

*Summary of the One Hundredth Meeting*

**Special Committee 159**

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

The one hundredth meeting of SC-159 was held March 16<sup>th</sup>, 2018 at RTCA Headquarters, 1150 18<sup>th</sup> Street NW, Suite 910, Washington, D.C. 20036. The attendees were the following:

Christopher Hegarty (Co-Chairman)	The MITRE Corporation
George Ligler (Co-Chairman)	Project Management Enterprises Inc.
Karan Hofmann (Program Director)	RTCA
Ken Alexander (DFO)	Federal Aviation Administration (FAA)
John Savoy (Secretary)	Honeywell International, Inc.
<b>NAME</b>	<b>COMPANY</b>
Hamza Abduselam	Federal Aviation Administration (FAA)
Shiva Anand	The MITRE Corporation
Ken Ashton	Nu-Approach Ltd
Laurent Azoulai	Airbus
John Barry	Federal Aviation Administration (FAA)
Mats Brenner	Honeywell International, Inc.
Denis Bouvet	Thales Group
Rick Cassell	Systems Enginuity, Inc.
Barbara Clark	Federal Aviation Administration (FAA)
Loic Davain	Safran Electronics & Defense
Jed Dennis	NAVTAC (Exempt)
Dee Ann Divis	Inside GNSS (Media)
Pierre Durel	European GNSS Agency
Santann Dutter	Ligado Networks
John Foley	Garmin Ltd.
Masashi Giho	Civil Aviation Bureau of Japan
Alain Guillet	Airbus
Matt Harris	The Boeing Company
Victor Iatsouk	Consultant
Robert Jackson	Lockheed Martin Corporation
Sai Kalyanaraman	Rockwell Collins, Inc.
Yutaka Marukawa	Japan Radio Air Navigation Systems Association
Hal Moses	Citizen
Takeshi Ono	Japan Radio Air Navigation Systems Association

NAME	COMPANY
Timothy Padden	U.S. Air Force
Ajay Parikh	Ligado Networks
Andrew Roy	Aviation Spectrum Resources, Inc.
Bernald Smith	Soaring Society of America
Geoff Stearn	Ligado Networks
John Studenny	Esterline CMC Electronics
Dale Swanson	The MITRE Corporation
Francois Tranchet	Airbus
Hans Trautenberg	European Aviation Safety Agency (EASA)
Joel Wichgers	Rockwell Collins, Inc.
Jim Williams	JHW Unmanned Solutions LLC
Tin Ying	U.S. Air Force

The agenda for the meeting follows:

1. Introductory Remarks: DFO, RTCA and Co-Chairs
2. Approval of Summaries of Previous Meetings
  - a. Ninety-Ninth Meeting held October 27, 2017, RTCA Paper No. 012-18/SC159-1067.
3. Final Review and Comment (FRAC) activities
  - a. DO-235() Update
  - b. GNSS L1/L5 Antenna MOPS
4. Review Working Group (WG) Progress and Identify Issues for Resolution.
  - a. GPS/WAAS (WG-2)
  - b. GPS/GLONASS (WG-2A)
  - c. GPS/Inertial (WG-2C)
  - d. GPS/Precision Landing Guidance (WG- 4)
  - e. GPS/Interference (WG-6)
    - i. Discussion regarding taking draft DO-292 revision into Final Review and Comment (FRAC)
  - f. GPS/Antennas (WG-7)
5. Review of EUROCAE Activities and Discussion of Joint Activity with EUROCAE on a Dual-Frequency, Multi-Constellation GNSS Receiver MOPS
6. Update on ICAO/Navigation Systems Panel Dual Frequency/Multi Constellation Concept of Operations (CONOPS)
7. Discussion of Terms of Reference Updates
8. Action Item Review
9. Assignment/Review of Future Work
10. Other Business
11. Date and Place of Next Meeting
12. Adjourn

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 In accordance with the Federal Aviation Advisory Committee Act, Ken Alexander, Federal Aviation Administration (FAA), was the Designated Federal Official for this meeting.  
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Note that, with the agreement of the chairmen and other participants, the agenda was reordered to accommodate the availability of certain participants. The order in the minutes below reflects the actual sequence of topics.

**Agenda Item 1. Chairman’s Introductory Remarks.**

- At the suggestion of Co-Chairman Chris Hegarty, attendees introduced themselves.
- Ken Alexander read a statement indicating that this Advisory Committee meeting is open to the public, that notice of the meeting was published in the Federal Register and that members of the public may present written or oral statements with the permission of the committee chairmen and program director.
- Karan Hofman, Program Director of RTCA, discussed RTCA’s proprietary references policy and committee participation membership policy.
- All attendees were present in person.

