SPACEKEYS

Latest Evolution of RAIM Prediction Systems

SPACEKEYS is a project funded by the European Space Agency
Topics

- Rationale
- Requirements
- Objectives
- Results
- Achievements
- Relevant case study
- Roadmap way forward
SPACEKEYS Rationale

As the GPS satellites themselves have evolved over the years, so have the systems that allow operators to take the benefit of satellite navigation. SPACEKEYS presents the ultimate evolution of GNSS RAIM prediction solution for aviation. It provides for worldwide RAIM predictions for all aircraft types and for all navigation and surveillance specifications. SPACEKEYS is a project partly funded by European Space Agency (ESA) under the NAVISP programme (NAVISP EL2-007).

- Airlines
- CAA/ANSPs
- Flight Planning
- Flight Following
- Weather
- Business Jets
- General Aviation

Create competition

Black Box Design
The RAIM solution performs predictions for all currently known receiver types in commercial aviation. This includes receivers compliant with TSO-C129, TSO-C196 and TSO-C145/146. The system is Future Ready For Multi-Constellation Receivers and Advanced Horizontal RAIM.

The following GNSS receiver parameters are supported:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Options</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Algorithm</td>
<td>FD or FDE</td>
<td></td>
</tr>
<tr>
<td>Barometric Aiding</td>
<td>ON, OFF or ON only on Failure</td>
<td>The option „On only on Failure“ provides the user the possibility to apply BA only in case the RAIM prediction resulted in an outage excluding BA. This is only available in the Spacekeys RAIM prediction solution.</td>
</tr>
<tr>
<td>Selective Availability</td>
<td>ON or OFF</td>
<td></td>
</tr>
<tr>
<td>Mask Angle</td>
<td>-25° to 30°</td>
<td></td>
</tr>
<tr>
<td>HAL Multiplier</td>
<td>Any certified value</td>
<td>Some aircraft are certified to apply a horizontal alert limit bias during RAIM predictions.</td>
</tr>
</tbody>
</table>
The RAIM solution performs predictions in compliance with the following navigation specifications. Terrain screening is performed as required for RNP AR predictions.

<table>
<thead>
<tr>
<th></th>
<th>RNAV 10 RNP 10</th>
<th>RNAV 5 Basic-RNAV</th>
<th>RNAV 2 US RNAV Type A</th>
<th>RNAV 1 Precision-RNAV US RNAV Type B</th>
<th>RNP 4</th>
<th>RNP1</th>
<th>RNP Approach</th>
<th>RNP AR Approach</th>
<th>MNPS</th>
</tr>
</thead>
<tbody>
<tr>
<td>FAA (U.S.A.)</td>
<td>AC 90-105A (replaces Order 8400.12C)</td>
<td>AC 90-96A</td>
<td>AC90-100A</td>
<td>AC 90-105A (repl. order 8400.33)</td>
<td>AC 90-105A</td>
<td>AC 90-105A</td>
<td>AC 90-105A</td>
<td>AC 90-101A</td>
<td>AC20-138D</td>
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<tr>
<td>EASA (EU, EFTA and other countries)</td>
<td>AMC 20-12</td>
<td>AMC 20-4 JAA TGL 2</td>
<td>AMC 20-16 JAA TGL 10</td>
<td>AMC 20-16 JAA TGL 10</td>
<td>AMC 20-16 JAA TGL 10</td>
<td>AMC 20-16 JAA TGL 10</td>
<td>AMC 20-27 (LNAV, LNAV/VNAV)</td>
<td>AMC 20-28 (LNAV, LNAV/VNAV)</td>
<td>AMC 20-26</td>
</tr>
<tr>
<td>CASA (Australia)</td>
<td>AC 91U-2(0)</td>
<td>CAAP B-RNAV-1</td>
<td>AC 91U-II-3-B</td>
<td>AC 91U-II-3-B</td>
<td>AC 91U-3(0)</td>
<td>AC 91U-II-3(0)</td>
<td>AC 91U-II-C-5 (LNAV)</td>
<td>AC 91U-II-Attachment (LNAV/VNAV)</td>
<td>AC 91U-II-C-5 (RNP AR)</td>
</tr>
<tr>
<td>SVRSOP (Latin America)</td>
<td>AC 91-001</td>
<td>AC 91-002</td>
<td>AC 91-003</td>
<td>AC 91-003</td>
<td>AC 91-004</td>
<td>AC 91-006</td>
<td>AC 91-008 (LNAV)</td>
<td>AC 91-010 (LNAV/VNAV)</td>
<td>AC 91-009</td>
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<tr>
<td>Transport Canada</td>
<td>AC 700-015</td>
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Requirements (Surveillance)

The RAIM solution performs predictions in compliance with the FAA ADS-B 2020 specification AC90-114A Change 1. As other Worldwide surveillance requirements are developed the system will ensure all requirements are complied with.

