



Summary of the Ninety-Fourth Meeting

Special Committee 159

**Minimum Operational Performance Standards for Airborne Navigation
Equipment Using the Global Positioning System (GPS)**

The ninety-fourth plenary meeting of SC-159 was held on October 23rd, 2015 at RTCA Headquarters, 1150 18th Street NW, Suite 910, Washington, D.C. 20036. The attendees were the following:

Christopher Hegarty (Co-Chairman)	The MITRE Corporation
George Ligler (Co-Chairman)	PMEI
Kyle Wesson (Secretary)	ZETA Associates
Ken Alexander (DFO)	Federal Aviation Administration

Hal Adams	Aspen Avionics
Andrey Anikin	Institute of Aircraft Equipment
Alberto Arredondo	The Aerospace Corporation
John Ashley	The MITRE Corporation
Laurent Azoulai	Airbus
James Behmer	The Aerospace Corporation
Denis Bouvet	Thales Group
Mats Brenner	Honeywell International, Inc.
Kevin Bridges	Federal Aviation Administration
Deane Bunce	Federal Aviation Administration
Rick Cassell	Systems Enginuity, Inc.
Barbara Clark	Federal Aviation Administration
Jed Dennis	NAVTAC
Yi Ding	Esterline CMC Electronics
Dee Ann Divis	Inside GNSS
Pierre Durel	European GNSS Agency
Philippe Estival	Ecole Nationale de l'Aviation Civile
Didier Flament	European Space Agency
John Foley	Garmin Ltd.
JoAnn Ford	Federal Aviation Administration
Michael Hall	The MITRE Corporation
Matt Harris	The Boeing Company
Adrian Hiliuta	Esterline CMC Electronics
Victor Iatsouk	Russian Federal Space Agency (ROSCOSMOS)
Barry Irwin	The MITRE Corporation
Robert Jackson	Lockheed Martin Corporation

Sai Kalyanaraman	Rockwell Collins, Inc.
Julien Lapie	ASECNA
Vladimir Latev	Universal Avionics Systems Corp.
George Ligler	Project Management Enterprises Inc.
Yutaka Marukawa	Japan Radio Air Navigation Systems Association
Harold Moses	RTCA, Inc.
Masaru Naruoka	Japan Aerospace Exploration Agency (JAXA)
Shinichi OCHIAI	Japan Radio Air Navigation Systems Association
John Owen	Defence Science Technology Laboratory (DSTL)
Darrell Pennington	Air Line Pilots Association
Nathalie Ricard	European GNSS Agency
Catalina Rodriguez	European Space Agency
Abdel Nasser Santanna	EGNOS Africa Joint Programme Office
John Savoy	Honeywell International, Inc.
Karl Shallberg	ZETA Associates
Oleg Skubiy	Navis
John Studenny	Esterline CMC Electronics
Dale Swanson	The MITRE Corporation
David Thomas	European Space Agency
Hans Trautenberg	European Aviation Safety Agency (EASA)
Toshiaki Tsujii	Japan Aerospace Exploration Agency
Monica Vafiades	U.S. Air Force
A.J. Van Dierendonck	AJ Systems
Karen Van Dyke	US Department of Transportation
Kyle Wesson	ZETA Associates
Ammyanna Williams	Federal Aviation Administration
Lu Xiaochun	National Time Service Center
Rui Xue	Aviation Data Communication Corporation
Tin Ying	U.S. Air Force
Li Ziji	Aviation Data Communication

The agenda for the meeting was as follows:

1. Chairman's Introductory Remarks.
2. Approval of Summary of the Ninety- Third Meeting held March 20, 2015, RTCA Paper No. 076-15/SC159-1037.
3. Review Working Group (WG) Progress and Identify Issues for Resolution.
 - a. GPS/3rd Civil Frequency (WG-1)
 - b. GPS/WAAS (WG-2)
 - c. GPS/GLONASS (WG-2A)
 - d. GPS/Inertial (WG-2C)
 - e. GPS/Precision Landing Guidance (WG- 4)
 - f. GPS/Airport Surface Surveillance (WG-5)
 - g. GPS/Interference (WG-6)
 - h. GPS/Antennas (WG-7)
4. Review of EUROCAE Activities.
5. Response to EASA – Deviation Request ETSO-C145c – Review

6. SC-159 Terms of Reference – PMC approved June 18, 2015 - Review
7. Briefing - FAA GNSS Intentional Interference and Spoofing Study Team (GIISST)
8. Assignment/Review of Future Work.
9. Other Business.
10. Date and Place of Next Meeting.
11. Adjourn.

