



## **System Development - GAGAN**

**GBAS/SBAS Implementation Workshop  
Seoul, 3-5 June 2019**

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- 1. Evolution of GAGAN**
- 2. GAGAN Certification & System Performance Monitoring**
- 3. Challenges in GAGAN implementation**
- 4. GAGAN coverage and scope of GAGAN services expansion**
- 5. AAI new initiative - GMS (GAGAN Message Service)**

# **GAGAN**

## **[ GPS Aided GEO Augmented Navigation ]**

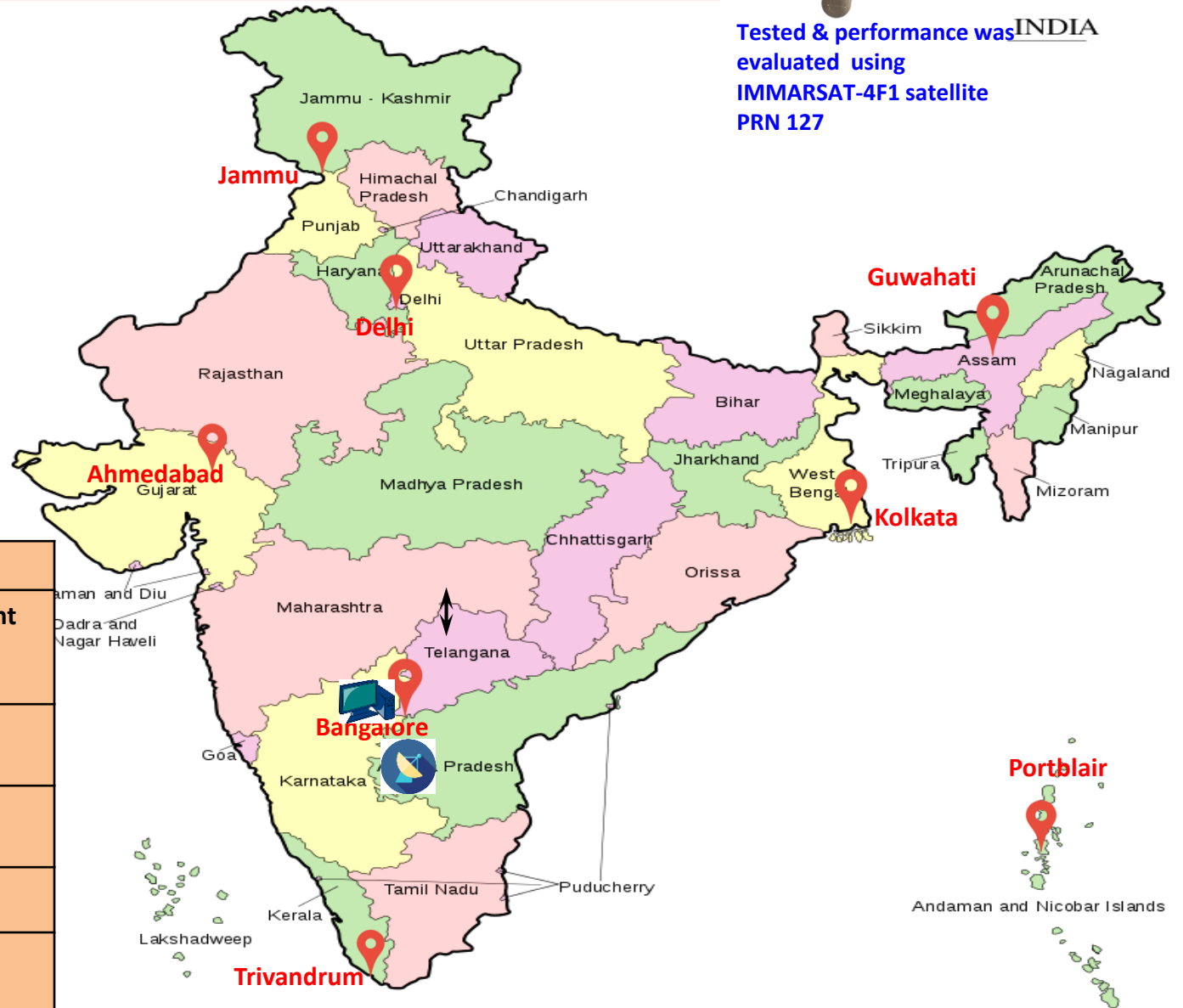
- **GAGAN is an India's Regional Satellite Based Augmentation System (SBAS).**
- **GAGAN is a Joint Program of AAI & ISRO started in the year 2002.**
- **GAGAN Provides correction messages to GPS L1 Signals and corrections are broadcasted through three Indian GEO Satellites.**
- **Developed in a phased manner building the architecture incrementally.**
- **Certified signals of GAGAN are available continuously from 2013 for RNP 0.1 operations over the Indian FIR and for APV I operations from 2015 over more than 76% of Indian land mass on nominal days.**





