Next-Generation GNSS Avionics Standards and Spectrum Protection

Christopher J. Hegarty

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Overview

- This presentation provides a summary of standardization activities towards next-generation GNSS avionics and spectrum protection.
- GNSS avionics standardization work is primarily conducted within three standards organizations:
  - RTCA, Inc.
  - European Organisation for Civil Aviation Equipment (EUROCAE)
  - International Civil Aviation Organization (ICAO)
- Majority of current civil GNSS avionics are GPS L1 C/A-code only, augmented with one or more of the following:
  - Aircraft-based Augmentation System (ABAS), e.g., receiver autonomous integrity monitoring (RAIM)
  - Satellite-based Augmentation System (SBAS)
  - Ground-based Augmentation System (GBAS)
- Next-generation GNSS avionics will embrace dual-frequency, multi-constellation.
What is RTCA, Inc.?

- Founded in Washington, D.C. as the Radio Technical Committee for Aeronautics in 1935
- Chartered by the Federal Aviation Administration (FAA) to operate Federal advisory committees
- Develops consensus-based standards for aviation systems and recommendations on aviation policies

President Truman presenting Collier Award to RTCA in 1948
What is EUROCAE?

- Non-profit dedicated to aviation standardization since 1963
- Headquartered in Malakoff, France
- Often works jointly with RTCA, and at times publishes joint documents
- Two GNSS working groups (WGs): WG-28 (GNSS), WG-62 (Galileo)

Celebration of A.J. Van Dierendonck’s birthday at WG-62 meeting in Toulouse, November 2014

RTCA-EUROCAE Coordination Meeting, Oct. 2015
What is ICAO?

- ICAO is a specialized agency of the United Nations
  - Established in 1944; headquartered in Montreal
  - Develops international aviation Standards and Recommended Practices (SARPs)

- GNSS SARPs first adopted in 2001
  - First version in Amendment 76 to Annex 10, Vol. 1, to the Convention on International Civil Aviation
  - Many updates, with latest in Amendment 89 (applicable Nov. ‘14)

- Current SARPs address:
  - Two core constellations: GPS and GLONASS (both L1-only)
  - Augmentation systems: Aircraft-based (ABAS), ground-based (GBAS), satellite-based (SBAS), and ground-based regional (GRAS)

- ICAO Navigation System Panel (NSP) is updating SARPs to add CAT II/III GBAS, L5, GLONASS evolution, Galileo, BeiDou
  - Next meeting: Nov-Dec 2015
RTCA Special Committee (SC)-159 on GNSS

Left-to-right SC-159 co-chairs George Ligler and Chris Hegarty, Program Director Hal Moses, WG-2 co-chair Laurent Azoulai, WG-4 chair Joel Wichgers, WG-6 chair Bob Erlandson, WG-6/7 co-chair Sai Kalyanaraman

Leadership not shown:
- Secretary Kyle Wesson
- WG-2C co-chairs Mats Brenner and Kevin Bridges
- WG-4 co-chair Matt Harris

WG-2 co-chair John Studenny
WG-7 co-chair A.J. Van Dierendonck
Designated Federal Official Ken Alexander
SC-159 Organization

SC-159 (GNSS)
Chris Hegarty, Co-chair
George Ligler, Co-chair
Ken Alexander, Designated Federal Official
Hal Moses, Program Director
Kyle Wesson, Secretary

WG-1 (3rd Civil Frequency) (inactive)

WG-2 (SBAS)
John Studenny, Co-chair
Laurent Azoulai, Co-chair

WG-3 (Inertial)
Mats Brenner, Co-chair
Kevin Bridges, Co-chair

WG-4 (GBAS)
Joel Wichgers, Co-chair
Matt Harris, Co-chair

WG-5 (Interference)
Bob Erlandson, Co-chair
Sai Kalyanaraman, Co-chair

WG-7 (Antennas)
A.J. Van Dierendonck, Co-chair
Sai Kalyanaraman, Co-chair

SBAS = Satellite-based Augmentation System
GBAS = Ground-based Augmentation System
### FAA Technical Standard Orders invoking RTCA Standards

