propose requirements for carrier phase accuracy/carrier phase uncertainty to be used by the Inertials if not covered in DO-384 or future revision of it (Vignesh Krishnan)

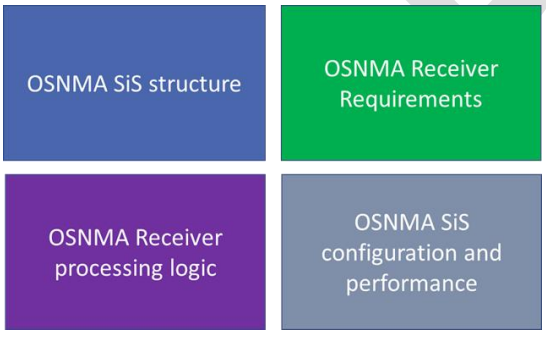
- GNSS MOPS provides standard/assumptions that are then used in the testing needed to certify device functions
- They define assumptions, requirements and test procedures regarding GNSS signals

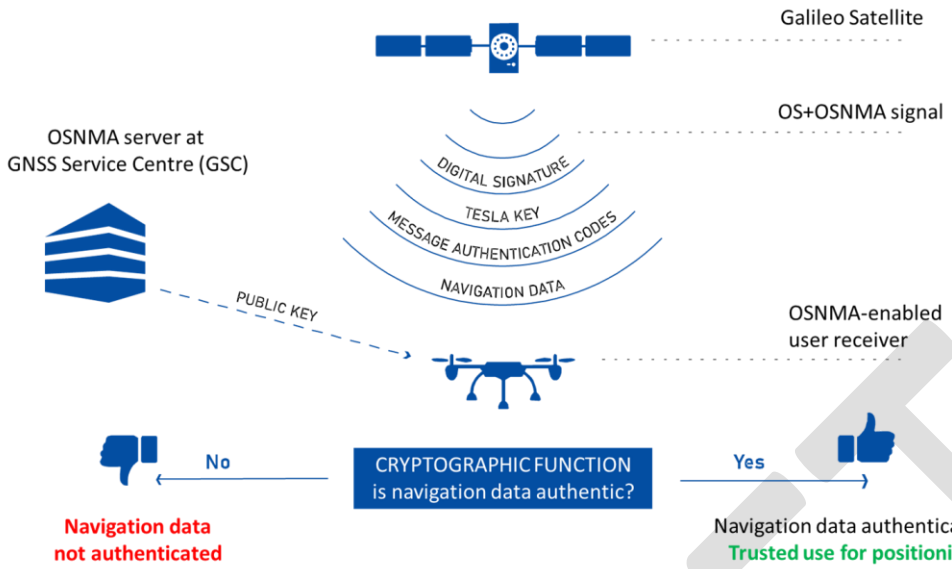
- Honeywell is developing dual-antenna algorithms, including using carrier phase measurements from multiple antenna in order to compute heading
- no means to certify any functions that rely on carrier phase accuracy/integrity
- Carrier phase accuracy/integrity requirement needed in the GNSS MOPS
- There will be a carrier phase accuracy requirement on the order of 3,5 mm 1 sigma
- The Rx manufacturer community agrees to do it and add it to the MOPS
- Need other inertial manufacturers to tell what they need
- Need to detect locks slips to provide integrity on heading

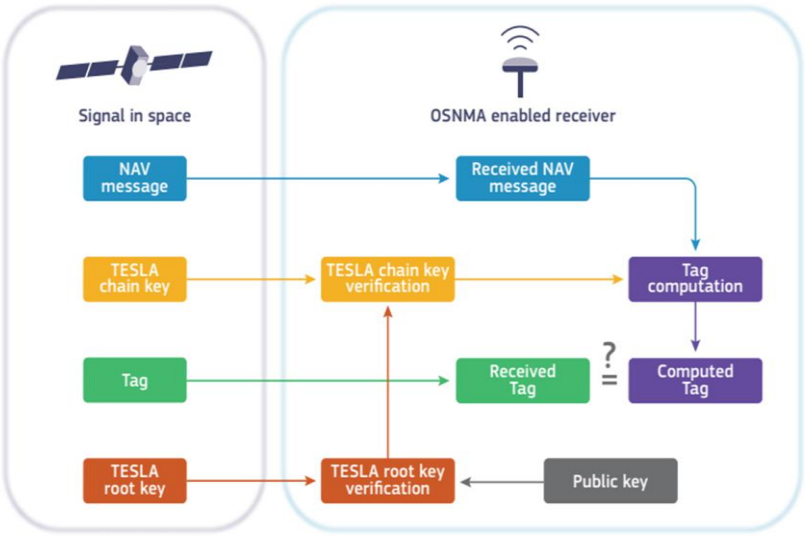


7.o OSNMA Receiver Guidelines briefing (Ettore Canestri)

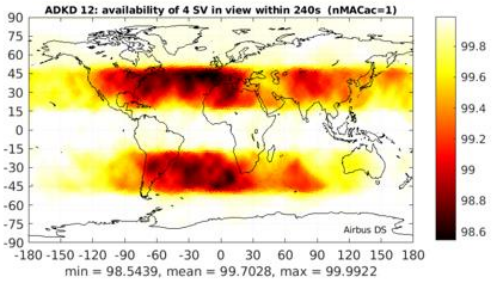
- OSNMA signal, global coverage
- Open access (following registration process at GSC to get access to key material).
- Continuous signal provision
- Programme documentation available to users/developers on the GSC web portal.







Tags for I/NAV ephemeris and clock correction (ADKD#12) for at least 4 SV in view (every 240 secs), December 2023



WUL: 98.54%
AUL: 99.70%
BUL: 99.99%

- Galileo I/NAV Ephemeris, Clock, Status, and timing parameters
- Need to store the Merkle tree and possibly a new one 2 years in advance.
- Time synchronization min. requirement with GST is 30 sec
- Galileo OSNMA is not always available all the time for all satellites
- Same level of accuracy performance
- ICAO Annex 10 planned and encurage to start for rev B
- New Work Item proposal paper will be brought at ICAO JWGs/12 in May 2024 to include OSNMA in Annex 10.
- EC/EUSPA will launch studies towards proposing requirement associated to OSNMA in the MOPS, already for Rev. B

7.s Proposal to simplify/streamline the measurement accuracy test cases related to the CW interference test cases (John Foley)

- Working Group preliminarily accepted changes to combine test cases
- Will prepare test procedure updates for further review

Options to reduce test time

The measurement accuracy test cases are extremely similar, with the main differences being the measurement type being assessed and interference conditions.

Several ideas for reducing test time are proposed.

1. Combining the evaluation of the smoothed and unsmoothed measurement accuracy into the same scenario so that both terms can be evaluated simultaneously.

2. Using a common I_{Test} value for the various signals of interest to allow simultaneous evaluation of GPS, GAL, and SBAS measurement accuracy during the CW cases.

3. Restricting testing of "other band" in-band CW jammers to the minimum power broadband noise test cases for single frequency measurements to allow simultaneous evaluation of single frequency and dual frequency measurements for the other CW cases.

4. Potentially reducing the 200 second sampling interval specified for determining independent samples for the accuracy test, at least for the CW test cases.

- Working Group did not agree with these changes.
- Additional analysis and receiver test data would be needed to consider reducing sample interval.

Reducing sample interval time

The length of each measurement accuracy case is driven in large part by the sampling interval between independent samples. This has long been specified as twice the carrier-aided smoothing filter time constant, or 2 x 100s = 200s.

Is such a long interval between "independent" samples necessary? Is it possible to shorten this interval?

7.v SBAS MT25/32 Time of applicability (Timo Warns)

SBAS L1 MT25 / L5 MT32 allow a time-of-applicability up to half day in the past or future (with day crossover adjustments).

While day crossover adjustments (for time-of-applicability) are addressed in Annex 10, Vol I, 8th edition, ED-259A does not cover them via requirements or test procedures.

Discussion items:

- Constraining the time-of-applicability w.r.t. time of reception
- Coverage of day crossover adjustments by requirements or test procedures
- We need to have a SARPs requirement to make an assumption in the MOPS and check the time of applicability within a certain distance past or future : Objective is to contain SBAS spoofing
- We will do a paper for ICAO NSP to suggest that and amend SARPs to have commitments from Service Providers

7.w SBAS authentication Key management (Jed Dennis)

- Paper provides a review the key management and what happened at the various NSP meetings with evolutions on how to manage them
- Working to complete baseline SARPs by November
- Working session in May
- Can benefit from broader community input on key management beyond navigation experts
  - Impact to AIRAC standards or other aircraft interfaces
  - Identify mechanisms to provide key material
  - Aeronautical Data?
- Proposal to reach out to SC-217

8.b ED-259B wrap up (Fan Liu)