 In accordance with the Federal Aviation Advisory Committee Act, Ken Alexander, Federal Aviation Administration (FAA), was the designated Federal Employee for this meeting.

Agenda Item 1. Chairman’s Introductory Remarks.

- At the suggestion of Co-Chairman Chris Hegarty, attendees introduced themselves.
- Harold Moses, Program Director of RTCA, discussed RTCA’s membership policy.

Agenda Item 2. Approval of Summary of the Ninety- Third Meeting held March 20, 2015, RTCA Paper No. 076-15/SC159-1037.

The summary was approved with the following revised summary of Agenda Item 5:

Agenda Item 5. Review/Approve Response to Questions 1-3 from FAA’s GPS Adjacent-Band Compatibility Study Methodology and Assumptions

- The WG-6 co-chairs presented the draft response from the working group and the Plenary reviewed the document section-by-section for approval.
- LightSquared raised objections about the review process, in particular from their perspective (1) the short duration and pace of the review process, (2) the applicability of the 6 dB safety margin during operations, (3) and the lack of ability to review substantive new material introduced by the chair the day before the final work session. LightSquared subsequently requested that WG-6 reconvene in two weeks to provide WG- 6 participants more time to review the study and response.
- At the suggestion of the FAA and RTCA Co-Chairs, the Plenary concluded that it would invite LightSquared to provide a minority opinion/response to RTCA by April 3, 2015 that will be attached to the WG-6 response approved at the Plenary. The minority response will not be reviewed by WG-6 or the Plenary.
- The Plenary approved the WG-6 response with a few minor changes.

Agenda Item 3. Review Working Group (WG) Progress and Identify Issues for Resolution.

a. GPS/3rd Civil Frequency (WG-1)

- WG-1 was disbanded in October 2012, and there is no activity to report.

b. GPS/WAAS (WG-2) (Co-chairs: John Studenny and Laurent Azoulai)

- A FAA Wide Area Augmentation System (WAAS) update was provided by Deane Bunce. His presentation discussed WAAS LPV coverage, WAAS GEO 5/6/7 activities, dual-frequency multi-constellation capability (DFMC), Advanced RAIM (ARAIM), and current airports with WAAS LPV/LP Instrument Approaches in the U.S.
- An ESSP presentation on EGNOS Performance and LPV Status was provided by Nuria Blanco. The presentation discussed EGNOS current APV-I availability, performance, and ionospheric

monitoring improvements for EGNOS Release ESR 2.4.1M. The LPV-200 service availability, continuity, and performance were discussed: 280 approaches were targeted to be published by the end of 2015.

- An EGNOS Status was provided by Nathalie Ricard that detailed new EGNOS capabilities. The estimated EGNOS V3 entry in operations date is 2022. The DFMC SBAS MOPS is needed as input to develop EGNOS V3. She noted that “Aviation DFMC SBAS Receiver Prototype” GSA tender 2015/S 149-274502 was published on July 23rd, 2015.
- Comments on SBAS PRN list expansion were provided by Jason Burns.
 - The current list of PRN allocated for SBAS satellites contains 19 numbers (DO229D, Appendix A, Table A-1) PRN 120 to PRN 138
 - Only 3 PRNs are currently unallocated (as of Sep. 2015)
 - However, 3 PRNs are already allocated outside the original list preventing their use with existing avionics
 - GAGAN (PRN 139) and SDCM (PRNs 140 and 141)
 - New SBASs under development already exceed the available 3 PRNs
 - ICAO Navigation System Panel concluded in April 2015 that there is need for urgent action
 - NSP/1 recommends RTCA and EUROCAE manufacturers to commit themselves to only sell new avionics that will use the expanded list of PRNs after a specified date in the near future
 - Laurent provided the summary of WG-2’s views:
 - Updates to receivers in the field will be cost prohibitive unless mandates are issued by states
 - WG 2 open to update DO-229 with PRN expansion (would only affect future equipment post MOPS publication), but a number of steps need to be completed before that can happen
 - Complete study validating the max number of PRNs needed for the foreseeable future
 - Complete impact assessment of MOPS and propose requirements changes
 - SBAS and GNSS Providers need to validate if the max number of PRNs are limited by cross correlation interference between L1 C/A PRNs.
 - SBAS Providers should need to consider whether sharing of PRNs between providers is possible
 - Using same PRN in different regions – work need to investigate and identify new requirements/constraints
- A clarification of MOPS DO-229D Appendix T (GPS-GEO bias) was provided by Frederic Bauer.
 - Paper discussed problems with regard to how the tool addresses new GEO characteristics and how it is checked by receivers
 - Expressed wish to have the GEO bias tool evolve
 - WG-2 believes it is taken into account in UDRE and that enough margin is allocated for the future GEOs
 - GEO bias tool should only evolve with a new version of the MOPS
 - Post meeting: GEO bias data as part of a TSO application package are not submitted to FAA thus FAA has no means to rerun the tool for new GEOs
 - Proposal for an alternate smoothing filter to reduce ionosphere divergence
 - Could be introduced in a future version of the MOPS
- Kevin Bridges (FAA) and Barbara Clark (FAA) discussed a note related to IPP equations that will be introduced in the next revision of the MOPS.