**Agenda Item 2. Approval of Summaries of Previous Meetings.**

- a. The summary for the 99<sup>th</sup> meeting, RTCA Paper No. 012-18/SC159- 1068, had not been reviewed by the chairmen at the time of the meeting. Pending their review, the summary would be posted and the minutes approved at the next meeting.

**Agenda Item 3. Final Review and Comment (FRAC) activities.**

- a. DO-235() Update

Chris Hegarty reminded the committee that DO-235 was discussed during the previous meeting. He indicated that, as the document continued to remain on schedule for release this fall, the committee would not discuss the matter further.

- b. GNSS L1/L5 Antenna MOPS

Sai Kalyanaraman reviewed the working group’s progress towards the closure of the FRAC for the L1/L5 Antenna MOPS. Sai noted that, with the cooperation of the FAA, George Ligler and some receiver manufactures, the committee was able to receive feedback from several antenna manufacturers. With this data, most open issues have been resolved.

Nevertheless, the requirements regarding selectivity continue to be debated. Two separate antenna selectivity masks have been proposed. While it seems clear that multiple antenna manufacturers feel confident that they can manufacture the less stringent of the two proposed antenna, Mask 1, it is not clear that the more stringent requirements of the other mask, Mask 2, are equally manufacturable. A single antenna vendor asserts that Mask 2 is achievable. Another antenna manufacturer recommended against approving Mask 2, but neither confirmed nor denied their ability to comply with the proposed standard. There was some concern that the antenna manufacturer supporting Mask 2 might have insufficient understanding of the development of avionics to make such a claim, but this concern was allayed through further discussion. It was recognized that a small additional delay might allow one or more additional antenna vendors to provide more complete feedback regarding the proposed mask.

The group further discussed the possibility of accepting a mask that was different from either Mask 1 or Mask 2. The group noted that there would be impacts on other studies.

The final decision was to elicit further feedback from the antenna vendors. To facilitate this additional feedback, the European and U.S. regulators were asked to accept and anonymize data from the disparate vendors. The feedback was to be limited to only the question of selectivity and **all other MOPS questions are to be considered closed.**

The committee agreed to hold a special plenary to approve the final MOPS with the selected selectivity mask on 2018 May 3, 10-12 EST via WebEx.

#### **Agenda Item 4a. Review GPS/WAAS Working Group (WG 2) Progress and Identify Issues for Resolution.**

Laurent Azoulai, co-chairman for working group 2, discussed the progress made during the week.

- Working groups 2 and 4 met throughout the week to make common progress on the new dual frequency, multi-constellation MOPS. There were four themes for the joint meetings.
  - SBAS and core constellation program status and maintenance of DO-229
  - DF/MC SBAS MOPS work plan
  - Discussion of EUROCAE WG-62 DF/MC SBAS MOPS requirements
  - ICAO DF/MC concept of operations
- Laurent indicated that in his presentation to the SC-159 plenary, he would try to restrict comments to only pertinent information and that interested parties should find additional information on the RTCA WG-2 workspace.
- Jed Dennis gave a presentation regarding WAAS status, which showed that coverage of the LPV-200 functionality remains excellent. Jed had discussed the fact that 2 replacement WAAS satellites were under development with a third in the procurement process. A total of 4527 procedures have been published. Over 99,000 aircraft are equipped with WAAS in the NAS. Finally, Jed indicated that delays in the GPS-III development will, in turn cause delays in the transition from L2 to L5. This transition is now expected to occur no sooner than 2026.
- Pierre Durel briefed the working group on the current status of EGNOS. With four satellites on orbit (two as test or backup) and 40 monitoring stations as far south as North Africa, availability of the LPV-200 capability is very good. Pierre further discussed EGNOS v3 development. Airbus Defense and Space will be has been awarded a contract to develop EGNOS v3. EGNOS v3 services are to be introduced in two increments. The first increment will focus on backward compatibility with enhancements to ionospheric modeling as well as the use of both GPS and Galileo. The second increment will include both L1/E1 and L5/E5a corrections for both GPS and Galileo. Laurent stressed that the current development of the receiver MOPS by EUROCAE will play an important role in the development of the future SBAS systems and that RTCA should take care to provide guidance in an effort to ensure future capabilities meet expectations. EGNOS will switch from SBAS message type 27 to message type 28. The working group noted that the schedule for DFMC SBAS SARPS is very aggressive with a goal to provide a SBAS

SARPS by the end of 2018. The group also noted the misalignment between the RTCA and EUROCAE development schedules for the DFMC MOPS.