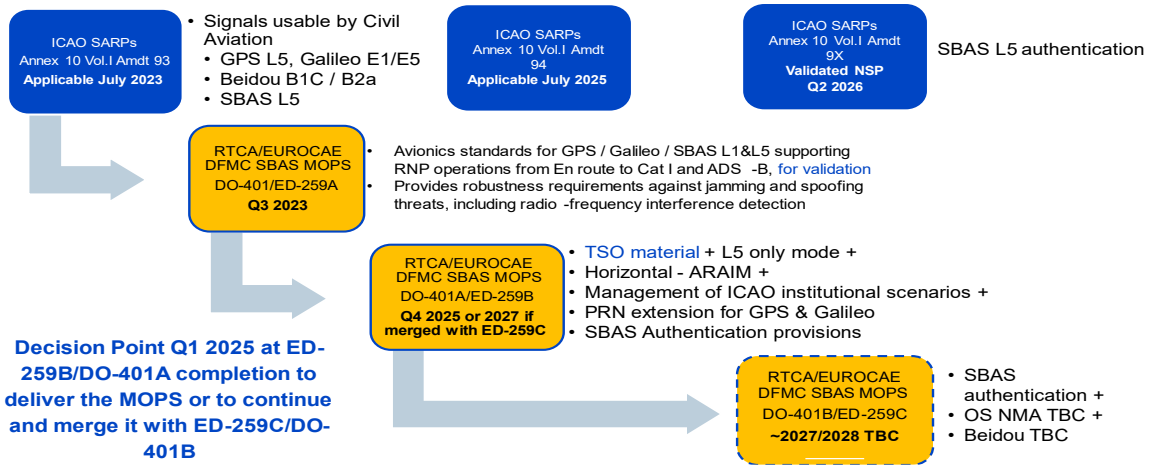
ED-259B content	Completion date	Champion	Version
H-ARAIM (GPS, GPS/GAL, SF, DF)	In progress	Juan/Jed/Receiver OEM /John S.	
ISM and Appendix K	In progress	Jed/Jason/Ettore	
GPS and GAL PRN range change (1-63)		Ettore/Receiver OEM	
Single constellation robustness [DMS:802]		Receiver OEM John S.	
SF L5 mode		Fan/Christophe O.	
Date output requirement and test procedures	In progress	Fan	
Date/time valid flag			
velocity valid flag			
Carrier phase measurement accuracy		Vignesh	
Integrity monitoring selection		Laurent/John S.	
Select/de-select SBAS service provider		Laurent/John S./Capucine	
Select/de-select core constellation		Laurent/John S. /Capucine	
SPID & APD requirements (additional req)		Jed/Ettore	
NACv=3		Vignesh	
Time to output deviations		Francois/John B.	
Institutional scenarios		Laurent Azoulai/Capucine	
GPS almanac accuracy 7-day/20-day 99.7% bound	In progress	Hamza	

ED-259B content	Completion date	Champion	Version
update in IS-GPS-200 and IS-GPS-705 impacting valid GPS L1/L5 signal ([DMS:240] and [DMS:056])	Oct 2024	Jed/Hamza	
update ED-259B with latest GPS ICD version and GAL ICD version	On-hold till newer ICD version	Hamza/Ettore	
RFI detection		Francois/Receiver OEM	
Spoofing mitigation/spoofing detection	In progress	Francois/John S.	
ED-259B synchronized with DO-292 and DO-373A		C. Ouzeau/C. Macabiau/Sai	
Test procedures: L5 signal main peak		Christophe O.	
Test procedures: Gamma test, lateral and vertical deviation for LPV minima		John Foley	
Scintillation environment & receiver improvement to support equatorial regions LPV 200		Todd/Jed	
Iono scintillation Appendix X		Todd/Jed	
satellite re-acquistion time after scintillation		Todd/Jed/Receiver OEM	
V-ARAIM		Juan/Jed/Receiver OEM/John S.	
SBAS authentication		Todd/Jed/Ettore	
Cat I/II Autoland (monitoring)		Laurent/Hamza	
Non-GEO SBAS (monitoring)		Toru	

8.a Review of actions (Mikael Mabilleau)

Number	Action	Responsible	Due By	Status
AI-70/1	Provide answers to the questions raised on the EV3 SF & DF message content presented in the EDD briefing and investigate possibility to share EMS files for test within WG2/62.	F. Tranchet	June 2024	Open
AI-70/2	Analyse the need for validity flag under normal and abnormal RF environment and associated test cases for 1) Date 2) Time 3) Velocity 4) Altitude	Authors' group	June 2024	Open
AI-70/3	Analyse the need for integrity bound under normal RF environment and associated test cases for 1) Date 2) Time 3) Velocity 4) Altitude	Authors' group	June 2024	Open
AI-70/4	Revise the requirement updates proposed in presentation 7n in light of the decision to make smoothing mandatory under all integrity mode covered in ED-259B and to cover possible impact on RAIM test	M. Mabilleau and Editors	June 2024	Open
AI-70/5	Check the ARAIM requirement baseline in ED-259B to validate proper handling of situations with no valid subsets provided by the algorithm.	John Studenny	June 2024	Open
AI-70/6	Prepare a paper for next NSP meeting to get a tighter commitment on the allowed window for toa and td value with respect to broadcast time based on discussion's outcome from presentation 7v in WG2/62#70 meeting.	T. Warns	May 2024	Open

8.c Work Plan, scope, and schedule of ED-259B/DO-401A (All)



During the review of the work plan, Mr Abduselam asked when V-ARAIM would come into Play. Mr. Azoulai indicatedthat detail workhad not started to set a date for inclusion into the SARPS. SARPS first then the MOPS.

Additional actions requested

.Requested Action item 1:

RTCA to please ask Jammertest, contact point is Nicolai Gerrard nge@nkom.no if they wish to participate in our new Ad Hoc Spoofing Working Group and contribute to our Body Of Knowledge concerning spoofers, spoofing signals, and actual spoofing incidents.

Requested Action Item 2:

1. RTCA to please ask all known GNSS simulator manufacturers if they wish to participate in our new Ad Hoc Spoofing Working Group, we need to be aware of testing capabilities and the simulator manufacturers may wish to contribute to our Body of Knowledge.
   a. Spirent point of contact: Andrew Hart Andrew.Hart@spirent.com
   b. Francois Tranchet will bring Safran on-board, please contact Francois for the Safran point of contact.
2. Maybe RTCA can host a GNSS simulator industry day as part of our next SC-159 meeting in October?

- **The next WG2/62 meetings are planned as follows for 2024:**
  - **June 24th Eurocontrol**
  - **October 2024, Washington DC**
  - **Request 3 days Monday/Tuesday/Wednesday jointly with WG-4 and EUROCAE WG-62 for next RTCA meeting in October 2024**
- **Short/mid-term priorities are:**
  - **Author's group teleconferences to progress on the MOPS next revision**
  - **Launch of Appendix W ad-hoc with a monthly meeting (Lead John Studenny: please send him an email to be part of this ad-hoc group)**
  - **Coordinate with ICAO NSP SAAG on SBAS authentication concepts and receiver architecture**

This concluded the WG2 presentation by Mr. Azoulai. The group then took a break until 11:15am.

The plenary resumed at 11:16am. Mr. Joel Wichgers conducted the brief of WG4 activities since the last plenary session.

Item 5c. GPS/Precision Landing Guidance (WG-4), to include update on related ICAO/Navigation Systems Panel Activities

WG-4 Work Products per TOR

- Future Documents [from SC-159 Terms of Reference (TOR)]
  - **Initial GNSS/GBAS L1/L5 MOPS & ICD for V&V to include GPS and Galileo**
    - Schedule per TOR is **Dec. 2024**, coordinated with ICAO NSP GBAS Working Group (GWG)
      - Dependencies: Lag initial DFMC GPS + Galileo SBAS MOPS (RTCA/ED-259A), and in parallel with ICAO NSP developing and completing baseline DFMC GBAS SARPs]
        - Documents:
      - MOPS: Plan is a new document, separate from DO-253 and DFMC SBAS MOPS
        - (Described as Option #2 in WP06 from March 2023 meeting)
        - ICD: Incorporate in an update to DO-246
  - **Validated GNSS/GBAS L1/L5 MOPS & ICD to include GPS and Galileo**
    - Schedule per TOR is **Dec. 2028**, coordinated with ICAO NSP GBAS Working Group (GWG)
      - Dependencies: Lag validated DFMC SBAS GPS + Galileo MOPS (i.e., RTCA/ED-259B) and in parallel with validated ICAO NSP validation and approval of DFMC GBAS SARPs

Note: Schedule exceptionally high risk, lack of resource commitments.

- GBAS MOPS & ICD Maintenance – *[No new items]*
  - **DO-253D with Change 1 GPS/LAAS Airborne MOPS → 4 minor changes**
    - 3 minor issues in non-normative explanatory appendices, 4th is a clarification
      - 1) Appendix K: Identified a small correction/clarification for the Rationale for VDB Requirements Appendix *[See WP-2 and WP-5 from October 2019 Meeting]*
      - 2) Appendix I: Identified minor update to GBAS classifications *[WP-8 from March 2020]*

- 3) Appendix J: Identified minor clarification if ICAO SARPs change is approved to allow E_{IG} > 2.75 m *[See WP10 and WP-10a from October 2020 meeting]*
- 4) Section 2.3.11.2: Identified minor recommended clarification for one clause of the Precision Approach Region (PAR) definition
  - No change to PAR, just clarification. *[See WP07 (page 3) from March 2023 meeting]*
    - No current TOR plan to update DO-253 document, but SC-159 plenary should of possible future update to address changes associated with testing against FM signal evolution of hybrid analog + digital signals, future FM all digital signals, and all maintenance items.