# GAGAN – TDS Configuration: 2004-2007

To demonstrate the proof of concept over Indian Region by deployment of minimum set of elements



Tested & performance was evaluated using **INDIA** **IMMARSAT-4F1** satellite PRN 127



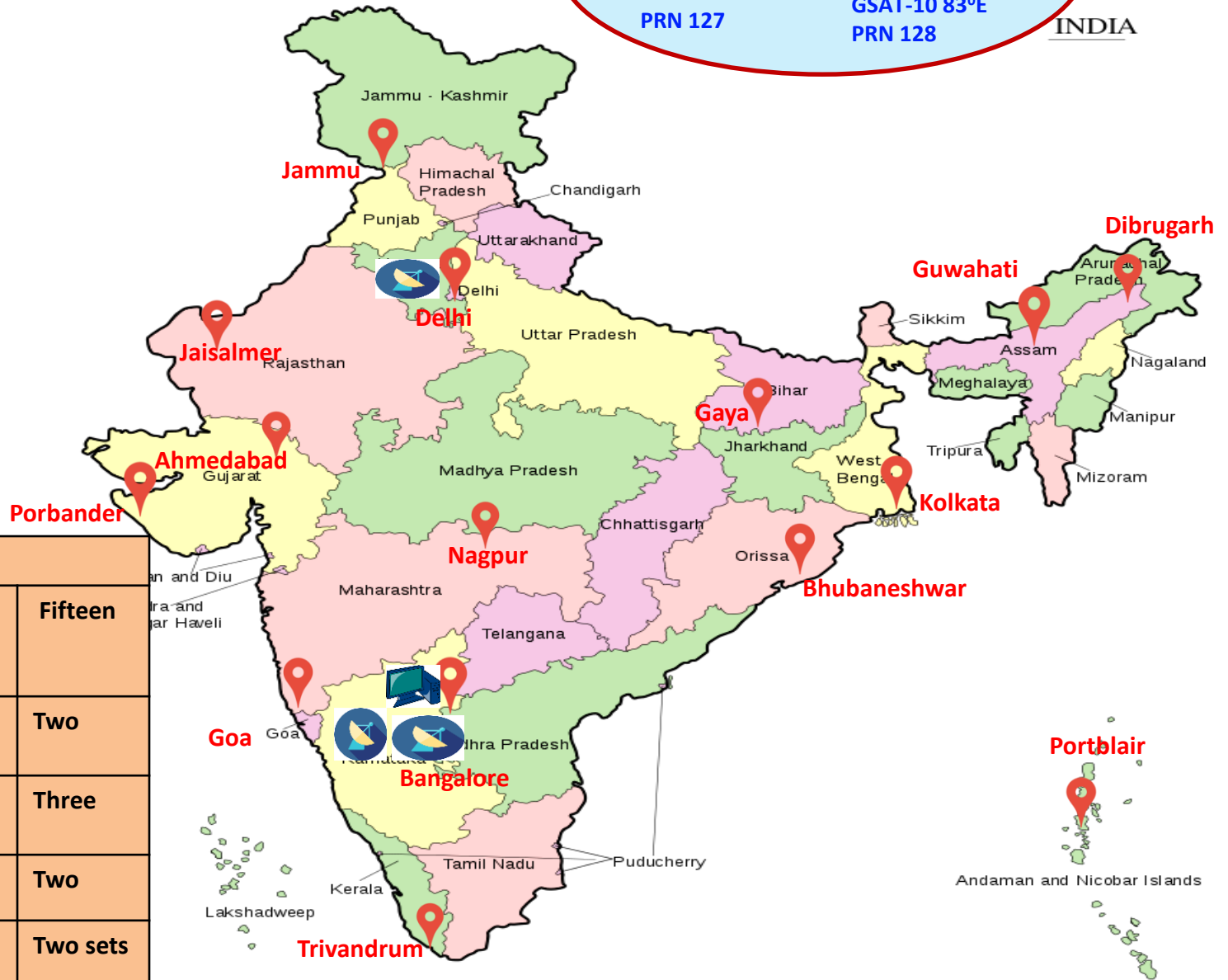
Sub Systems		
	Reference stations (INRES) with 2 chains	Eight
	Master Control Center (INMCC)	One
	Ground uplink station (INLUS)	One
	GEO	One
	Data links	One set