- Kevin Bridges (FAA) and James P. Fernow (MITRE) offered clarifications for DO-229D based on questions received from a receiver manufacturer.
 - A EUROCONTROL presentation on ICAO GNSS CONOPS was provided by Paco Salabert.
 - DFMC Con Ops are in a state of discovery.
 - Clearly identifiable DFMC benefits to major airspace users (airlines for example) to existing airspaces remain to be identified.
 - DFMC Con Ops remains focused on “engineering” and “technology” and should put more emphasis on end-user benefits.
 - WG-2 recommendation: refocus on major end-user DFMC benefits (we understand the technology).
 - A DFMC SBAS Definition Document Status and SBAS ICD was provided by Jed Dennis of NAVTAC.
 - IWG identified work items:
 - Create DFMC definition Document
 - Create SBAS L5 ICD
 - A-RAIM versus SBAS integrity
 - GLONASS second frequency “L3” not L5 is an issue
 - Beidou is largely unknown (L?)
 - Technical L1 & L5 specifications have started
 - Remark: Focusing on developing a solution PRIOR to identifying the “problem that needs to be solved” – the “end-user benefits” over what is available today. Not clear what has to be stressed or focused on.
 - A presentation on User equipment classes for the DFMC MOPS was provided by James P. Fernow of MITRE.
 - A presentation on DFMC MOPS basis was provided by John Studenny of Esterline CMC Electronics. He discussed:
 - MOPS Introduction and Rationale
 - Receiver filtering sensitivity and noise tolerance
 - Satellite Failure Modes and “Evil Waveforms”
 - Integrity: RAIM, ARAIM, Augmented GNSS
 - DFMC Fallback Modes, SBAS, and GBAS
 - Spoofing: threat space, false alarms, mitigations
 - Constellation Use/Don’t Use criteria and Integrated All-In-View (or not)
 - International GNSS Issues
 - MOPS Structure and Equipment Classes
 - **Action Item** (Chris Hegarty): Coordinate with EUROCAE Working Group 62 on Galileo assumptions and brief the result at at the next SC-159 Plenary meeting in March 2016.
 - **Suggestion**: SC-159 leadership develop a plan to coordinate our TOR with other groups to include SC-227, SC-213, SC-229, and SC-186 to ensure their input to the DFMC MOPS effort in a timely manner
 - WG-2 will meet 1.5 days during the week of the next SC-159 meeting.
- c. **GPS/GLONASS (WG-2A)** (Chair: Victor Iatsouk)
- Background of GPS/GLONASS MOPS development:
 - Fourth SC-159 draft MOPS presented
 - New SC-159 TOR – to develop “New MOPS for GPS/GLONASS (FDMA + antenna) L1-only airborne equipment”
 - Target date – March 2016
 - Review of preliminary comments on previous drafts (MITRE, Thales, Boeing, Rockwell-Collins)

- General (page-by-page) review of Draft 4 and identification of concerns to be addressed
- Additional – LightSquared proposal for new antenna/interference mask for GPS/GLONASS FDMA L1 MOPS
- FRAC-like tables reviewed and noted
- MOPS Draft 4 review at the meeting deemed inefficient and alternative follow-up action agreed
- Issues discussed in particular:
 - RAIM functionality (system-specific vs crossed)
 - LightSquared antenna proposal (to be studied by GLONASS experts taking account of WG-7 developments)
 - Interference mask alternatives (system-specific vs integrated)
- New requirements (jamming, spoofing mitigation)
- Committee members to be invited to comment on Draft 4 by 30 November 2015 (comments to be sent as shown at the MOPS front page)
- Draft 5 and FRAC-like tables to be produced using comments for presentation at next WG-2A
- SC159-95 Plenary will be requested to recommend for formal FRAC procedure subject to TOR requirements
- WG-2A will consider inclusion in the draft MOPS of one acceptable means for integrity calculations.
- WG-2A will meet for one day during the week of the next SC-159 meeting.