- **DO-246E with Change 1 GPS/LAAS ICD -- Nothing currently on Maintenance List, but will update along with DFMC GBAS MOPS**

2. Prototype Implementation of GAST E and Discussion [by Dominik Hoeltge and Helmut Blomenhofer]

Presentation

- Presented results from implementing GAST-E Message Type Formats
- Completed Initial First Results Testing of GAST E DFree and IFree Processing
- Also Completed Initial RTK Solution Feasibility Investigation

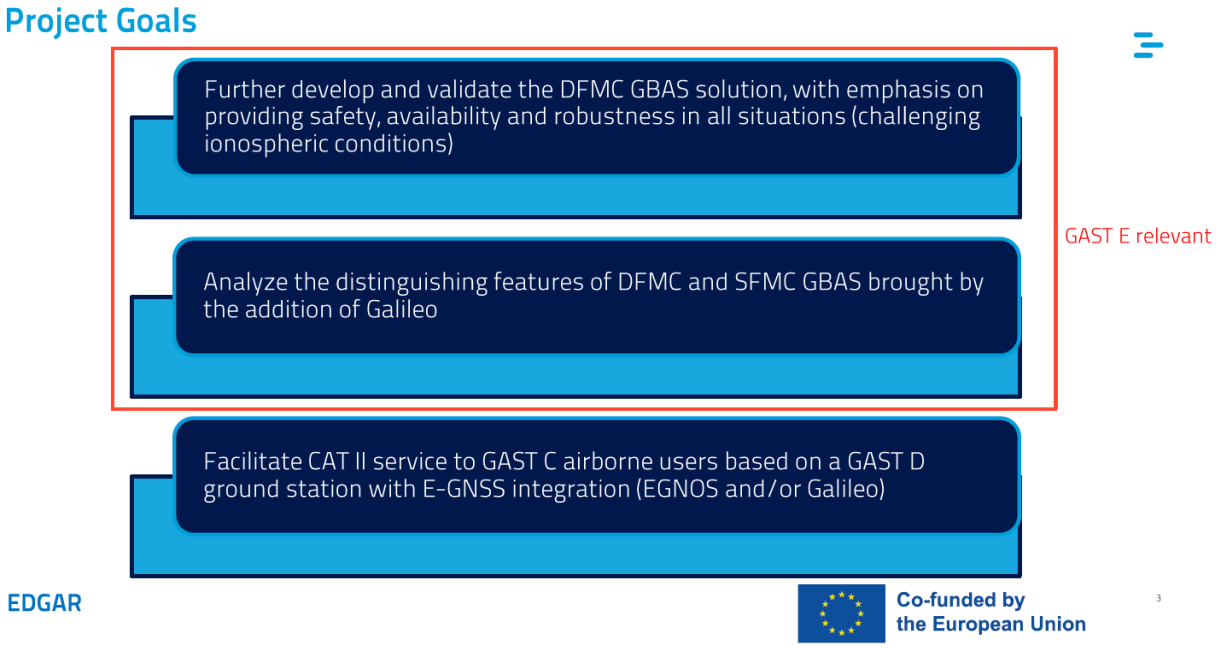
Configuration

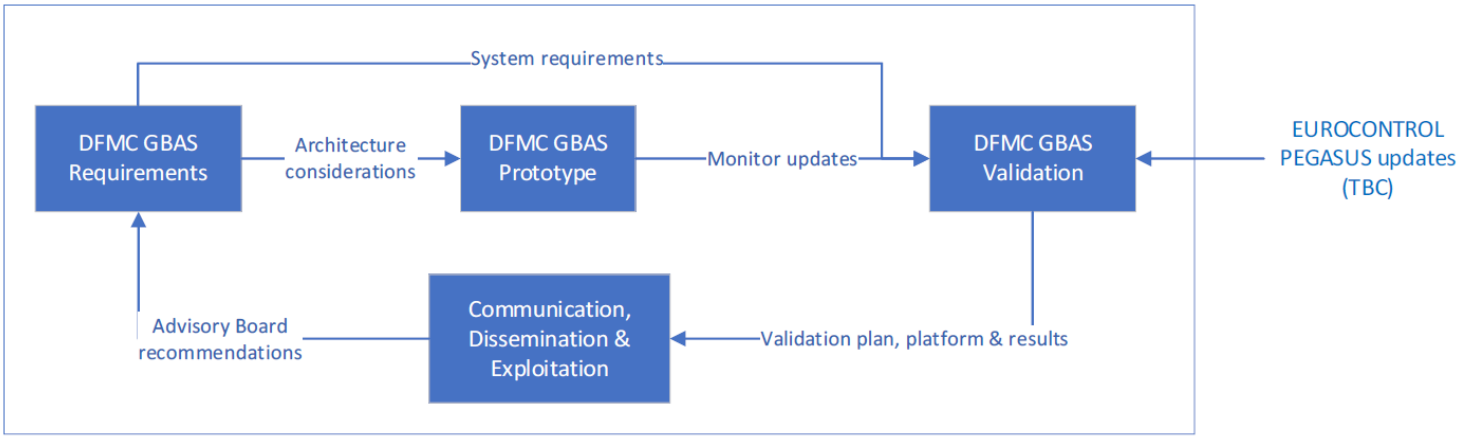
- **Prototype GLS202x & IGM compliant with main ED114a/b Functional Requirements**
- **GLS202x GBAS Base:** GBAS Message Generation and Broadcast
  - **19“ GLS202x GAST-C/D/E GBAS Base Unit**
    - Processing & Communication Unit: MT1, MT2, MT3, MT4, MT11, MT23, MT50
    - VDB Tx; Option: VDB Antenna, Mast, Obstruction Light, etc.
    - GLS202x GBAS Base Receiver Unit including 4x DFMC GNSS Rx
  - **4x GPS/GNSS Antennas**

Conclusions

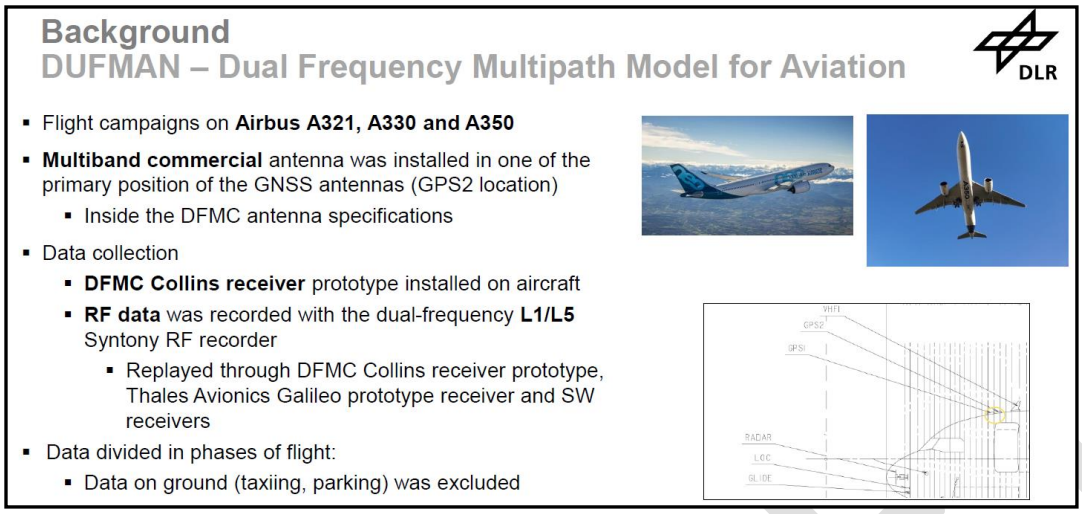
- General GAST-E DFree and IFree Online Software Processing works as expected
- First MT23/GAST-E RTK Feasibility was shown for Zero-Baseline
  - GPS + Galileo L1/E1+L5/E5a Geometry will further improve over current DF GPS + Galileo Geometry, since currently 17 of 3 GPS satellites broadcast L5 signals
- A number of next steps identified (unfunded)

3. EUSPA Project EDGAR (European GNSS DFMC for GBAS bAsed opeRations) [by Luisa Cavero]





4. Extension of DUFMAN Models in Support of DFMC GBAS Standardization Activities - Planned First Steps [by Maria Caamano]