# GAGAN – FOP Configuration: 2009-13






## Certified for RNP 0.1 & APV I operations



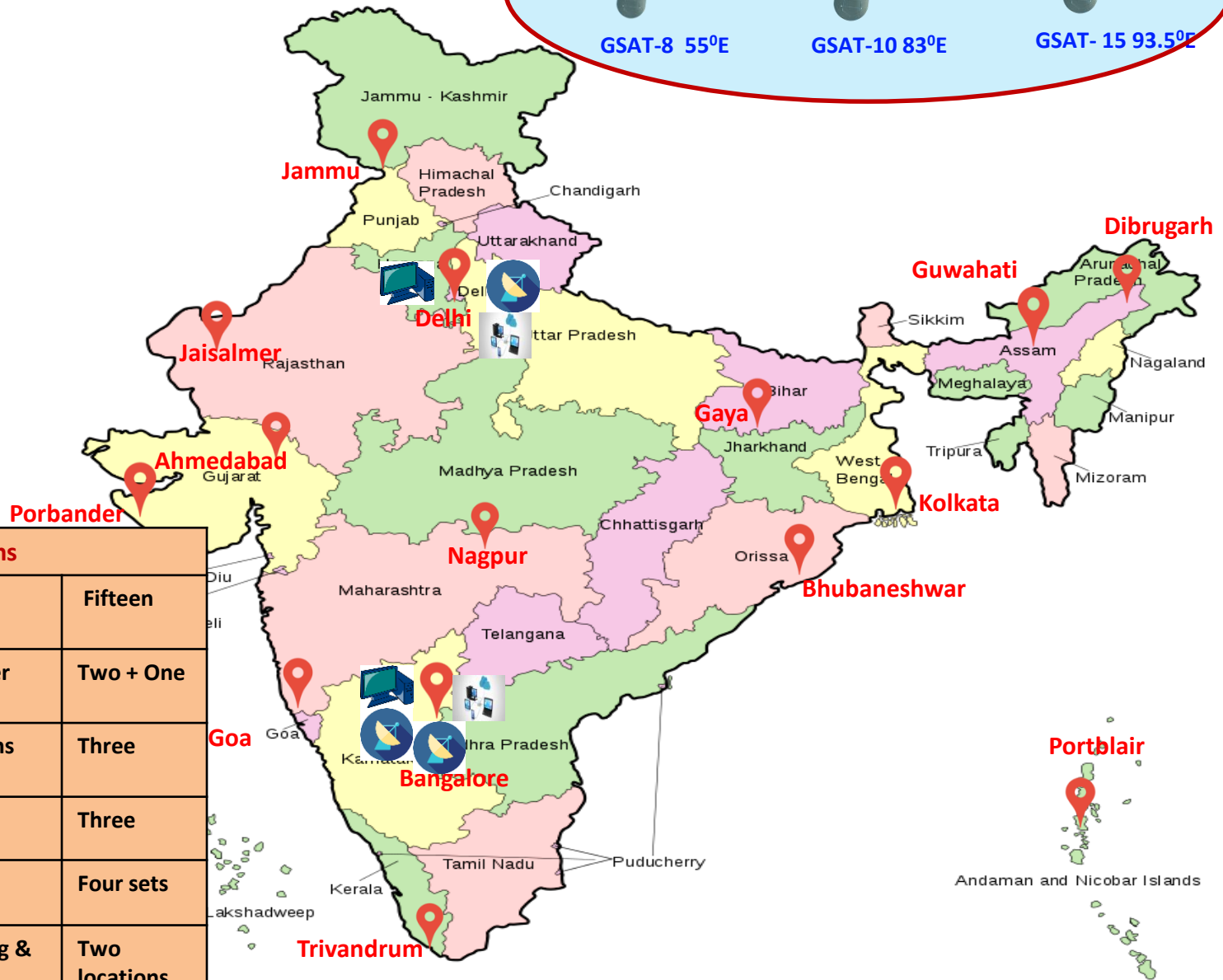
INDIA



### Sub Systems

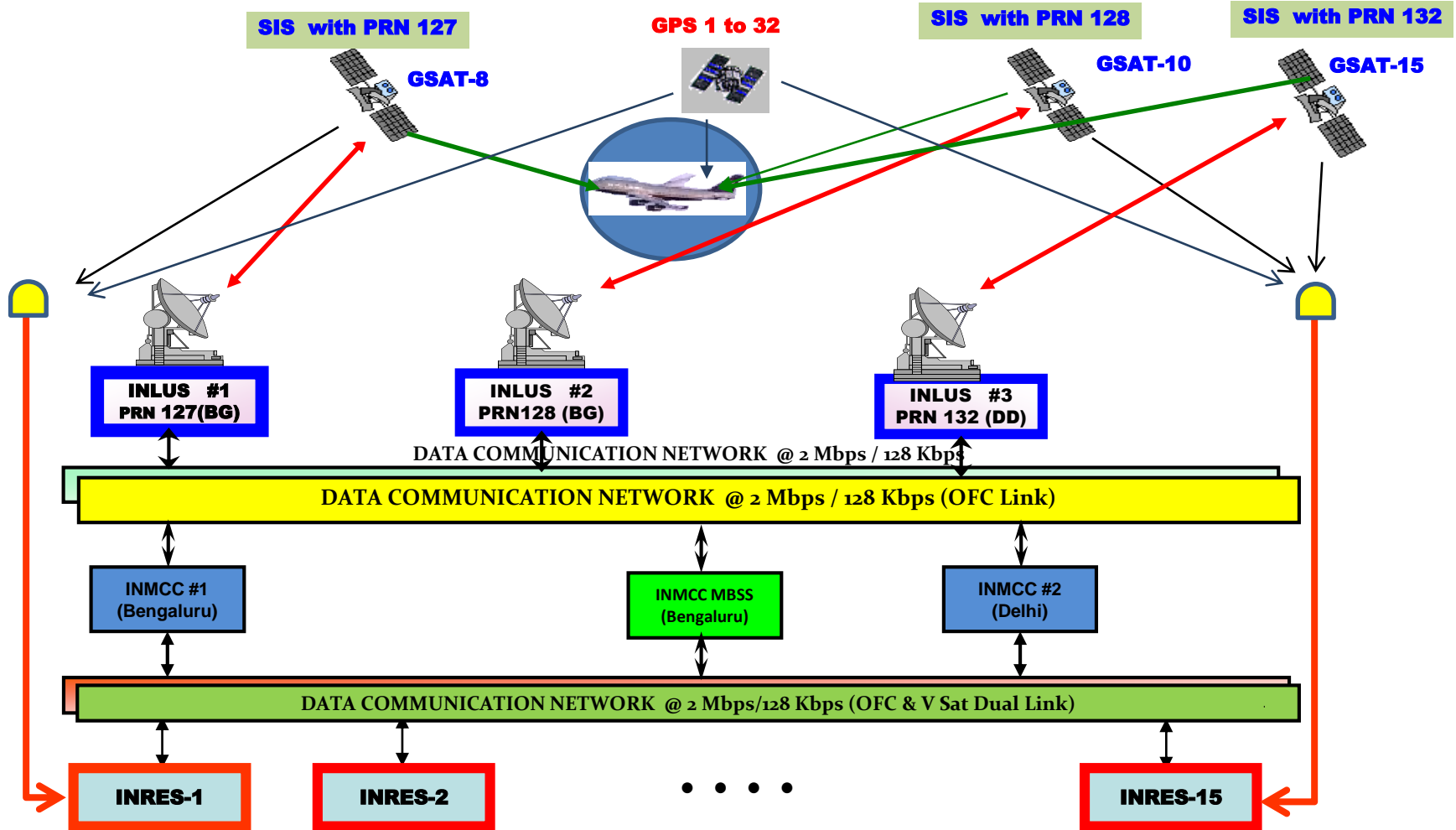
	Reference stations (INRES) with 3 chains	Fifteen
	Master Control Center (INMCC)	Two
	Ground uplink stations (INLUS)	Three
	GEO's	Two
	Data links	Two sets