d. GPS/Inertial (WG-2C) (Co-chairs: Kevin Bridges and Mats Brenner)

- The meeting started with a refresher on the new WG-2C efforts and PMC approved goals by Kevin Bridges
- This was followed by a scintillation update from JAXA
 - Gradient of 850 mm/km has been observed and discussed in the ICAO IGM Ad-hoc Team
 - JAXA made adjustments to their depletion bubble model to find out what parameters would need to be modified to explain such large gradients
 - A change of the wall thickness (TEC transition zone) from 30 to 15 km with standard activity based on the NeQuick model yielded gradients of that size
- The second presentation from JAXA looked at the impact of the trajectory on the attitude accuracy and illustrated the inability of the low grade integration to improve heading in straight and level flight
- Later in the meeting it was concluded that we would use this information to establish models for testing the impact of scintillation (repeated loss of lock) and frequent abrupt delay changes caused by depletion bubbles.
 - Sub-group formed to define these models for incorporation into the MOPS
- Mats gave a presentation summarizing the result from the WG-2C telecon in September regarding the TSO label related class notation
 - Concluded that goal for testing was to have one set of tests used for all classes (using different parameter sets); Testing to include velocity, attitude, heading
 - Concluded that we to start with could write separate set of requirements for the different classes and reduce the number of sets later if they turned out to be the same; Base each category requirements section on Appendix R structure
 - Concluded that sub-categories (i.e., 0, 1, 2) apply to all categories.
- Mats gave presentation on ionosphere storm testing (WAAS data versus Stanford model)
- Jim Doty's presentation on flight test data based testing
- Decided to include dual antenna based heading determination as an aiding option (complementing the magnetometer) for low grade sensor based integrated systems
 - A sub group was formed develop these requirements

- NG Litef (Klaus Blatter) presented Litef’s current view on Monte Carlo testing
- Ohio U (Michael Braasch) provided an overview of their simulation and flight test capabilities related to inertial integration
- Mats presented some slides that explained the CDF based bounding used in GBAS and SBAS
- Michael Braasch took an **action** to summarize problems with the use of the mix of fault modes currently specified in Appendix R for testing
- Reviewed Appendix R descriptions for applicability as MOPS appendices and will continue monthly telecons
- WG-2C will meet for 2.5 days during the week of the next SC-159 meeting.

e. GPS/Precision Landing Guidance (WG-4) (Chair: Joel Wichgers)

- The Plenary thanked Dean Rudy for many years of service of Vice Chair of WG-4.
- The Plenary nominated and confirmed Matt Harris of Boeing to be co-chair of WG-4.
- Short Term Work Products:
 - Revise RTCA GPS/LAAS Airborne MOPS (DO-253 rev. C to D)
 - Revise RTCA GPS/LAAS Interface Control Doc. (ICD) (DO-246 rev. D to E)
- Longer Term Work Products
 - Revise RTCA GPS/LAAS Airborne MOPS Requirements
 - Revise RTCA GPS/LAAS Interface Control Doc. (ICD) Requirements
- Please see the WG-4 summary on the RTCA workspace for further details of the meeting and for access to the individual presentations.
- WG-4 plans to meet 2.5 days during the week of the next SC-159 meeting.

f. GPS/Airport Surface Surveillance (WG-5)

- There has been no activity since the last meeting.

g. GPS/Interference (WG-6) (Chair: Sai Kalyanaraman)

- The Plenary thanked Bob Erlandson for many years of service as Co-Chair of WG-6.
- Presentation on Pulse Blanking and Suppression
 - Questions raised at Eurocae WG-62 about pulse blanking/suppression needs
 - Clarifications on pulse blanking / suppression provided
 - Needs for pulse blanking vs suppression re-affirmed
- Presentation on L5 Interference Observations
 - L5 pulse blanking observed at ground reference stations indicate higher than expected interference (25-30% pulse blanking)
 - Most likely caused from DME multipath reflections above the detection threshold but not yet confirmed
 - HNL DME adjacent to runway so aviation receivers would likely experience similar pulsed environment
 - Flight test results with G-III show 50% or greater blanking at altitude consistent with earlier work of Harrisburg “hot spot”
 - Without pulse blanking functionality degradations would be much greater (but amount not currently quantified)
- Presentation on C/A on C/A Interference
 - Results currently being reviewed – Effective $I_{o,C/A}$ peaks up to -196.3 dBW/Hz
 - Work could drive changes in DO-235 allocation for self-interference and impact CNR margins
 - This will be brought forth to WG2 and WG4 once the assessment is finalized
- Actions:
 - Assess DME Multipath impacts on L5 pulse blanking