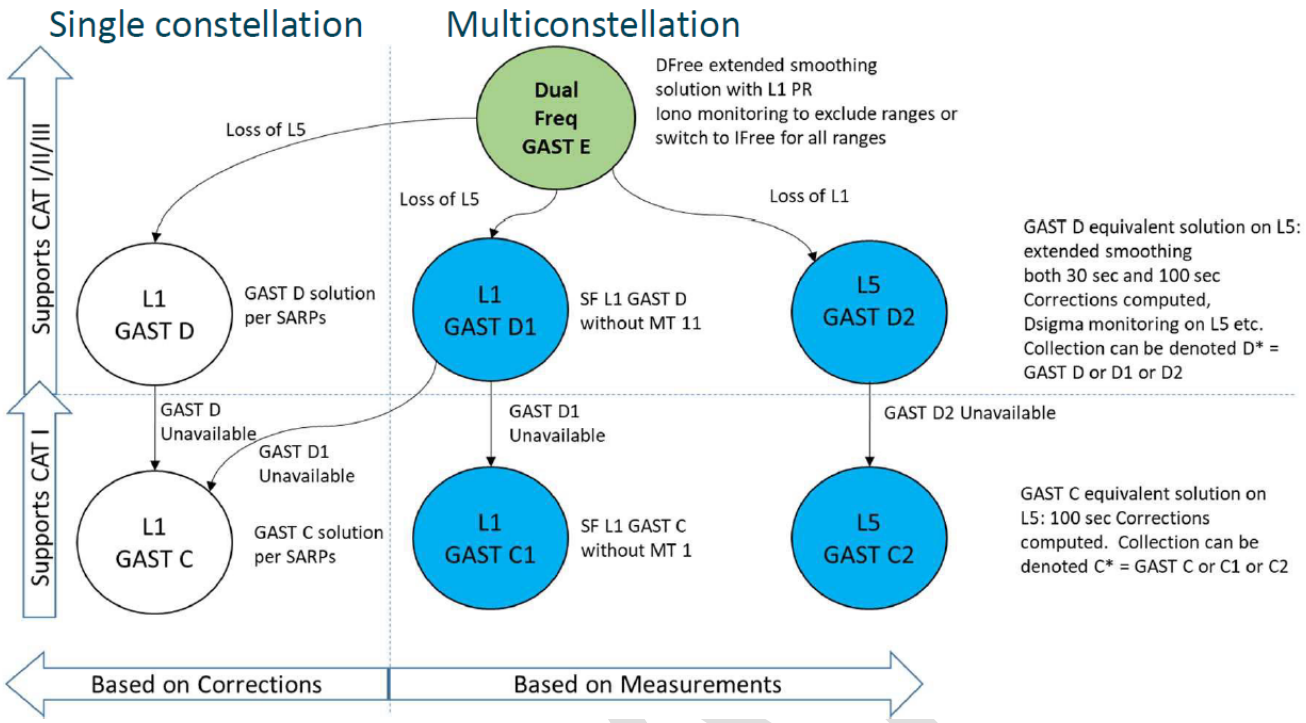


- Request from RTCA SC-159 WG4 in October 2023 to extend the DUFMAN multipath models (σ_{MP}) for:
  - The use of Divergence free (Dfree) smoothing in addition to conventional single frequency and Ionospheric free (Ifree) smoothing.
  - The impact of shorter/longer smoothing intervals on the results.
  - The use of time-variant smoothing from raw up to 600 seconds, including smoothing filter convergence characteristics.
  - The effect of Dfree, time-variant smoothing and longer smoothing time constants on antenna errors.
- DLR has decided to support this activity and part of the work will be performed, in agreement with EUSPA and Project Partners, in the framework of project EGNSS DFMC GBAS bAsed opeRations funded by the European Union(*).

Expected Result: Validated DFMC GAST E Multipath Models

5. GAST E Fallback Modes [by Morten Topland]

GAST E



Presentation Conclusions

- The following processing modes are envisaged to be supported by a GAST E ground station
  - Nominal mode: Dfree
  - Fallback modes: Ifree (ionospheric gradient present), GAST C1/C2/D1/D2 (frequency lost)
  - Legacy modes: GAST C/D
- It is desirable to take credit for dual constellation when assessing performance of the fallback modes to reduce inheritance of constraints from these modes.
- The drawback of taking credit for dual constellation is that continuity and availability of the fallback modes are impacted when e.g. only one constellation is available. However, the nominal mode is used most of the time, so this should not be a big issue.
- DFMC GBAS includes several constellations, frequencies and processing modes. Integrity threat mitigation has not been shown for all combinations. Relaxing ranging source integrity requirements in the range domain by assuming dual constellation could be an important benefit for the concept.

6. Status and Discussion of the entire ICAO Navigation Systems Panel activities with focus on the GBAS Working Group [by Tim Murphy]

- NSP Active Job Cards
    - NSP001 – Nav Roadmap;
    - NSP002 – GNSS Multi-Constellation;
    - NSP003 – SBAS Evolution;
    - NSP004 – ARAIM;
    - NSP005 – GBAS Evolution;
    - NSP006.02 – GNSS RF Interference;
    - NSP007 – Space Weather;
    - NSP 008.02 – Rationalization of Navaids;
    - NSP009.03 – APNT
- NSP Recent Accomplishments
    - Annex 10 Amendment 93 – Approved by panel at NSP 6 – Effective 2023

Added DFMC – L5 and New core constellations (Galileo, Beidou)
Added DFMC SBAS standards
Added modifications to GBAS SARPs for improved Iono Gradient Mitigation (GAST D)

    - Annex 10 Amendment 94? (TBV) – Approved by panel at NSP 7 – in ICAO process

Adds HRAIM requirements
GPS and Galileo - Updates (reflect latest versions of ICDs into the SARPs)
SBAS – Coordinated UTC standard identifier change – minor modification to Type 12 message
DFMC SBAS - It introduces modifications in the vertical protection level (VPL) calculation for DFMC SBAS receivers to correctly address the tropospheric error. Removes 600 s time out associated with SPID (aligns with actual usage)
DME – adds coverage requirements for DME's not associated with VOR, ILS or MLS.
Frequency assignment planning and utilization for ILS, VHF VOR, DME and GBAS
Expected to be Published

- NSP GNSS Evolution - *GBAS Job Cards*
    - NSP005.04 - GBAS Evolution
        - DFMC GBAS concept and architecture definition [Q4 2024]
        - DFMC GBAS baseline development SARPs & RTCA MOPS [Q4 2024]
        - DFMC GBAS SARPs [Q4 2030]

        - DFMC GBAS updates to GNSS Manual & GBAS Manual [Q4 2030]
        - Single Frequency GAST C & D GBAS Manual Draft [Q4 2025]
    - NSP GWG Major Activities
        - GBAS SARPS Maintenance
        - Impact to Other Annexes
        - ICAO Doc 8071 update for GBAS (Done)
        - Updates to the GNSS Manual (Doc 9849) (Done)
        - Development of a GBAS Manual
        - Dual Frequency - Multi-Constellation GBAS
            - Including support for maintenance of the DFMC ConOps

7. Status of ICAO DFMC GBAS GAST E draft SARPs [by Tim Murphy]

- ***Draft ICAO DFMC GBAS GAST E draft SARPs***
    - May 2023: JWGs/10 - WP 19A - First draft of the DFMC GBAS Annex 10 changes was introduced
    - November 2023: JWGs/11 – WP 15 – Updated Draft version 0.9
    - May 2024: JWGs/12 – Another Updated Draft will be available
- ***Issues Matrix***
    - Used to capture open issues related to the architecture and draft SARPs requirements
    - Most recent Version – 0.6
        - 33 issues logged
        - 6 closed so far

8. Update on DFMC GBAS Iono Gradient Monitoring validation with flight data collection campaign in October 2023 and March 2024 [by Susumu Saito]

- Another flight test campaign processed (Oct. 5 to 9, 2023) with more severe iono conditions analyzed.

Objectives:

- Evaluate DFMC GBAS concept performance under ionospheric disturbances
- Updated using flight data from Ishigaki DFMC GBAS testbed data during October 2023

Flights and ionospheric conditions (October 2023)

Date	5 Oct	6 Oct	7 Oct	8 Oct	9 Oct
Day (# approaches)	Ferry	o (5)	o (6)	o (5)	o (5)
Ionospheric condition		Quiet	Quiet	Quiet	Quiet
Night (# approaches)	o (3)	o (6)	o (6)	o (7)	o (5)
Ionospheric condition	Quiet	Strong	Strong	Weak	Weak
Sky condition	Partially cloudy	Partially cloudy	Partially cloudy	Partially cloudy	Partially cloudy

- 9 flights (4 in daytime, 5 in nighttime)
- 48 approaches (21 in daytime, 27 in nighttime)
- 2/0/2/1 strongly disturbed/moderately disturbed/weakly disturbed/quiet ionospheric condition(s)

Conclusions

- Flight data on 7 October 2023 night at Ishigaki were analyzed.
- "bias" term associated with ionospheric decorrelation were as large as 10m at larger distance (~50km or 30NM)
- "bias" term is dominant in VPLiono.
- Differences of "bias" term of DF with respect to that of CP were mostly bounded by the "sigma" term, but there are cases where they were not bounded.

9. Review of VHF Navigation Band MOPS Testing Against FM Broadcast Signals [by Mark Dickinson]

VOR, ILS LOC, and VDB Tests

- **VOR and ILS LOC MOPS were both issued by SC-153 on November 17, 1986.**
- **Only Analog FM Broadcast signals at this time.**
- **Intermodulation, Spurious Response & Desensitization Tests use FM Broadcast Band signals.**
- **Similar testing methods for VOR & ILS systems.**
- **Testing method/FM signal description carried on to DO-253D in 2.5.2.1.1 Standard Test Signals.**

Summary of FM Testing Signals

- **Currently, Only Analog FM Broadcast signals used.**
- **Widest FM signal used: ±75kHz (Pink, CCIT, or ITU-R Recommendation BS.559-2).**
- **Current FM Broadcast channel 200kHz wide**
- **Hybrid signals ± 200kHz.**
- **Use of some digital content since 1992**
  Radio Data System (RDS)
  RDS2 (2015)
- **Full digital FM Signals in the future?**

Tested against a simulated analog FM Broadcast Signal, no FM Hybrid Analog/Digital Signals in MOPS/TSO Test Procedure

10. Update on FCC Notice of Proposed Rulemaking (NPRM) Regarding FM Hybrid Analog/Digital Transmissions [by Joel Wichgers]

- Previously Reported: August 22, 2023 – On the Federal Register: FCC Released the original Notice of Proposed Rulemaking (NPRM) regarding FM Broadcast Signals
  - Summary: NPRM proposes to permit FM stations to increase FM hybrid digital effective radiated power (FM Digital ERP) to higher levels as identified in the NPRM without the need for individual Commission authorization, as well as allowing asymmetric digital sideband operations.
- Update: On February 29, 2024 – On the Federal Register: FCC Released additional notice for public comment → Comments due April 1, 2024
  - Summary: National Association of Broadcasters (NAB) proposes a "clarification" (really a change) to allow up to a 40% increase in the power levels of the digital sidebands without need for individual Commission authorization over the August 22, 2023, NPRM requested maximum level of -10 dBc.
  - A 40% increase represents another 1.5 dB increase because the original notice stated that the maximum power in the digital sidebands was -10 dBc (which is appropriate for the MP1 hybrid mode of operation), and they want full power for other hybrid Modes of Operation (extended hybrid) which have different digital signal partitions that (if allowed) could increase the total digital power by 10%, 20%, or 40% over what was indicated in the August 22, 2023 NPRM up to -8.5 dBc.