- Mashashi Giho gave a presentation to the working group regarding the development of MSAS. JCAB is currently developing an LPV capability to be released in MSAS V3 in approximately 2023. Specification of the LPV capability will take place in 2018-2019 with development beginning in 2020. The working group was shown material that indicates, as in other regions, increasing adoption of SBAS functionality, in general, as well as interest in LPV. The working group discussed the use of SBAS satellites in inclined orbits rather than geostationary orbits broadcasting at L5. Concerns were raised regarding the implications of such orbits to the Doppler offset of signals from those satellites, additional interference that may not have been included in the DO-235 assessment as well as PRN assignments. Finally, the working group was informed of the results of experiments in the use of a DFMC SBAS prototype developed by Japan. QZS-2,-3 and -4 have been used to broadcast SBAS data at L5 since August of 2017.
- Robert Jackson discussed the use of SBAS in Australia and New Zealand. Cost Benefit studies are currently underway. Efforts to introduce SBAS in this region have led to the discovery of several new issues. Authentication of SBAS data is very desirable, but proposed authentication methods remain immature. It is unlikely that the proposed protocols will be sufficiently mature in time to be included in the ICAO SARPS at the end of the year. There are also proposals to update the SARPS to include more detail regarding non-ranging geostationary satellites. Finally, there is a desire to use a variant of SBAS Message Type 27 to define the SBAS service volume.
- Stefan Wallner and Enrico Spinelli presented the current Galileo status to the working group. Currently, there are 22 satellites in orbit and there is a procurement effort underway to acquire an additional “8+4” satellites. The system is providing “initial services”, which includes good availability and measurements that, while not up to final standards, allow for the computation of position information. Measurement accuracy continues to improve. Support for safety-of-life applications continues to be an important priority for the Galileo Program. As a result, there is a work plan in place to gather the information necessary for standardization. This includes the information requested by SC-159 for the creation of MOPS.
- Olivier Julien gave a presentation to the joint working group regarding the evolution of the L1 interference mask. Of concern was how this mask was defined in DO-235, how readers of that document interpret or misinterpret that information and how the lessons learned can be applied to the development of the L5 interference mask. Oliver Julien agreed to present suggested changes to DO-235 for review by the working group.
- Jed Dennis posed several questions to SC-159 on behalf of the ICAO NSP. These included a proposal to increase the number of bits used in the SBS Service Provider ID field, a question regarding the need to differentiate between L1 and L5 SBAS procedure types, and a question regarding the expectations of manufacturers for the coherence of the code and carrier portions of SBS signals. The view of the working group is that backward compatibility is necessary when answering the first two questions. Code-carrier coherency should be addressed through the ICAO SARPS review process.
- Hans Trautenberg raised a suggestion from EASA regarding the use of different environmental performance tests for different types of equipment. For example a transponder integrating the GPS function may not require the full demonstration of

performance under all environmental conditions. The working group generally declined to re-evaluate the required testing for other equipment.