- Schedule and scope for DO-235 Update
- Schedule and scope for DO-292 Update
- Iridium – GPS Isolation
- **Action Item:** The FAA was requested to provide further information about the amount of DME interference in the future.
- WG-6 plans to meet for a half day during the week of the next SC-159 meeting.

h. GPS/Antennas (WG-7) (Co-chairs: A. J. Van Dierendonck and Sai Kalyanaraman)

- RTCA SC159 Working Group 7 jointly developing Airborne Antenna MOPS with EUROCAE
 - To include standards for GPS L5/Galileo E5a
 - With objective for operation with legacy L1 receivers as well as with new L1/L5 receivers
 - To address limitations in the existing DO-301 MOPS
 - Upgrade L1 requirements to minimize gain and group delay variations versus azimuth
 - Aim is to obtain better antenna response at 5 degrees elevation
- Agenda during recent WG7 meeting:
 - Antenna group delay variations across Az and El
 - Tighter antenna and interference mask proposal from LightSquared
 - Investigate asymmetric performance of patch antenna for L5 band
 - G/T discussions for L1/E1
- Please see the WG-7 summary on the RTCA workspace for further details of the meeting and for access to the individual presentations.
- WG-7 plans to meet for a half day during the week of the next SC-159 meeting.

Agenda Item 4. Review of EUROCAE Activities.

- Laurent Azoulai gave updates on EUROCAE activities (EUROCAE WG-28 and WG-62-39).
- Please access the presentations on the RTCA workspace for further details.

Agenda Item 5. Response to EASA – Deviation Request ETSO-C145c – Review

- The Plenary reviewed the response previously provided by members of SC-159 through WG-2 to EASA and determined that the response was sufficient to close the action.

Agenda Item 6. SC-159 Terms of Reference – PMC approved June 18, 2015 – Review

- The new SC-159 TOR was shown at the Plenary.
- It was suggested that DO-253 and DO-246 would take an additional year to complete.
- It was suggested that the GPS/GLONASS MOPS would take an additional six months to complete.
- **Action Item:** (SC leadership) to coordinate these date changes with the PMC.
- Please access the TOR on the RTCA workspace for further details

Agenda Item 7. Briefing - FAA GNSS Intentional Interference and Spoofing Study Team (GIISST)

- Ken Alexander (FAA) gave a presentation on the work of the GIISST.
- Please access the presentation on the RTCA workspace for further details.

Agenda Item 8. Assignment/Review of Future Work.

Agenda Item 9. Other Business.

Agenda Item 10. Date and Place of Next Meeting

The next meeting of RTCA SC-159 will be during the week of March 7th, 2016 at RTCA Headquarters. The proposed meeting schedule is as follows:

	March 7 (Monday)	March 8 (Tuesday)	March 9 (Wednesday)	March 10 (Thursday)	March 11 (Friday)
WG-1 (3 rd civil frequency)					
WG-2 (GPS/WAAS)	1 st day @ 9:00 a.m.	2 nd day (half) @ 9:00 a.m.			
WG-2A (GPS/GLONASS)		1 st day (half) @ 1:00 p.m.	2 nd day (half) @ 9:00 a.m.		
WG-2C (GPS/Inertial)		1 st day @ 9:00 a.m.	2 nd day @ 9:00 a.m.	3 rd day (half) @ 9:00 am	
WG-4 (GPS/Precision Landing)		1 st day (half) @ 1:00 p.m.	2 nd day @ 9:00 a.m.	3 rd day @ 9:00 a.m.	
WG-5 (Airport Surface Operations)					
WG-6 (Interference)				Half day @ 1:00 p.m.	
WG-7 (Antenna)				Half day @ 9:00 a.m.	
Plenary Session					One day @ 8:30 a.m.

The subsequent meeting will be during the week of October 17th, 2016.

-S-
Kyle Wesson
Secretary

CERTIFIED as a true and accurate summary of the meeting

-S-
Christopher Hegarty
Co-chairman

-S-
George Ligler
Co-chairman