More than Clarification, Changing Maximum Digital Sideband Power Levels

FM Extended Hybrid Signal

- NAB proposing "clarification" (per Feb. 29 Federal Register Posting) for NPRM that the total power in Upper and Lower Digital Sidebands can be 10%, 20%, or 40% higher than -10 dBc (depending on the specific service mode / number of digital partitions), now up to – 8.5 dBc.
- Asymmetric operation is allowed.

FM Hybrid Signal

Figure from Rev. H, HD Radio Air Interface Design Description - Layer 1 FM, iBiquity Digital Corporation, dated November 2022 that is available on NSRC web site: https://www.nrscstandards.org/standards-and-guidelines/documents/standards/nrsc-5-e/NRSC-5-E_reference_documents.pdf

Background

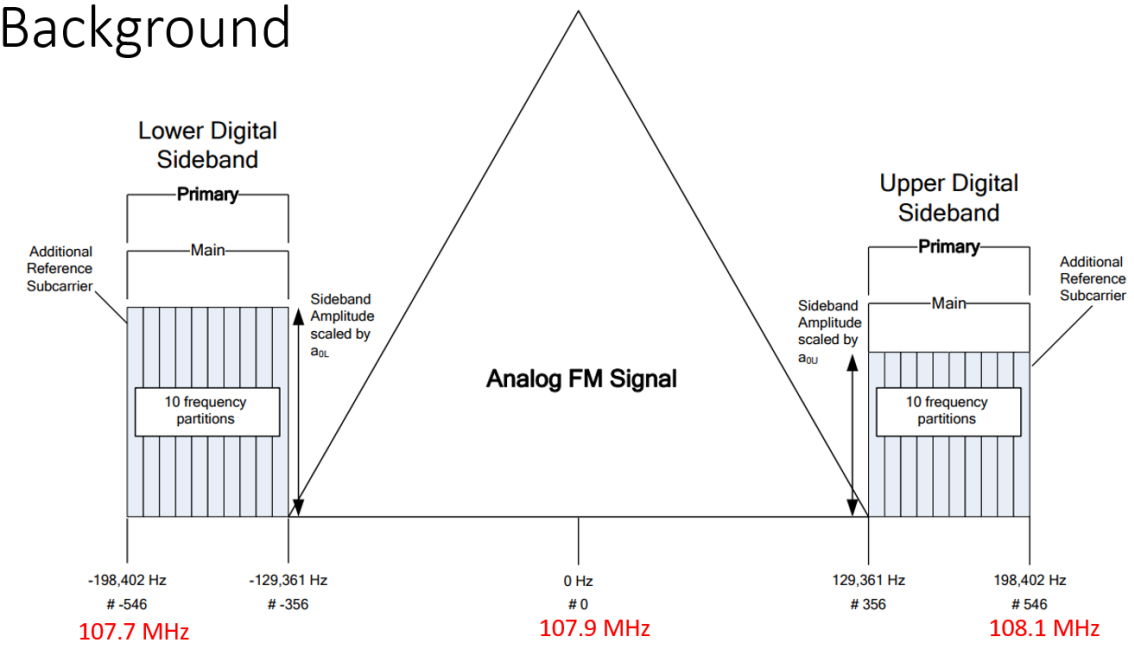


Figure 5-5: Spectrum of the Hybrid Waveform – Service Mode MP1

Example at 107.9 MHz FM Center Frequency

11. Work on Test Procedures for Testing VHF Navigation Band Avionics in the Presence of FM Transmissions [by Joel Wichgers]

Working update to ITU-R Doc for Testing compatibility of VHF Nav. With FM Broadcast Signals

Original SM.1140

- Developed and approved in 1990's
- ITU-Recommendation for Testing Compatibility between Sound Broadcasting Services in band of about 87 to 108 MHz and the Aeronautical Navigation Services in 108 to 118 MHz band.
- Recommends specific test procedures for determining interference immunity characteristics of ICAO Annex 10 1998 ILS localizer (LOC) and VOR receivers from Sound (FM) broadcasting stations.
- Test procedures were originally developed by Radiocommunication Task Group studying aeronautical/ broadcasting compatibility and were used in the bench testing of the ICAO Annex 10 1998 receivers at the Federal Aviation Administration (FAA) Technical Center (Atlantic City, New Jersey, United States of America) in 1993-94. Additional testing / cross-check tests conducted by other organizations.

Discrepancy Discovered In ILS LOC (DO-195) MOPS

- DO-195 Section 2.2.6 Desensitization subparagraph a.(4) includes the following

Frequency (MHz)	Maximum Level of Unwanted Signal at Receiver Input
88-102	+15 dBm
104	+10 dBm
106	+ 5 dBm
107.9	-10 dBm

The relationship is linear between adjacent points designated by the above frequencies. The levels are indicated by Figure 2-1.

(4) The undesired unmodulated carrier will have an RF input level of -13 dBm at the receiver input terminals on any frequency from 50 kHz to 1215 MHz except as follows:

(a) Excluding the frequency range of 108.0 to 118.5 MHz.

(b) Its level shall not exceed the levels shown in Figure 2-1 for frequencies between 88 MHz and 107.9 MHz.

Table Matches ICAO Annex 10 Volume I Section 3.1.4.2.
Thus, it appears Figure is incorrect.

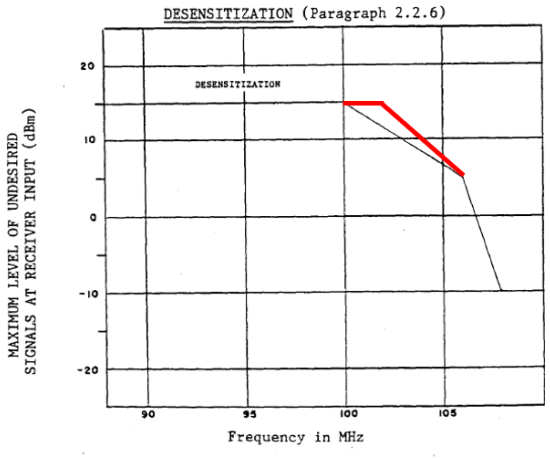
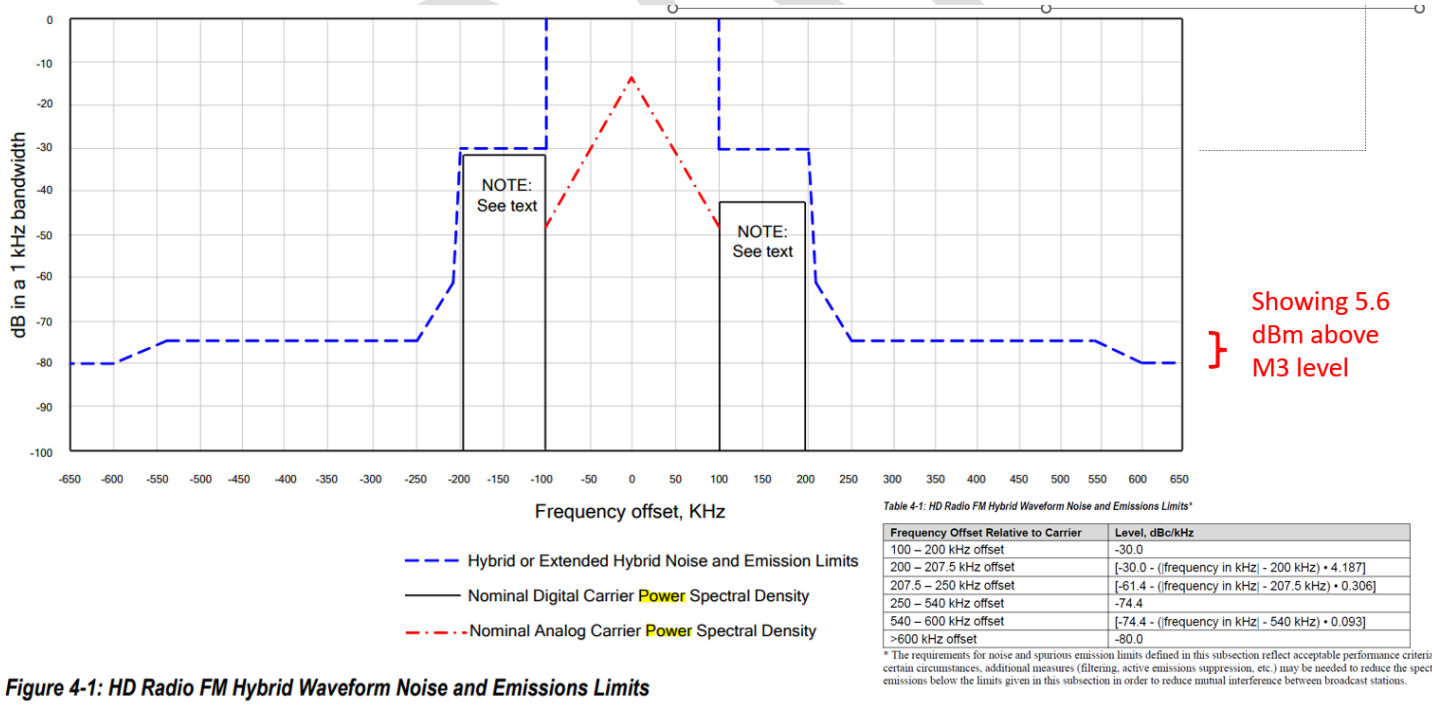


FIGURE 2-1 FREQUENCY OF UNDESIRED SIGNAL (MHZ)

Correction to Desensitization Plot to Match Table

Hamza Abduselam checked TSO-C36e to see if the discrepancy is noted/corrected. It is not.