- Laurent Azoulai summarized for the working group efforts by the SC-159 “drafting group” to provide feedback to the ICAO DFMC concept of operations. Laurent suggested that this was the most important part of the meeting representing the opportunity for equipment manufacturers to define what equipment they wish to provide. This feedback must be complete prior to the completion of the CONOPS activity in Fall of 2018.
- Two separate discussions regarding ADS-B parameters highlight the need for SC-159 and SC-186 to coordinate in the definition of requirements for future GNSS receivers. J. P. Fernow discussed apparent fluctuations in the velocity reported by some ADS-B equipment and proposed some methods by which this “jitter” could be reduced. There was additional discussion regarding the “integrity” of velocity parameters. Barbara Clark proposed some requirements addressing parameters that are consumed by ADS-B equipment that are not necessarily required by the MOPS. The working group believes that SC-186 should formally request SC-159 to coordinate any required changes. The SC-159 plenary session discussed the Inter-Special Committee Coordination process and Karan Hofmann agreed to discuss the issue with the SC-186 program director.
- Pierre Durel raised a concern that the ICAO SARPS for Galileo, Beidou and SBAS L5 are under development and are expected to be complete by the end of 2018. These SARPS are a primary input into the RTCA MOPS and as such, working group 2 must review the proposed material prior to its acceptance. EUOCAE has already reviewed this material and provided feedback, with not significant concerns or issues. RTCA has not yet provided this feedback. The working group would like for Barbara Clark to act as the liaison between the FAA and ICAO to ensure that the RTCA members have an opportunity to actively participate in the SARPS development.
- Denis Bouvet discussed the differences between EUROCAE draft DFMC SBAS MOPS and proposals made at RTCA. Of particular interest was the interrelationship between the ICAO SARPS and the MOPS and in particular the definition of the signal-in-space Interface Control Document.
- Denis Bouvet also raised questions concerning the required mode transitions during initial acquisition. Is it appropriate to allow a single frequency/single constellation or is it necessary to have multiple GNSS constellations in use? Denis also asked to committee to provide rationale for DO-229E navigation alerts. There is some question as to whether these requirements remain appropriate for the DFMC MOPS. Manufacturers have provided feedback for both of these issues, but there is currently no consensus.
- Ed Williams and Deane Bunce discussed a proposal for an SBAS service message that would clearly define the service boundaries of an SBAS provider. The intent is to provide an unambiguous demarcation between adjacent service providers and to control the liability of a provider whose broadcast footprint may be significantly larger than the service regions. This new message would be an evolution of the existing message type 27. It was noted that ICAO had not yet agreed to support this message.
- The joint working group had also intended to discuss a concept of operations for Advanced Receiver Autonomous Integrity Monitoring, however, they were not able to have that discussion. Laurent noted that, as with the DFMC Concept of Operations,

RTCA was given the opportunity to comment on the work done. RTCA feedback was received and incorporated in the ICAO work.

- The joint working group discussed the production of the DFMC MOPS. The combined group feels that a coordinated effort by both EUROCAE and RTCA will be required. Both working groups further concur that the initial multi-constellation MOPS will include ONLY GPS and Galileo signals due to the relative immaturity of the Beidou and CDMA GLONASS signals. There remains an inconsistency between the EUROCAE and RTCA working groups regarding the completion dates of the MOPS. EUROCAE has set a target date of 2020 for the final validated version of the MOPS. RTCA believes this date is too aggressive and that an initial MOPS to be used for validation would be available by 2020 and that a validated MOPS that could be used for certification would be available no sooner than 2022. The RTCA working groups have a short-term objective to review the draft EUROCAE MOPS so that it can be approved by December of 2018 to enable further development of EGNOS v3.
  - During the plenary session, Denis Bouvet commented that EUROCAE will have 3 meetings this year to mature their current draft of the MOPS. It would not be appropriate for RTCA to review the version of the MOPS available at this time (March 2018). Instead, a formal review should be begun by mid-September and would be expected to take 5 weeks, with comment resolution beginning in November. Victor Iatsouk asked for clarification about the development of integrity algorithms. Denis responded that some information to form the integrity requirements is not yet available and so integrity requirements development has been postponed. ICAO is expected to approve  $P_{const}$  and  $P_{sat}$  methodology.

**Agenda Item 4b. Review GPS/GLONASS Working Group (WG 2A) Progress and Identify Issues for Resolution.**

Working Group 2A chairman, Victor Iatsouk, is retiring. The working group is currently inactive and Chris Hegarty recommended that a new chairman be selected only when the group is reactivated. This was generally accepted.

**Agenda Item 4c. Review GPS/Inertial Working Group (WG 2C) Progress and Identify Issues for Resolution.**

Mats Brenner, chairman of WG 2C, presented the current status of that group.

- The working group was continuing to develop performance standards for GNSS-aided inertial systems. This included systems utilizing less accurate Attitude Heading Reference Systems (AHRS) or Micro-Electro-Mechanical systems (MEMS) sensors. Drafts of much of this work was completed prior to this plenary.
- The group has been meeting for some time and the current draft contains sections 1 and 2, including introductory text, requirements and testing guidance as well as drafts of appendices A through P.
- Since October, the working group has been focused on addressing changes requested by the FAA, as well as the resolution of MOPS draft comments.
- During this week, the group planned to focus on the review of material adapted from the current appendix R of DO-316.

