GNSS.Asia India – Industry Workshop

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Indian SBAS System - GAGAN
GAGAN

• **GPS Aided GEO Augmented Navigation (GAGAN)** is India’s regional Satellite Based Augmentation System (SBAS)

• India is working towards attaining
  - APV 1 capability over the entire Indian land mass.
  - RNP 0.1 capability over the entire Indian FIR.

• The footprint of the GAGAN space segment covers large portion of the Asia-Pacific region.

• The neighboring countries can derive benefit of the Indian experience to provide SBAS services by appropriately augmenting ground segments.
GAGAN implementation - Teams

1. Supply of Selected GAGAN Ground Elements
2. Installation, Integration, & Testing of GAGAN System

AAI

ISRO

Raytheon
GAGAN Implementation

• The GAGAN Project is being executed jointly by ISRO and AAI.

• GAGAN is implemented in two Phases:
  – Technology Demonstration Systems (GAGAN TDS) phase has been completed in 2007
  – Final Operations Phase (GAGAN FOP) has commenced in 2009 and is nearing completion.
GAGAN TDS Phase

• **The objective**
  - To demonstrate feasibility of SBAS implementation over Indian region with minimum set of elements
  - To study the ionosphere over the Indian region & to collect data for system development and necessary modifications for the Indian region for the Final Operational Phase

• **Implementation**
  - Completed with 8 Indian Reference Stations, One Master Control Station and One Land Uplink Station
**GAGAN – TDS Configuration**

### Indian Reference Stations (INRES)

- Jammu
- Delhi
- Ahmedabad
- Bangalore
- Trivandrum
- Kolkata
- Guwahati
- Port Blair

### Sub-System Configuration

<table>
<thead>
<tr>
<th>#</th>
<th>Sub-System</th>
<th>Qty</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>INRES</td>
<td>8</td>
</tr>
<tr>
<td>2</td>
<td>INMCC</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>INLUS</td>
<td>1</td>
</tr>
<tr>
<td>4</td>
<td>DCN</td>
<td>1</td>
</tr>
<tr>
<td>5</td>
<td>GEO</td>
<td>1</td>
</tr>
<tr>
<td>#</td>
<td>Parameter</td>
<td>Requirements</td>
</tr>
<tr>
<td>----</td>
<td>-----------------------------------</td>
<td>-----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>1</td>
<td>Vertical and Horizontal Accuracy</td>
<td>&lt; 7.6m (95% of time)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Within the perimeter of the GAGAN-TDS INRES during nominal ionospheric conditions</td>
</tr>
<tr>
<td>2</td>
<td>Time-to-Alarm</td>
<td>&lt; 6.2 Sec.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Using MT 62</td>
</tr>
<tr>
<td>3</td>
<td>GEO ranging capability</td>
<td>Demonstration Using MT 9</td>
</tr>
<tr>
<td></td>
<td>- Clock Steering</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>GEO ranging capability</td>
<td>Evaluation Using Recorded data</td>
</tr>
<tr>
<td></td>
<td>- Code Carrier Coherence</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>SBAS Receiver Demonstration</td>
<td>Lock to GAGAN PRN &amp; Process GAGAN –TDS Messages</td>
</tr>
</tbody>
</table>

In TDS phase no Integrity and Level of service requirement
GAGAN FOP Phase Objective

• To provide a certified satellite based navigation system for all phases of flight by augmenting the TDS system suitably

• To provide redundancies, Implement Suitable region specific IONO model, Get safety Certification for the system for the Civil Aviation use from DGCA, the regulatory authority in India.
GAGAN FOP

Realize a certified and operational SBAS to provide air navigation services of
- RNP 0.1 en route navigation within India FIR
- APV-1/1.5 precision approach over landmass of Indian FIR

Common coverage of GAGAN GEO satellites (GSAT-8, GSAT-10) is beyond Indian FIR

GSAT-8 launched on 21-May’11. *Signal-In-Space available since 15-December-2011*

GSAT-10 launched on 29 Sep’12. Integration activities with INLUS-2 are in progress

GSAT-15 is planned to launch in 2015 as an In orbit spare.