11. Work on Test Procedures for Testing VHF Navigation Band Avionics in the Presence of FM Transmissions [by Joel Wichgers]



Showing 5.6 dBm above M3 level

*Table 4-1: HD Radio FM Hybrid Waveform Noise and Emissions Limits**

Frequency Offset Relative to Carrier	Level, dBc/kHz
100 – 200 kHz offset	-30.0
200 – 207.5 kHz offset	[-30.0 - (|frequency in kHz| - 200 kHz) • 4.187]
207.5 – 250 kHz offset	[-61.4 - (|frequency in kHz| - 207.5 kHz) • 0.306]
250 – 540 kHz offset	-74.4
540 – 600 kHz offset	[-74.4 - (|frequency in kHz| - 540 kHz) • 0.093]
>600 kHz offset	-80.0

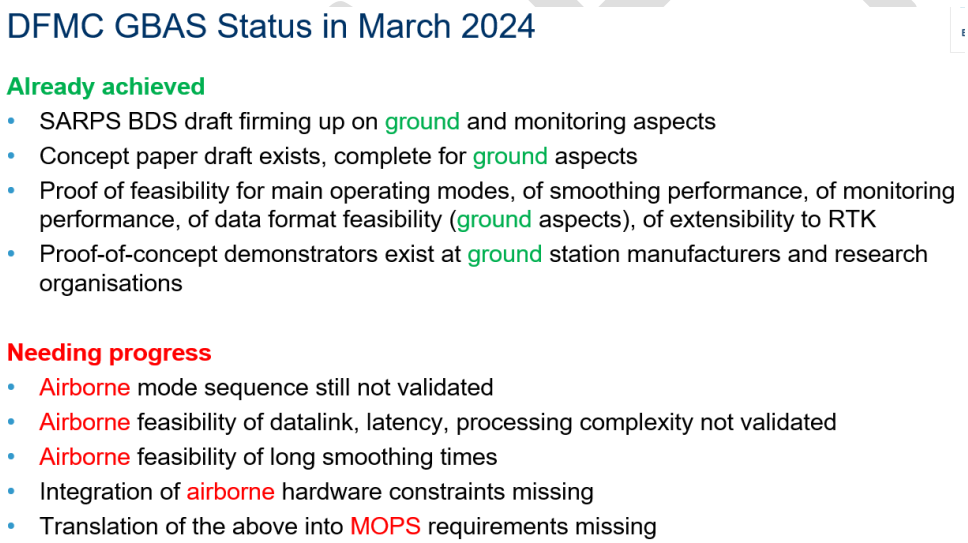
* The requirements for noise and spurious emission limits defined in this subsection reflect acceptable performance criteria. In certain circumstances, additional measures (filtering, active emissions suppression, etc.) may be needed to reduce the spectral emissions below the limits given in this subsection in order to reduce mutual interference between broadcast stations.

Figure 4-1: HD Radio FM Hybrid Waveform Noise and Emissions Limits

Discussion Item: Test Nominal Signal from Worst Case Emission Mode or Test Based upon the FM Transmit Mask.

At this point in the presentation Dr. Kalyanaraman indicated that the focus was on developing an update to the SM1140 test plan and obtaining test results that address the evolution of the FM signals. He said that there coud be a need to look at frequencies much further away from 108.0 MHz but for right now the focus should be on the continued operational safety case. Mr. Wichgers expressed concern that if we negotiated and agreed on compatibility with the FCC just to meet the safety case for the currently deployed services and then had to go back for another change, it could become problematic. For example, just satisfying continued operational safety with the currently deployed services may limit future siting flexibility for Aviation services center frequencies below 108.2 MHz since the FAA currently has no operational ILS LOC, VOR, or GBAS VDB services below 108.2 MHz. Dr. Kalyanaraman agreed but still called for need for more data to know what options are available. Mr. Abduselam agreed to take this discussion to the FCC while Mr. Wichgers added that the FAA may also have to update their Airspace Analysis Model (AAM) spectrum compatibility tool. Then Dr. Kalyanaraman asked Mr. Abduselam if the FAA's AAM tool accounted for FM hybrid analog/digital signaling in addition to the traditional FM analog signals. He responded that he did not know, but subsequent discussions with FAA representatives have concluded that the AAM tool does not currently account for the FM hybrid analog/digital signals.

12. Work Plan Discussion



Discussion in RTCA SC159 WG4

Will it be possible to resolve the outstanding airborne aspects before the end of 2024?

- If yes, then establish work plan for:
  - Tests with airborne architectures using DFree smoothing times longer than 100s
  - Tests with representative airborne noise and multipath environments (other than zero baseline)
  - Tests with the degraded modes D1 and D2 (and possibly helping the definition of C1 and C2)
  - Running the different modes concurrently on representative hardware to investigate processing power limitations
  - Transitions between the primary and the fallback modes and interactions/benefits that can be achieved from concurrent SBAS/ARAIM processing
  - Translation of these results into MOPS requirements, notably on message latency and GNSS time format limitations
  - Translation of these results into optimisation of the datalink message, notably the definition of an optimised MT23
- If no, then establish alternative timeline and work plan for presentation to NSP in May '24:
  - How the RTCA work plan fits into the SARPS development timeline?
  - Who are the contacts for the above work plan items and how and when will they report to the SARPS drafting group ?
  - Why this enables to not reopen discussion on GAST D+ ?

- Resources
  - Overall Lack of Organizations / Companies providing sufficient committed resources
  - Need MOPS authors team leader
  - Need committed volunteers to develop
- Schedule
  - Very unlikely to meeting end of 2024 draft DFMC MOPS schedule, unless there is a significant change to resources

Mr. Wichgers concluded his presentation with some comments on GBAS DFMC development. With growing areas of GPS jamming and spoofing, many operators have lost interest in future near-term development of DFMC GBAS and instead are more near-term focused on solutions to GNSS jamming and spoofing. He also sugested that WG-4 was going to need to do an update of the VDB requirements / test procedures to address the evolution of the FM signals (e.g., to address the hybrid analog/digital FM signals and possible future all digital FM signals).

Andreas Lipp expressed other concerns with potentail new threats. Since there is low aircraft operator utilization of GBAS operations (i.e., while there are many aircraft equipped for GBAS Category I precision approach operations, there are relatively few GBAS capable groundstations approved to support GBAS Cat. I Operations), is there a plan for making ILS more robust to cybersecurity threats in place today? Mr. Alexander responded that ILSs can be spoofed. This concluded the WG-4 presentation.

Dr. Hegarty suggested that we deviate from the agenda to address the date for our next Plenasry inn the spring of 2025 given our European colleagues and others might be Dropping from the meeting soon. After schedues were checked for ICAO meeting Conflicts, a week in march of 2025 was decided. **Dr. Hegarty proposed that the 118th Plenary for SC-159 be held on March 14th, 2025 with work groups meeting that Week of the 10th. There were no objections and the date was agreed to.**

Item 5d. GPS/Interference (WG6), to include update on related ICAO/Navigation Systems Panel activities

WG6 – Status
Agenda

1. Update on LEO PNT impacts to I_{GNSS}
2. Proposed 2nd series of tests of injecting C-UAS and spoofer signals into Civil Aviation GNSS Rx
3. SBAS Link assessment (under expanded PRN set)
4. 292A document updates

Ignss impacts LEO PNT

LEO PNT projects

Several LEO PNT projects with an L-band component are under consideration:

- SATNET LEO Augmentation Navigation System (ITU filing received in 2020)
- Xona Pulsar (ITU filing : 2023)
- Synchrocube (ITU filing: 2023)
- NSAT01 (ITU filing: 2019)
- Centispace (ITU filing 2018 ?)
- Jukebox
- ESA LEO PNT…

These projects, which may contain a significant number of SVs to provide a global service, may impact the airborne civil aviation receiver $(C/N_0)_{eff}$ link budget.

In particular, they may be viewed as impacting the airborne civil aviation I_{GNSS}, although I_{GNSS} is for aeronautical components when these LEO PNT L-band radiations may not be aeronautical components.

They may also impact the EPFD as per ITU Res 609, not discussed here.

Ignss impacts LEO PNT SBAS L5

Strategy for L-band LEO PNT compatibility analysis

Bound on I0 due to L-band LEO PNT from $I_{0,NON\_AERO\_Max} = -201.58\ dB\ W/Hz$ (ICAO)

The maximum tolerable equivalent wideband noise density level from non aeronautical components for L5/E5a signal processing channel has been evaluated by ICAO at the FL400 hot spot to be equal to

$$I_{0,NON\_AERO\_Max} = -201.58\ dB\ W/Hz$$

There are at least 2 known non-aeronautical components which are on-board PEDs and terrestrial emitters, whose impact is bounded to be -202.5 dB W/Hz (DO292A).

Therefore, the room left for all other non-aero components is -208.7718 dB W/Hz.

If we consider a 6 dB back-off to allow for unknowns, and an apportionment ratio -Q, any modification on the RNSS intra/inter system RFI environmnent should not cause an aggregate noise level higher than :

$I_{L-band\_LEO\_PNT\_L5\_MAX}$ < -208.7718 -6 -Q = -214.7718 -Q dB W/Hz

This is the selected option to analyze the aggregate noise from Nvis SVs presented in these slides.