- Since the previous plenary session, the working group held a series of 6 teleconferences to address the following topics:
  - Updates of the test methodology of appendix M to reflect the new coasting requirements in section 2
  - Updates of appendix N to include speed changes and terminal area maneuvers
  - Updates of scintillation statistics
  - A new example integration method was added to appendix F
  - Review and updates to appendix B (sensor testing)
  - The formation of a new subgroup to coordinate with the FAA on RNP topics.
  - The specification of ranges for “claimed” velocity and attitude performance parameters
  - The working group had extensive discussions concerning the use of a filtered “horizontal exclusion level” to replace HPL. Mats noted that this was significantly different from the approach taken in DO-229, DO-253 and DO-316.
  - Updates of appendix P to separate position coasting performance claims from claims regarding velocity and attitude related parameters
  - More specific requirements on data collection during environmental testing to quantify sensor performance
  - Tests for depletion bubbles and scintillation were added
  - Changes to section 1 to reflect new FAA objectives
  
- The Japanese Aerospace Exploration Agency (JAXA) presented interim results from studies concerning ionospheric depletion bubbles and their expected effects on GNSS tracking. Data collected in southern Japan, although not as severe as that seen in Brazil was nevertheless sufficient to cause a predicted loss of lock as frequently as once every 40 seconds. In an effort to achieve sufficiently conservative requirements, the group continues to search for additional data regarding the large plasma bubbles observed in Brazil.
  
- The working group spent significant time discussing the application of advisory circulars addressing RNP and RNP AR to the “coasting” of GNSS and GNSS-aided inertial systems during the unavailability of RAIM or GPS position. These AC both support coasting of GNSS data when HPL parameters meet certain conditions. The RNP AR AC also provides for coasting when preflight predictions determine that the HPL should be sufficiently low but the GNSS capability is lost. There is a potential opportunity to improve RNP and RNP AR availability by exploiting potential outputs from an integrated system. The working group would like to coordinate with SC-227 to ensure that this improvement can be exploited.
  
- Ohio University presented findings from studies of the EGM 2008 gravity model. These findings are expected to be published at the upcoming IEEE PLANS conference and address a number of questions posed by the working group including maps of areas with large deflections, maps of areas with large spatial gradients, and stochastic processes bounding the error introduced by different truncation levels. Because the computation of the gravity model is so computationally intensive, the working group asked Ohio University for additional help to determine the errors would be observed if the parameters of the model were to be precomputed and stored as a database. Alternatively, there may

be some value in using a gravity model with a lesser degree of complexity that can be computed in real time.

- The working group reviewed several requirements modifications in several sections of the draft
  - The definition of qualified AHRS types for the integration of legacy systems not compliant with DO-334.
  - The definition of a “fault-free” protection level that can optionally be used to support ADS-B
  - The specification of what data must be collected during environmental tests to support inertial sensor modeling was moved to the error model section of the MOPS
  - Environmental requirements and tests for any added hardware to host integration function will refer to DO-334 environmental requirements and tests
- The working group discussed the relative merits of using the International Reference Ionosphere, the NeQuick ionospheric model and the Klobuchar ionospheric model for testing. The group remains convinced that the IRI model should be required for all testing.
- Working group 2C discussed the requirements for various inertial aiding sources, which are to be captured in appendices J, K and L.
  - Magnetometer attitude and heading requirements are in place and reviewed
  - Pressure altitude aiding requirements are derived from DOO-316, appendix G. WG-2C was not familiar with these requirements and will need more time to complete this section
  - Dual-antenna based heading aiding is in a very raw stage. The group needs more time to discuss what may be published
    - The plenary discussed the fact that this particular functionality remains very proprietary. Karan Hoffman reiterated the RTCA policy regarding the inclusion of intellectual property. Barbara Clark pointed out that these IP issues can add several months to MOPS development schedules.
    - George Ligler specified the requirements for including proprietary data
      - The working group needs to define exactly what proprietary data will included in the document for the PMC
      - The working group needs to ensure that any examples conform completely to the RTCA policy
      - The working group needs to give every participant an opportunity to provide other examples
      - Inclusion of proprietary material, even in a normative manner, requires the permission of the material copyright holder. This is l
- The working group considered the testing for response to ionospheric depletion bubbles. There were two test methods to be included in the MOPS; one using CDF bounding and the other using Monte Carlo simulation. As mentioned previously, the group is aware of some, presumably extreme events that took place in Brazil that were significantly more extreme than events observed in other places. The working group would like to use a model with 99.9% bounding, but to achieve this needs more data.

