GNSS Integrity Technology Development Methodology

Li Rui
Beihang University
Overview & Outline

- Integrity Technology Architecture Analysis
- Integrity Technology Development Propose
- Integrity Monitoring during the Construction of GNSS
Integrity Technology Architecture Analysis

- Integrity: From the **Performance Stability Requirement of Dynamic User for Navigation**
  - SOL Service: Civil Aviation, Railway
  - Reliability Service: ITS, Fishing, Disaster Alarm, ...
Integrity Technology Architecture Analysis

- **GNSS Development Status**
  - With the improvement of clock and ephemeris propagation accuracy, SPS users will enjoy navigation service with accuracy better than 10m;
  - Integrity is under consideration during both the GPS modernization and Galileo design:
    - GPS: URA and UDRA are introduced to ensure navigation accuracy
    - Galileo: SoL service is designed for high integrity requirement users
Integrity Technology Architecture Analysis

- SBAS Development
  - SBAS is designed to provide integrity augmentation service for aviation users
  - WAAS improvement
  - EGNOS and QZSS building
Integrity Technology Architecture Analysis

- Current GNSS Integrity Architecture

<table>
<thead>
<tr>
<th>Requirement Level</th>
<th>Tight</th>
<th>Slack</th>
</tr>
</thead>
<tbody>
<tr>
<td>En Route</td>
<td>RNP 5-20</td>
<td></td>
</tr>
<tr>
<td>Terminal</td>
<td>RNP 1-5</td>
<td></td>
</tr>
<tr>
<td>Departure</td>
<td>RNP 0.3-0.5</td>
<td></td>
</tr>
<tr>
<td>Initial Appr.</td>
<td>RNP 0.3/125</td>
<td></td>
</tr>
<tr>
<td>NPA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>APV-I</td>
<td>RNP 0.3/50</td>
<td></td>
</tr>
<tr>
<td>APV-II</td>
<td>RNP 0.03/50</td>
<td></td>
</tr>
<tr>
<td>CAT-I</td>
<td>RNP 0.02/40</td>
<td></td>
</tr>
<tr>
<td>CAT-II</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CAT-III</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- GPS
  - GPS+RAIM
  - GPS+SBAS
  - GPS+GBAS

- Galileo
  - Galileo
  - Galileo +GBAS
Integrity Technology Architecture Analysis

- The Similarity between System Integrity Service and SBAS Service
  - Space segment error monitoring ability;
  - Reference stations net distributing in wide area.
Integrity Technology Architecture Analysis

- **Integrity Service Development Consideration**
  - Integration Design between System Integrity Service and SBAS Service;
  - Multi-GNSS Compatible and Seamless transition ability;
  - Supporting multiple user requirement
Overview & Outline

- Integrity Technology Architecture Analysis
- Integrity Technology Development Propose
- Integrity Monitoring during the Construction of GNSS
Integrity Technology Development
Propose

- Basic Principle for System Design
  - Reference to relative civil aviation standard (RTCA DO-229D, FAA-E-2892b, ICAO Annex 10, etc.), compatible with current equipment;
  - Augmentation Service Capability of Multi- GNSS System.
Integrity Technology Development Propose

- Future Integrity Service Performance Suggestion
  - GNSS System Integrity Service (SPS users)
    - Broadcast ephemeris & clock accuracy evaluation
    - Capability of global broadcasting
    - Integrity performance – NPA level
  - SBAS Integrity Service (aviation users)
    - Ephemeris, clock and ionosphere correction and confidence information
    - Capability of Wide Area Augmentation
    - Integrity performance-CAT I level
Integrity Technology Development Propose

- **Global Integrity Service Consideration**
  - Capability of global service;
  - Assess user requirement, confirm reasonable service performance;
  - The interoperation with GPS, GALILEO, *etc.*;
  - Reference station optimizing distribution for global integrity service;
  - Feasibility of inter satellite links.
Integrity Technology Development

Propose

- **SBAS Service Consideration**
  - Capability of wide area augmentation;
  - Capability of multi-GNSS compatible augmentation service;
  - Seamless transition with current system (WAAS, EGNOS, etc.);
  - Taking full advantage of GEO, IGSO and LEO satellite communication recourse;
  - Taking full advantage of ground communication recourse such as VHF, Internet, etc.
Overview & Outline

- Integrity Technology Architecture Analysis
- Integrity Technology Development Propose
- Integrity Monitoring during the Construction of GNSS
Integrity Monitoring during the Construction of GNSS

- GNSS Development Stage:
  - Test Stage, Basic Construct Stage, Enhance Stage, Architecture Construct Stage
- BeiDou: Basic Construct Stage
- Galileo: Test Stage
- Similar Problem During GNSS Construction:

Solution:
Integrate with other navigation method, ensure user integrity by RAIM
Integrity Monitoring during the Construction of GNSS

- Integrate with INS

<table>
<thead>
<tr>
<th>Operation</th>
<th>GPS</th>
<th>BeiDou Demonstration System</th>
</tr>
</thead>
<tbody>
<tr>
<td>En-Route</td>
<td>✅</td>
<td>✅ Major Error</td>
</tr>
<tr>
<td>Terminal</td>
<td>✅</td>
<td>✅ Major Error</td>
</tr>
<tr>
<td>NPA</td>
<td>✅</td>
<td>✅ Major Error</td>
</tr>
</tbody>
</table>
Integrity Monitoring during the Construction of GNSS

- Integrate with accomplished GNSS

<table>
<thead>
<tr>
<th>Constellation Configuration</th>
<th>GPS Only (24 SVs)</th>
<th>BeiDou Demonstration System + GPS</th>
<th>BeiDou Regional Coverage Constellation + GPS</th>
</tr>
</thead>
<tbody>
<tr>
<td>RAIM Availability</td>
<td>96.38%</td>
<td>99.94%</td>
<td>100%</td>
</tr>
</tbody>
</table>
THANK YOU!