Mr. Alexander asked if any of the new satellite entrants had expressed a desire to provide aviation services. Dr. Kalyanaraman answered that fi they do then they need to engage with WG6 so we could discuss their integration if they want to go that far. It is unclear if they will want to step up to be an RSS aviation safety of life provider. Mr. Abduselam added that these providers would have to get included in the SARPS and then come back to RTCA and the MOPS development.

Aggregate

With the available information, predicted bounds on the I_0 induced by 4 LEO constellations on L5/E5a:

- XONA (258 SVs):

$$I_{LNK2} < -136+17.0333-90.95 = -209.92 \text{ dBW/Hz Mode 1 Final Phase}$$
$$I_{LNK2} < -140.1+17.0333-92.23 = -215.30 \text{ dBW/Hz Mode 2 Final Phase}$$

- SATNET (504 SVs):

$$I_{SATNET} < -154.1+11.83-70.9 = -213.17 \text{ dBW/Hz (1174.404 MHz)}$$
$$\text{or } I_{SATNET} < -157.1+11.83-70.91 = -216.18 \text{ dBW/Hz (1178.496 MHz)}$$
$$I_{SATNET} < -159.1+10.00-98.14 = -247.24 \text{ dBW/Hz (1202.025 MHz)}$$

- SYNCHROCUBE (24+1 SVs):

$$I_{SYNCHROCUBE} < -140.6+2.34-75.9 = -214.10 \text{ dBW/Hz}$$

- NSAT01:

$$I_{NSAT01\_L5T} < -203.04 \text{ dBW/Hz}$$
$$I_{NSAT01\_E5T} < -219.66 \text{ dBW/Hz}$$

where $I_{L-band\_LEO\_PNT\_L5\_MAX}$ = -214.7718 - Q dB W/Hz from I_{0,NON_AERO_Max}

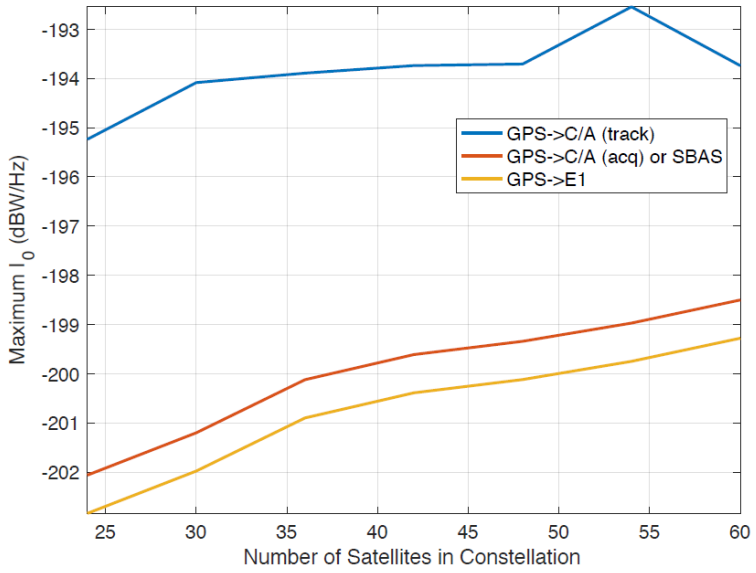
Therefore, individual (except SATNET 1202) and aggregate contributions exceed allowed I_{0,NON_AERO_Max}

Mr. Alexander now asked if all four displayed above had expressed any desire. Dr. Kalyanaraman answered that only XONA had expressed any interest.

- Aggregate I0 from 4 L-band LEO PNT at L5/E5a reaches -208.14 dB W/Hz
  - already exceeds the whole allowed aggregate -208.77 dB W/Hz threshold (even w/o 6dB safety margin),
  - each of the 4 L-band LEO PNT is exceeding individual threshold.
- A 5th one identified: GEESAT: 240 SVs planned, 1191.8 MHz and 1603.04 MHz, 20 satellites launched (9 in 2022, 11 in Feb 2024), not clear which spectrum they are transmitting on.

Ignss impacts PRN Expansion L1 C/A and SBAS

Total GPS Interference to GPS C/A, SBAS, and Galileo E1 OS



MITRE

Summary

- Presentation provided results for growth in GPS interference to GPS and Galileo L1/E1 signals with GPS constellation size
- Interference growth dependent on constellation configuration
  - For results in this presentation, 24 and 30 satellite configurations taken from SPS Performance Standard; 36, 42, and 48 satellite configurations assume insertion of satellites into “gaps”; Walker assumed for 54 and 60 satellites
- With larger constellations, elevation angle of lowest critical satellite will increase so importantly $C/N_{0,eff}$ of importance for L1 GPS C/A may not be worse than computed in DO-235C
  - E.g., DO-301 compliant antenna picks up 1.5 dB in minimum gain from 5 to 10 degrees

MITRE

WG6 work plan

- Items to address:
  - 1) assess LEO PNT impacts
  - 2) Impacts from pulsed interference to Beidou signal processing
  - 3) Continue to support ED-259() test proc development efforts
  - 4) LDACS – GNSS Assessment for compatibility
  - 5) MSS direct to device link assessment (impact of aggregation on board the aircraft)
  - 6) Coupling in the L5 band (from onboard sources) to the GNSS antenna installed on the aircraft , and ...

Spoofing / Jamming RFI assessment activity

Suggested spoofing/jamming RFI environment characterization activity (by WG6)

Model RF Environment at output of antenna port(s):

$$S_1(t) = \sum_{i=1}^{N_s(t)} A_i(t)c_i\left(t-\tau_i(t)\right)d_i\left(t-\tau_i(t)\right)\cos\left(2\pi f_i\left(t-\tau_i(t)\right)+\theta_i(t)\right) + authenticGNSS + \sum_{i=0}^{N_j(t)} J_i(t)$$

For each identified spoofing scenario parameters including all signals history, considering Rx_state(t):

1. Determine proba for Authentic+Non-Authentic signals to be acquired or re-acquired, tracked, demodulated given the RF environment
2. Implementent data validation checks for validation of range measurement
3. Determine Pmd for CMC, Step Detector not to detect range errors
4. In SBAS mode, determine Pmd for local RAIM not to detect and exclude pos failure due to spoofing
5. In ARAIM mode, determine Pmd for ARAIM not to detect and exclude pos failure to spoofing
6. Determine probability for integrity failures (xPE>xPL, xPE>xAL, time error > 1s, …)

From the integrity risks for each scenario

- Determine requirement for spoofing detector (if any)
- Determine threat models for which integrity is required, claim table
- Determine continuity performance
- Determine recovery capability
- Determine test cases which need to be run (and which test cases are bounding other test cases)

1

DO-292A completion

- FRAC Opened : 18 Sep 2023
- FRAC Closed: 17 Oct 2023
- Comments received: 206, High: 13, Medium:86, Low: 27, Editorial: 79, Non-concur: 0
- Dispositioned all comments except the editorial
    - Concurrence with WG6 on addressing editorial comments offline.
- About 80% of the comments implemented
    - Plan to bring finished document back to WG6 (SC-159) for final review (ahead) of submission to PMC in June

Dr. Kalyanaraman concluded the WG6 presentation and there were no questions. He then turned to the WG7 presentation.

Item 5e. GPS/Antennas (WG7)

Status

- Input/Feedback from COMAC on DO-373
- PNT Robustness in Aviation – Multi Antenna Systems as effective countermeasure to RFI
- RTCA/DO-373A update

COMAC Antenna Update

- Presented material on antenna developed with a goal to conform to DO-373 within the ARINC 743A footprint
    - BLUF: Design was able to meet 10 of the 12 reqs of 373 as it stands and 2 more need to be optimized.
    - The 2 items are to be optimized (2.2.3 antenna unit relative radiation pattern and passive element gain, 2.2.11 group delay).

Overview of Test Results – COMAC

No.	Performance Parameters		Performance Requirements	Test Results
1	Frequency of Operation	B1C/L1/E1	1575.42MHz±10.23MHz	Met
		B2a/L5/E5a	1176.45MHz±10.23MHz	Met
2	Antenna Unit return loss and impedance	Antenna Unit Output VSWR	<1.5	Met
		Output VSWR when 0.5 inches of ice is accumulated over the antenna	<2.0	Met
		Active subassembly Input VSWR	<1.8	Met
3	Antenna Unit Relative Radiation pattern and Passive Element Gain	Antenna Unit Relative Radiation Pattern	see performance requirements	To be optimized
		Passive Element Gain	≥-4.5dBic@≥5	To be optimized
			≤4dBic@≥75°	Met
4	Polarization and Axial Ratio	Antenna Radiation Pattern Polarization	Right-hand Circularly Polarized	Met
		Axial Ratio	≤3dB@≥50°～90° (new version：≤3dB@≥65°～90°)	Met
5	Antenna Sensitivity: The G/T Ratio	B1C/L1/E1	-30.6dB/K（5°～90°）	Met
		B2a/L5/E5a	-32.5dB/K（5°～90°）	Met
6	Total Transducer Gain and Gain Compression	Minimum Boresight Total Transducer Gain	≥29.5dBic	Met
		Active Sub-Assembly Transducer Gain	≥26.5dB	Met
		The difference in overall gain across the L1/E1/B1C and L5/E5a/B2a RF chains	≤6dB	Met
		1 dB Input Compression Point	see performance requirements	Met