- The MOPS now includes a test for the continuity of functionality during scintillation events. The group does not believe that integrity is an issue as scintillation will only cause losses of measurement data rather than corruption.
- The working group declined to introduce C/N<sub>0</sub> monitoring as the errors in the carrier measurements were too small to require remediation.
- Finally, the working group introduced the testing of FOM-based coasting using a variety of potential aircraft trajectories. Tests for HPL-based coasting remain in development.
- Mats summarized the status of the blended GNSS inertial MOPS development.
  - Completion is scheduled for min-2019
  - Has much material in support of the MOPS but there is concern that the full implication of the new text will be fully understood in a shorter timeframe.
  - The group plans to continue meeting via telecom and to solicit additional data from Brazil.

#### **Agenda Item 4d. Review GPS/Precision Landing Guidance (WG 4) Progress and Identify Issues for Resolution**

Joel Wichgers, co-chairman for working group 4, discussed the activities of that group.

- Joel began with a discussion of the current status of working group 4 work products
  - The group is working to update DO-253D to include new requirements to ensure that VDB equipment is sufficiently resistant to interference from navigation aids such as ILS or VOR assigned in adjacent frequency bands. This includes changes to section 2.2, the test procedures of section 2.5 as well as Appendix K. The working group is coordinating with the ICAO NSP and, assuming that the ICAO NSP will adopt changes to the SARPs addressing the adjacent channel compatibility in fall of 2018, the working group plans to release DO-253E in March of 2019.
  - Similar to DO-253, DO-246 would also require updates to several notes in Appendix B to support the adjacent channel compatibility requirements. Again, pending the approval of the ICAO NSP of SARPs changes in fall of 2018, DO-246E would be released in March of 2019.
- Joel went on to discuss the plans for future updates to WG 4 documents.
  - The group plans to complete initial development of a dual-frequency, GPS-Galileo MOP in approximately 2020-2021. The intent is to trail the development of the working group 2 SBAS MOPS by one year to allow the working group resources to remain focused on the SBAS MOPS.
  - Working group 4 would develop a new MOPS and ICD. The group has not decided whether DO-253 would be further updated or a new document developed from scratch. The group does plan to update DO-246 with dual-frequency, multi-constellation changes. There is no intent to update the current MASPS.
  - The goal is for the group to have a validated GPS/GBAS MOPS and ICD by 2022-2023, again trailing the development of the working group 2 SBAS mOPS by one year.

- Joel noted the dependency of the GBAS specification on ICAO NSP work products and indicated that if the ICAO specifications are delayed, so too would be the working group 4 work products.
- Joel briefly touched on the joint meeting between working group 2 and 4 and declined to provide additional discussion of the topics addressed there and already discussed in plenary. Joel did reiterate the joint working group commitment to ensuring that the SBAS and GBAS work products remain consistent.
- Working group 4 did spend some time working GBAS specific issues and Joel summarized that effort.
  - The working group intends to increase the requirement for the VDB receiver to resist so-called desired to undesired (D/U) by an additional 14 dB while continuing to meet the current message failure rate requirements. A second set of requirements would require the VDB to tolerate still greater D/U but would allow the message loss rate to increase by two orders of magnitude. This modification greatly reduces the constraints on siting of ILS and VOR stations at the same airports utilizing GBAS stations. The intent is that current GAST C operations can be handled under all conditions, while GAST D operation may require the temporary deactivation of near-by ILS signals to ensure the continuity of that function.
  - Joel showed a slide that summarized the various use cases the working group considered when deriving these new requirements.
- Joel discussed work done by Rick Cassel to consider the impact of the inclusion of VDB message type 11 on the continuity of GAST D operations. The working group accepted Rick's findings that this effect does not negatively impact the continuity of the GAST D operation.
- During the working group's discussions of D/U signals, it was found that one case that could not be reconciled occurred "at those locations where there is an ILS facility that serves the opposite end of a runway with a GBAS approach" in which case the emissions from the localizer antenna array were very powerful as the aircraft flew directly overhead at low altitude. To address this, the working group proposed changes to the SARPs to require that the localizer be disabled during GBAS approaches, primarily GAST D, when interference might result. This is similar to current requirements to disable the localizer at the opposite end of the runway when conducting a CAT II or CAT III ILS approach.
- Joel mentioned that the working group considered a minor error in table 2-26 of DO-246 and referred interested parties to the presentation which would be stored in the working group workspace on the RTCA website.
- Joel again noted that the working group intends to seek approval of the previously described changes in March of 2019.
- Barbara Clark informed the working group that the FAA is planning to update AC 20-138 to incorporate updates regarding the installation of VDB antenna. Support material for this AC update will be included in Appendix K of the DO-253 MOPS.
- Joel noted that working group 4 considered, with working group 2, section 6 of the draft ICAO concept of operations for dual-frequency, multi-constellation receivers.
- Joel concluded with a summary of the work plan, to continue virtual meetings to complete changes to the VDB requirements for the March 2019 release. He noted that working papers would be available at the RTCA workspace.