# GAGAN – Present configuration with added redundancies and additional performance monitoring & analysis Tools



Sub Systems		
	Reference stations (INRES) with 3 chains	Fifteen
	Master Control Center (INMCC)	Two + One
	Ground uplink stations (INLUS)	Three
	GEO's	Three
	Data links	Four sets
	Additional Monitoring & Analysis Tools	Two locations

# GAGAN Architecture



# Certification

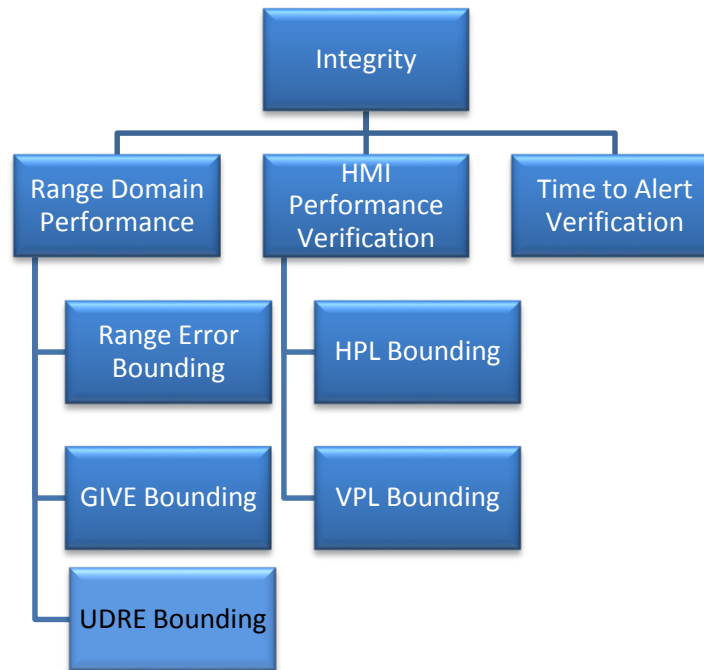
- Major objective of certification is to ensure that system design provides sufficient proof that integrity requirements are achieved.
- Facility Certification process ensures that all ground based installations, documentations, system safety analysis, review of safety artefact's, system performance monitoring & maintenance meets the requirements of safety, continuity & availability of services.
- M/s MITRE Corporation of USA was engaged to support DGCA/AAI for GAGAN certification activities.
- GAGAN was certified in two steps.
  - on 30-12-2013 for RNP 0.1 operations
  - on 21-04-2015 for APV-I services



## **System Performance Monitoring**

- **Since completion of GAGAN APV 1 certification during 2015, AAI is continuously validating the system performance parameters such as Accuracy, Integrity, Availability and Continuity requirements by using following tools.**
  - i. Service Monitoring Sub System (SMSS)**
  - ii. Software Tools delivered by System Integrator**
  - iii. Operational Test & Evaluation (OT&E) tools developed by AAI team**
- **In addition, AAI has installed FAA Certified user SBAS receivers at selected six INRES locations. Data is being collected on 24x7 basis for verification and validation of GAGAN SIS.**
- **AAI analyzes the data and generates the system performance reports as per the prescribed test procedure document prepared & reviewed during the GAGAN certification process.**

# Integrity Analysis with OT & E tools



Stanford Charts of INRES sites generated by SMSS indicates the instances of HMI.