<table>
<thead>
<tr>
<th>Equipment</th>
<th>TSO</th>
<th>Invoked RTCA Document</th>
<th>Date First Published</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stand-alone GPS</td>
<td>TSO-C129</td>
<td>DO-208</td>
<td>1992</td>
<td>Cancelled</td>
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<tr>
<td>Stand-alone GPS</td>
<td>TSO-C196</td>
<td>DO-316</td>
<td>2009</td>
<td>Active</td>
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<tr>
<td>Antennas</td>
<td>TSO-C144a</td>
<td>DO-228</td>
<td>1998</td>
<td>Active</td>
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<tr>
<td>Antennas</td>
<td>TSO-C190a</td>
<td>DO-301</td>
<td>2007</td>
<td>Active</td>
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<tr>
<td>GPS/satellite-based augmentation system (SBAS)</td>
<td>TSO-C145</td>
<td>DO-229</td>
<td>1998</td>
<td>Active</td>
</tr>
<tr>
<td>GPS/SBAS</td>
<td>TSO-C146</td>
<td>DO-229</td>
<td>1998</td>
<td>Active</td>
</tr>
<tr>
<td>GPS/ground-based augmentation system (GBAS)</td>
<td>TSO-C161</td>
<td>DO-253</td>
<td>2003</td>
<td>Active</td>
</tr>
<tr>
<td>GBAS VDB</td>
<td>TSO-C162</td>
<td>DO-253, DO-246</td>
<td>2003</td>
<td>Active</td>
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</tbody>
</table>

*The latest revision of TSO-C144 (-C144a) is intended only for new passive antenna models. The latest revision of TSO-C190 should be used for new active antenna models.*

Airborne Equipment Built to SC-159 Standards

Rockwell Collins

Universal Avionics

… and much more! (well over 100,000 certified receivers delivered to date)
Ground Equipment use of SC-159 Standards

WAAS uplink facility in Paumalu, Hawaii

GBAS ground facility
<table>
<thead>
<tr>
<th>Product</th>
<th>Description</th>
<th>Due Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>DO-253D</td>
<td>Updated GBAS MOPS.</td>
<td>March 2016</td>
</tr>
<tr>
<td>DO-246E</td>
<td>Updated GBAS ICD.</td>
<td>March 2016</td>
</tr>
<tr>
<td>GPS/GLONASS L1-only MOPS</td>
<td>New MOPS for GPS/GLONASS (FDMA+antenna) L1-only airborne equipment.**</td>
<td>March 2016</td>
</tr>
<tr>
<td>GNSS-Aided Inertial System MOPS</td>
<td>New MOPS for GNSS-aided inertial navigation systems.</td>
<td>July 2017</td>
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<tr>
<td>DO-235C</td>
<td>Updated L1 interference environment report.</td>
<td>December 2017*</td>
</tr>
<tr>
<td>DO-292A</td>
<td>Updated L5 interference environment report.</td>
<td>December 2017*</td>
</tr>
<tr>
<td>GNSS L1/L5 Antenna MOPS</td>
<td>New GNSS dual-frequency (1575/1176 MHz) antenna MOPS for airborne equipment</td>
<td>December 2017*</td>
</tr>
<tr>
<td>GNSS(SBAS) L1/L5 MOPS</td>
<td>Initial MOPS for Verification and Validation Validated GPS/SBAS MOPS for dual-frequency equipment including, if possible, at least one additional core constellation.**</td>
<td>2019-2020*</td>
</tr>
<tr>
<td>GNSS(GBAS) L1/L5 MOPS</td>
<td>Initial MOPS for Verification and Validation Validated GPS/GBAS MOPS for dual-frequency equipment including, if possible, at least one additional core constellation.**</td>
<td>2020-2021*</td>
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<td></td>
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<td>2021-2022*</td>
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<td>2022-2023*</td>
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Spectrum Protection Activities

- Within aviation standards organizations:
  - RTCA SC-159
    - Work plan includes updates to L1/L5 interference environment assessment documents (DO-235/292)
    - New Terms of Reference calls for new Minimum Operational Performance Standards (MOPS) to address, to the extent practicable
      - Threats of intentional interference and spoofing
      - Possibility of higher levels of adjacent-band interference
    - July 2014 ICAO NSP letters to RTCA and EUROCAE and replies re: repeaters/pseudolites/jammers

- U.S. Department of Transportation’s GPS Adjacent-Band Compatibility Assessment
  - Objective is to develop power limit criteria for transmitters in the bands near GPS/GNSS
  - See http://www.gps.gov/spectrum/ABC/

- U.S. Federal Aviation Administration’s GNSS Intentional Interference and Spoofing Study Team (GIISST)
Summary

- Civil aviation organizations working towards dual-frequency multi-constellation (DFMC) avionics standards
  - Center frequencies of 1575.42 MHz and 1176.45 MHz
  - To the extent possible, GPS, GLONASS, Galileo, and BeiDou + augmentations

- Schedules are not yet fully synchronized; RTCA anticipates:
  - Validated DFMC GNSS/SBAS standards ~2021
  - Validated DFMC GNSS/GBAS standards ~2022

- Spectrum protection remains a concern and activities are underway to mitigate spectrum-related risks
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