- Andrew noted that the ICAO Spectrum Working Group has additional work to complete regarding guidelines for adjacent frequencies and that this work would take into account both the efforts of working group 4 and the ICAO NSO to address VDB compatibility.

**Agenda Item 4e. Review GPS/Interference (WG 6) Progress and discussion issues regarding taking DO-292 into the final review and comment process**

Sai Kalyanaraman, discussed the Working Group efforts during the week.

- Working group 6 considered the impact of adding additional SBAS PRN codes to be used for IGSO SBAS satellites on the L5 channel only.. The working group will need to perform a detailed analysis but an initial assessment based on ITU-R M.1831 indicates that there would be little impact. The working group had a discussion regarding how PRN numbers may be assigned to satellites. There is an implicit assumption by manufacturers that a PRN code will only be broadcast by a single satellite on any frequency. However, this assumption is not actually required. There is a desire to address that.
- The working group had some recommended changes for DO-253.
  - Include a justification for the “satellite acquisition” interference mask. The committee is well aware of why this mask is 6 dB below the “steady-state navigation” mask, but it is not necessarily clear to those attempting to use the mask to define policy.
  - Consider redefining the interference mask in two parts, non-aeronautical interference and a maximum allowed interference for components on board the aircraft. This will help inform regulators and policy makers when determining the tolerance to outside interference.
  - Re-evaluate the whether continuous wave interference cases are consistent with the notion of equivalent  $N_0$ .
- Working group 6 also reviewed the results of a study of the effects similar Doppler offset and different signal power on carrier tracking accuracy. That is, when a “victim” satellite has similar Doppler offset to another satellite whose signal is received at a higher power level, how is the carrier tracking impacted. This was done using data collected from the WAAS Reference Stations. The study showed a very clear correlation between carrier error and the relative power difference between the two signals. By contrast, there was no correlation to the offset in Doppler frequency, for up to 5 kHz of separation. However, errors observed were on the order of 2 mm. This information should be fed back into the Critical Satellite, link-budget assessment.
- Sai indicated that the working group would continue to meet throughout coming month, to close the review and comment process for DO-235 by the October 2018 SC-159 meeting. The group will begin work on DO-292 in July 2018 with plans to complete the document in time for the March 2019 SC-159 meeting.

**Agenda Item 4e. Review GPS/Antennas (WG 7) Progress**

Building on the earlier discussion, Sai Kalyanaraman, discussed the Working Group plan to meet during the following week to finalize the antenna manufacturer survey questionnaire.

Chris Hegarty asked the assembled plenary session to formally approve moving the proposed DO-235 document into the final review and comment process and this motion was unanimously approved.

Sai reaffirmed that only the interference mask was subject to further efforts and that the rest of the document was to be accepted as is.

#### **Agenda Item 5. Review of EUROCAE Activities and Discussion of Joint Activity with EUROCAE on a Dual-Frequency, Multi-Constellation GNSS Receiver MOPS**

Laurent Azoulai noted that he had not received any briefing from the current interim chairman of EUROCAE Working Group 28. Hans Trautenberg informed the plenary that the next meeting of WG 28 would take place the week of March 23<sup>rd</sup> in Brussels.

Pierre Durel presented an overview of the activities of EUROCAE WG62 during their 44<sup>th</sup> meeting.

- Pierre gave the EUROCAE web address noting that one must ask permission for access. <https://www.eurocae.sharepoint.com>
- The next meeting times for Working Group 62 have been set as
  - Jun 25-29, 2018, in Toulouse
  - September 11 -13, 2018 in the Czech Republic (location to be confirmed)
  - December 3-7 2018 in Paris
- Working Group 62 made little progress during the Galileo Open Service ad-hoc session, deferring work on the “default” ionospheric correction model for Galileo to June 18<sup>th</sup>.
- Working Group 62 focused primarily on the Multi-Constellation/Multi-Frequency ad-hoc session. The topics discussed include the following:
  - The ICAO GNSS Concept of Operations document, including particularly the “benefits” section.
  - Advanced Receiver Autonomous Integrity Monitoring concept of operations, algorithms, continuity requirements
  - Dual Frequency/Multi-Constellation SARPS, much as was covered during this week at SC-159
  - Frequency of updates of the Galileo F/NAV message
  - Methodology used by SC-159 in the development of the I<sub>GNSS</sub> noise for DO-235 and DO-292
  - Satellite selection
  - Definition of DF/MC modes and the associated transitions with a goal of reducing the complexity of the airborne receiver
  - Mitigation of reuse of the Issue of Data field
  - A proposal for requirements to address ionospheric scintillation errors
  - Requirements addressing cross-correlation and reacquisition
  - Galileo health status requirements
  - A detailed review of requirements addressing week-number roll over count, use of GPS satellites in extended mode and TTA, et cetera.
- Working Group 62 plans to produce an initial Dual-Frequency/Multi-Constellation SBAS GPS-Galileo MOPS by December 2018 focusing on SBAS augmentation for L5 signals