Advisory Circular

Subject: Automatic Dependent Surveillance-Broadcast Operations

Date: 3/7/16

Initiated by: AFS-400

AC No: 90-114A

Change: 1

1. PURPOSE. The intent of this advisory circular (AC) is to facilitate operations using Automatic Dependent Surveillance-Broadcast (ADS-B) technology in compliance with Title 14 of the Code of Federal Regulations (14 CFR) part 91, §§ 91.225 and 91.227, which are required after January 1, 2020. The appendices provide guidance for the authorization of additional ADS-B Out and ADS-B In operations and their associated aircraft qualification and maintenance requirements.

2. PRINCIPAL CHANGES. This change incorporates new ADS-B guidance related to a technical amendment to § 91.225; equipping type certificated (TC) aircraft, light-sport aircraft (LSA), and experimental aircraft; and preflight requirements in U.S.-designated airspace. This change also modifies guidance for Cockpit Display of Traffic Information (CDTI) Assisted Visual Separation (CAVS).
Requirements (Surveillance)

AC90-114A Change 1 – Prediction methods:

“Operators of large fleets of aircraft or users of flight planning programs may wish to use their own preflight availability verification tool. The operator is responsible for selecting a tool that accurately predicts the performance for their aircraft. The tool needs to account for the GPS satellites that are in service at the time of the prediction, and may take into account unique characteristics of the GNSS receiver, aircraft integration or installation; including performance better than required in FAA standards or use of inertial information integrated into the ADS-B Out position source. The FAA does not evaluate or approve a particular tool, but may evaluate the basis of the operator's determination that the tool is appropriate to their aircraft, particularly if its use results in noncompliant flights in airspace where ADS-B Out is required.”

Active engagement with VOLPE on validation
SPACEKEYS Objectives

- All Worldwide prediction requirements met, including ADS-B
- Modern System To System APIs
- Sophisticated Web User Interface – including flight plan cut/paste
- Daily Reports – Users Customisable
- File2RAIM – file the ICAO flight plan to us and get a RAIM report
- Dynamic “Just In Time” Terrain Screening for RNP-AR
- RAIM Outage Avoidance During Flight Planning
- Pro-Active Alerting
Achievements

• NAVISP
  • Design, implementation and validation/verification – MTR.

• SPACEKEYS
  • EUROCONTROL Augur.
  • Airlines in Europe, US and Asia.
  • SPACEKEYS sit on US Congressional ADS-B review committee.

• A case study – Europe on October 16th 2018.......a major aviation GPS event never seen in 20 years.
16th October 2018 – The Cause

Notice Advisory to Navstar Users (NANU) No. 2018046:

• Satellite PRN 5 ‘out of service’ from 1305 for 12 hours

SVN50 (PRN05) FORECAST OUTAGE JDAY 289/1305 - JDAY 290/0105 NOTICE ADVISORY TO NAVSTAR USERS (NANU) 2018046 SUBJ: SVN50 (PRN05) FORECAST OUTAGE JDAY 289/1305 - JDAY 290/0105


2. CONDITION: GPS SATELLITE SVN50 (PRN05) WILL BE UNUSABLE ON JDAY 289 (16 OCT 2018) BEGINNING 1305 ZULU UNTIL JDAY 290 (17 OCT 2018) ENDING 0105 ZULU.

15 min or greater 0.3Nm approach
16th October With NANU – SA Unaware

15 min or greater
0.3Nm approach
So Why? – Satellite Movements and GEOMETRY!
What Makes RAIM Outages?

We want good GEOMETRY!
- Different angles between us and the satellites. NOT the same angles.

UERE: User Equivalent Range Error
- Ionosphere
- Clock errors
- Electronics noise
- Multipath
- Troposphere
- Almanac/Ephemeris
Start of 42 Minute RAIM Outage @ Paris CDG
End of 42 Minute RAIM Outage @ Paris CDG
Roadmap

2018
• Algorithm
• APIs
• Web UI
• Scheduled Reports

2019
• NAVISP
  • GALILEO
  • Horizontal A-RAIM
• SPACEKEYS
  • GLONASS
  • COMPASS

2018
• Validation and Verification - MTR
• Launch Customers

Phase 2
• NAVISP
  • GALILEO
  • Horizontal A-RAIM
• SPACEKEYS
  • GLONASS
  • COMPASS

Operation
THANK YOU!

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