Compatible and Interoperable with other SBAS to provide Seamless navigation
GAGAN FOP Configuration

BSAT-15
GSAT-15 In-orbit Spare

GSAT-10
PRN 128

GSAT-8
PRN 127

GSAT

INRES # 1 - 15
INMCC - 1
INMCC - 2

DATA Communication Network - 1
Data Communication Network - 2

INLUS-1
1SG 1RF

INLUS-2
1SG 1RF

INLUS-3
1SG 1RF

INLUS

Bangalore

Delhi

Backup to INLUS 1/2

Bangalore

PRN 127

PRN 128

Bangalore

PRN 128

PRN 127

Bangalore

PRN 128

PRN 127

Bangalore

PRN 128

PRN 127

Bangalore
Data communication Network comprising of four Communication Links
Two terrestrial Links
&
Two Satellite based links

GAGAN SITES

INLUS

INMCC

INRES
GAGAN GEO COVERAGE

GSAT-8 – 55° E (PRN 127)
GSAT-10 – 83° E (PRN 128)
<table>
<thead>
<tr>
<th>Service Level</th>
<th>Parameters</th>
<th>Requirement</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>RNP 0.1</td>
<td>1. Availability</td>
<td>&gt;99 % over the Indian FIR</td>
<td>&gt;99%</td>
</tr>
<tr>
<td></td>
<td>2. Horizontal Accuracy</td>
<td>&lt;72 m 95% bound</td>
<td>0.7m Average</td>
</tr>
<tr>
<td></td>
<td>3. Vertical Accuracy</td>
<td>N/A</td>
<td>1.52m Average</td>
</tr>
<tr>
<td></td>
<td>4. Time to Alarm</td>
<td>10 s</td>
<td>6.2 s</td>
</tr>
<tr>
<td></td>
<td>5. Vertical Alert Limit</td>
<td>N/A</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>6. Horizontal Alert Limit</td>
<td>185.2m</td>
<td>&lt;185 m</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>APV1/1.5</td>
<td>1. Availability</td>
<td>99% over 76% of India</td>
<td>86.57%</td>
</tr>
<tr>
<td></td>
<td>2. Horizontal Accuracy</td>
<td>&lt;7.6 m 95% bound</td>
<td>0.7m Average</td>
</tr>
<tr>
<td></td>
<td>3. Vertical Accuracy</td>
<td>&lt;7.6 m 95% bound</td>
<td>1.51m Average</td>
</tr>
<tr>
<td></td>
<td>4. Time to Alarm</td>
<td>6.2 s</td>
<td>6.2 s</td>
</tr>
<tr>
<td></td>
<td>5. Vertical Alert Limit</td>
<td>50 m</td>
<td>VPL&lt;50</td>
</tr>
<tr>
<td></td>
<td>6. Horizontal Alert Limit</td>
<td>40 m</td>
<td>HPL&lt;40</td>
</tr>
</tbody>
</table>
Path Forward …..

- Installation & Testing 3rd INLUS at Delhi
- Hazard Analysis & database updation
- Integration of 3rd INLUS at Delhi with GSAT-8
- Static and Dynamic testing & System Performance Analysis
- Operation & Maintenance of GAGAN System
- O T & E Tool Development
- Development of SBAS Procedures
- Regression and Stability Testing
- HMI analysis Certification Process
- System Commissioning
GAGAN Future Plans

- Installation of INRES stations outside India to expand the GAGAN services to the neighboring countries.
- Installation of additional INRES stations to enhance the system performance.
- Installation of Third INMCC to provide geographical diversity.
- Interoperability with neighboring SBAS for seamless Navigation
GAGAN Benefits

• Safety
  – GAGAN provides India with a sovereign means to monitor GPS.
  – Improved situational awareness via low cost SBAS capable avionics. Nominal vertical accuracy is 2-2.5m (95%).
  – SBAS 3D precision guidance can reduce landing accidents 7-fold *
  – Higher accuracy, integrity, continuity and availability for both navigation and ADS-B surveillance
  – GAGAN provides seven 9’s of integrity (probability of a hazard 1 in 10 million per approach).
GAGAN Benefits

- **Capacity**
  - Improves availability of RNP RNAV routes, enabling safe reduction in aircraft spacing.
  - Offloads major airports by providing all weather operations at secondary airports.
  - Covers all routes and airports within a region – not limited by VHF broadcast station range.
GAGAN Benefits

- **Efficiency**
  - Enables optimum routes independent of ground navaids
  - Low incremental cost to expand regional system into new areas
  - No new equipment required at airports to benefit from GAGAN
  - Reduces navigation system operating costs
  - GAGAN is ICAO compliant and compatible with aircraft equipped for EGNOS, MSAS and WAAS.
GAGAN Benefits

- Economic Growth
  - Makes all weather air services available to more communities
  - GAGAN signal is compatible with non-aviation receivers with applications to farming, surveying and vehicle navigation.
  - Several million SBAS capable receivers currently in use
  - Enables many new multimodal precise navigation applications
Thank You

Redefining Navigation