and providing an initial set of test procedures for new requirements for which consensus is reached.

- The group continues to work towards releasing a final DFMC SBAS GPS-Galileo MOPS by the end of 2020.
- Karan Hofmann noted that RTCA participants who are NOT also EUROCAE members who wish to gain access to the EUROCAE website should not claim to be RTCA employees.
- Barbara Clark how WG 62 would proceed with the final definition of the DFMC SBAS GPS-Galileo MOPS if GPS L5 requirements for use in H-ARAIM/FDE mode were not available. Pierre replied that the information might not be available.
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#### **Agenda Item 6. Update on ICAO/Navigation Systems Panel Dual Frequency/Multi Constellation Concept of Operations (CONOPS)**

Chris Hegarty asked for a presentation on the status of the ICAO NSP Dual-Frequency/Multi-Constellation Concept of Operation document. No one at the meeting was able to offer any material and the agenda item was skipped.

#### **Agenda Item 7. Discussion of Terms of Reference Updates**

Chris Hegarty led the committee in a discussion regarding changes to the SC-159 Terms of Reference

- Ken Alexander will step down as Designated Federal Official for SC-159. Barbara Clark will take up that role.
- The leadership of SC-159 and WG 62 participated in a joint phone call in which it was decided in principal that it is desirable for there to be a joint MOPS for GPS/Galileo equipment. Chris noted that, although the prerequisites for a joint MOPS, the “scorecard”, were not yet met, sufficient information was available to begin work.
- George Ligler presented draft text for proposed updates to the SC-159 terms of reference that included both the administrative change of DFO as well as a proposal for a work schedule for a joint DFMC work product.
- There was some discussion surrounding how SC-159 should coordinate with the EUROCAE Technical Advisory Committee, which was to meet during the same week as the RTCA PMC. SC-159 decided to have the plenary session approve the proposed terms of reference, which could then be evaluated by the EUROCAE TAC, prior to approval by the RTCA PMC.
- The committee decided to add only Galileo to both the SBAS and GBAS MOPS. Other constellations would be added later after the Galileo-GPS MOPS was complete.
- The plenary voted to approve the proposed changes to the terms of reference.

#### **Agenda Items 8 and 9. Action Item Review and Assignment/Review of Future Work**

These items were addressed throughout the meeting and were not addressed again.

**Agenda Item 11. Date and Place of Next Meeting**

The 101<sup>st</sup> meeting of RTCA SC-159 was planned take place via teleconference as addressed in agenda item 3b.

The 102<sup>nd</sup> meeting will take place the week of October 1-5<sup>th</sup>, 2018. Working groups 2, 2C, 4, 6 and 7 plan meet throughout the week beginning on Monday with the plenary session on Friday morning.

The 103<sup>nd</sup> meeting will take place the week of March 4-8<sup>th</sup>, 2019.

**Agenda Item 10. Other Business**

There was no further discussion and the meeting concluded.

Margaret Jenny, the RTCA president, came to speak in celebration of the 100<sup>th</sup> meeting of SC-159. She discussed the innovation that SC-159 has driven in aviation and expressed her admiration of the work the group has done over the last 30 years.

Ken Alexander gave a brief presentation showing how GPS procedures have grown over the years. MITRE examined data in a Jeppesen database. In 2007, only 87 geographic regions had approved GPS approach procedures. In 2017, 187 of 193 regions have published GNSS terminal procedures.

Chris Hegarty adjourned the meeting.

-S-  
John Savoy  
Secretary

CERTIFIED as a true and accurate summary of the meeting.

-S-  
Christopher Hegarty  
Co-chairman

-S-  
George Ligler  
Co-chairman