No.	Performance Parameters		Performance Requirements	Test Results
7	Output Load Stability		normal	Met
8	Boresight Gain Relative Frequency Response	-3dB Relative Response Frequency	Lower frequency<1567.42MHz, upper frequency>1583.42MHz@B1C	Met
			Lower frequency< 1166.22 MHz, upper frequency> 1186.88 MHz@B2a	Met
		Maximum Boresight Gain Relative Frequency Response	See standard requirements	Met
9	Burnout Limit		≤20dBm@ +30dBm	Met
10	Pulse power Recovery Time	In band maximum pulse input at B1C/L1/E1 Band	≤10us	Met
		In band maximum pulse input at B2a/L5/E5a Band	≤10us	Met
		Out of band maximum pulse input	≤1us	Met
11	Group Delay	Boresight Differential Group Delay(BDGD)	25ns	Met
		Differential Group Delay versus Angle(DGA)	For 5° ≤ θ< 45° : $\Delta\tau \leq (1.5 - 0.02125 * (\theta - 5°))$ns ; For θ ≥ 45° : $\Delta\tau \leq 0.65$ns	To be optimized
		L1-L5Group Delay difference	≤15ns	Met
12	Power Interface	Load Capacitance	≤0.75uF	Met
		Operating voltage	4.5～14.4V	Met
		Operating current	≤200mA	Met

DO-373A table of frequencies with Beidou included

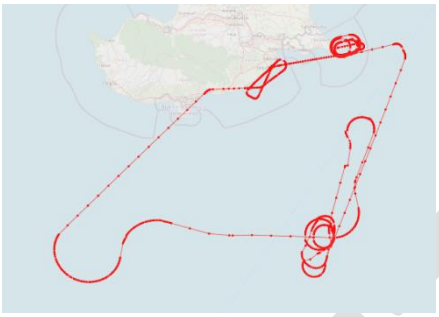
Band	Central Frequency (MHz)	Lower frequency limit (MHz)	Upper frequency limit(MHz)	Bandwidth (MHz)
E5a Galileo	1176.45	1166.22	1186.68	20.46
E1 Galileo	1575.42	1565.19	1585.65	20.46
L5 GPS	1176.45	1166.22	1186.68	20.46
L1 GPS	1575.42	1565.19	1585.65	20.46
B2a BDS	1176.45	1166.22	1186.68	20.46
B1C BDS	1575.42	1565.19	1585.65	20.46

Questions from COMAC

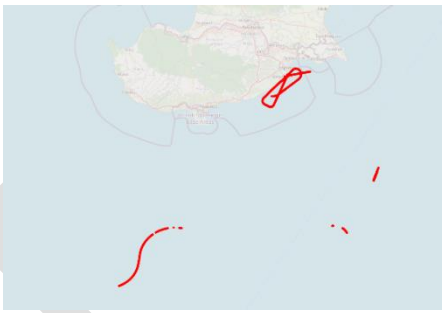
- Is it possible to provide the specific size and shape of the large reflecting surface used in the test?
- Is it possible to provide the specification of the RHCP source antenna used for the transmit antenna in the group delay test.
- Is it possible to use other alternative methods to measure group delay versus angle?
- Is there any design solution to effectively improve the antenna gain at low elevation angle under large reflection surface.
- The necessity of saturation pulse recovery time(≤1us) in Pulse power Recovery Time req.
- The necessity of 1dB compression point in Total Transducer Gain and Gain Compression req.
- The necessity of high limit of relative frequency response in Boresight Gain Relative Frequency Response.

DLR – RFI monitoring

- DLR flight measurement campaign on 13.02.2020 [1]
- Test flight with DLR A320 D-ATRA in Nicosia FIR / Cyprus
- Flight at FL300, FL210 and FL100 in area of size 250 km (east-west) x 170 km (north-south)
- GNSS reception significantly affected over large amount of time



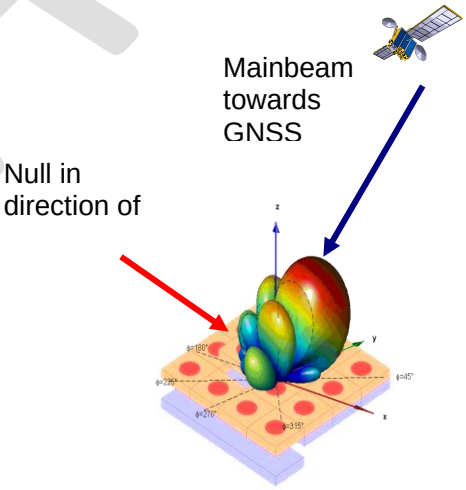
Flight track



Parts of track where GPS position was available

DLR – KN APNT and Multiantenna Robust Receiver

- What can be done?
- Awareness!
  - Jamming and spoofing tests
- Sensor fusion
- Integrity
- LDACS-NAV
- Cybersecure GBAS
- Multiantenna robust receiver



Are Multiantenna Systems Too Big, Complex and Expensive

Some Years Ago

Antenna:

30x30 cm^2 footprint (= bigger your PC)

CRPA receiver:

<50x40x100 cm^3 (=~ your hand luggage

Now

Antenna:

3.5” (9cm) or ARINC 743 footprint (as COTS Avionic single antennas)

CRPA receiver:

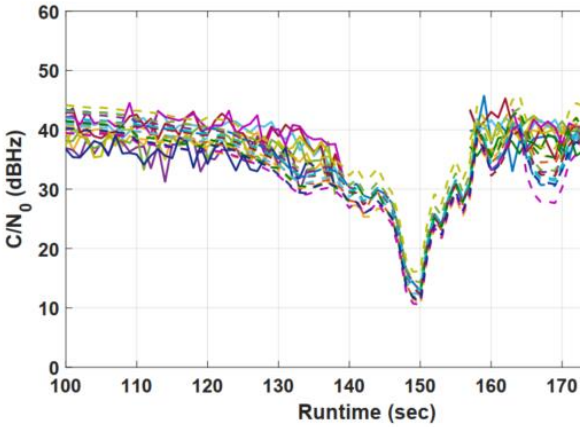
<20x10x10 cm^3 (=smaller than your PC)

Flight Campaigns – Single Antenna – Jamming Effects Cochstedt 2022

Measured data on single antenna

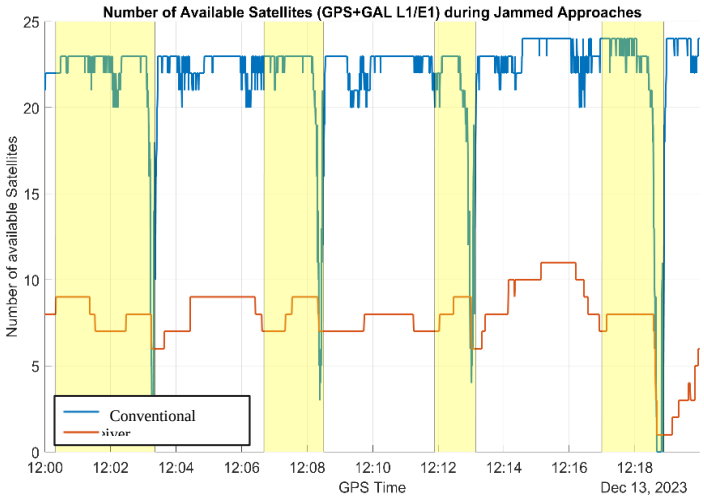
Predicted data on single Antenna

Single Antenna systems lose track when in jammed zone



They were able to predict accurately and then demonstrate in flight the effect of jamming on single antenna receivers

Flight Campaigns – Resilience through Multiantenna Cochesdt 2023



Test was accomplished by flying in front of a jammer at increasing jamming power. The multi-antenna demonstrates to be resilient and keep signal tracking even during jamming events.

DO-373A Update

- In support of compatibility with Iridium Certus updates are needed to improve:
  - Compression point spec
  - Antenna selectivity
- Antenna axial ratio spec update
- Shared list of updates with WG7 a few weeks back
  - Obtained feedback from Garmin and CMC
- WG7 to send marked up DFMC Antenna document to Karan to format and send out for FRAC
  - Plan to close FRAC out ahead of the October 2024 SC-159 plenary

Mr. Alexander then remarked after Dr. Kalyanaraman concluded his presentation that the FAA was working on a new contract for testing and information on antenna resiliency. Dr. Kalyanaraman asked if there could be changes to the ITAR. Mr. Alexander responded that had been submitted. Then Mr. Studenny asked if there would be a move to open the MOPS to consider a CRPA antenna. Dr. Kalyanaraman responded that it depended on what changes could be made to the ITAR. Based on what can be changed, Antenna manufacturers would have to decide what they could do with those changes. Dr. Kalyanaraman then asked others in the meeting if they had any other questions. There were none so he concluded his presentation.
Dr. Hegarty continued with the agenda.

Agenda item 6. Discussion Terms of Reference

Dr. Hegarty remarked that no changes were offered for this meeting, so this item was disposed as closed

Agenda item 7. Action Item Review

Dr. Hegarty disposed this item as complete as any action items were briefed out during each WG presentation

Agenda item 8. Assignment/Review of Future Work

There were no assignments or future work

Agenda Item 9. Other Business

No new business was presented.

Agenda Item 10. Date and Place of Next Meeting

Dr. Hegarty reviewed the dates for the next plenary meeting. SC-159 will meet the week of 21st of October 2024 with the plenary meeting being held on the 25th. The follow on Meeting of SC-159 will be the week of March 10th, 2025, with the plenary being held on the 14th.

Agenda Item 11. Adjourn

Dr. Hegarty thanked all participants and adjourned the meeting at 1:17 pm.

CERTIFIED as a true and accurate summary of the meeting.

-S-
Dr. Christopher Hegarty
Co-Chairman

-S-
Dr. George Ligler
Co-Chairman

-S-
Wes Googe
Secretary