The Time to Alarm (TTA) requirement of 10 Seconds for RNP0.1 and 6.2 Seconds for APV I was verified through analysis of the design and documented. Also real time monitoring of significant events/alerts ensures that the system satisfies the requirement of time to alarm.

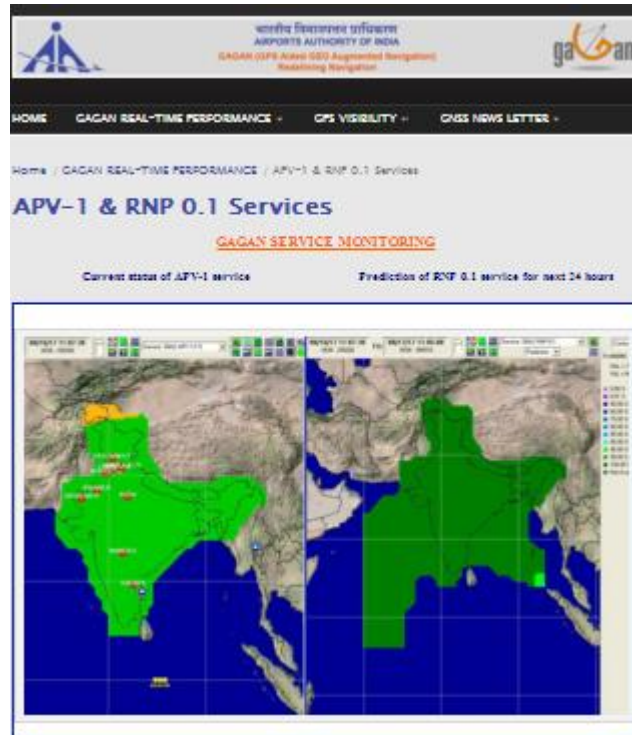
## Continuity

- **Continuity is the probability that the specified system performance will be maintained for the duration of a phase of operation, presuming that the system was available at the beginning of that phase of operation and was predicted to operate throughout the operation. Lack of continuity means that the operation must be aborted.**
- **The continuity is being analyzed at INRES site locations for APV1/1.5 services.**

# NOTAMS

- **Flight System Predictor (FSP) is one of the sub system of GAGAN meant for NOTAM of GAGAN services.**
- **FSP detects actual and predicted future outages of navigation service availability within defined geographic areas of interest, and it provides displays and controls that support generation and management of NOTAMs for predicted navigation service availability outages.**
- **Due to anomalous behavior of ionosphere, NOTAM's generated/cancelled automatically by FSP are more and hence automatic NOTAM generation function is not implemented.**
- **NOTAMs are being issued manually during the non availability of GAGAN RNP 0.1/APV I services due System Maintenance/Testing.**

Real-time GAGAN Performance can be seen at  
<http://gagan.aai.aero/gagan/>



# Major Challenges in GAGAN Implementation, Services Operationalization and Maintenance – AAI initiatives

- **Anomalous Ionosphere behavior over the equatorial region**

- i. Mitigated by development & implementation of iono algorithm suitable to equatorial region.
- ii. 24 TEC monitoring stations are functional at various airports of India and data is being collected continuously to study the ionosphere behavior.
- iii. GNSS R&D center is being established at Ahmadabad to monitor and analyze the TEC data in order to support improvement of iono algorithm.

- **99.999% Availability of data links between SBAS sub systems**

- i. Establishment of redundant data links with different telecom service provider
- ii. Implementation of GAGAN circuits under AAI FTI project- Managed telecom. Service provider.

- **LPV procedures validation**

- **Aircrafts equipage**

DGCA of India revised the mandate on aircraft equipage with GAGAN receiver. As per the revised mandate, all the aircrafts being registered in India from 30<sup>th</sup> June, 2020 will mandatorily have to be GAGAN enabled.

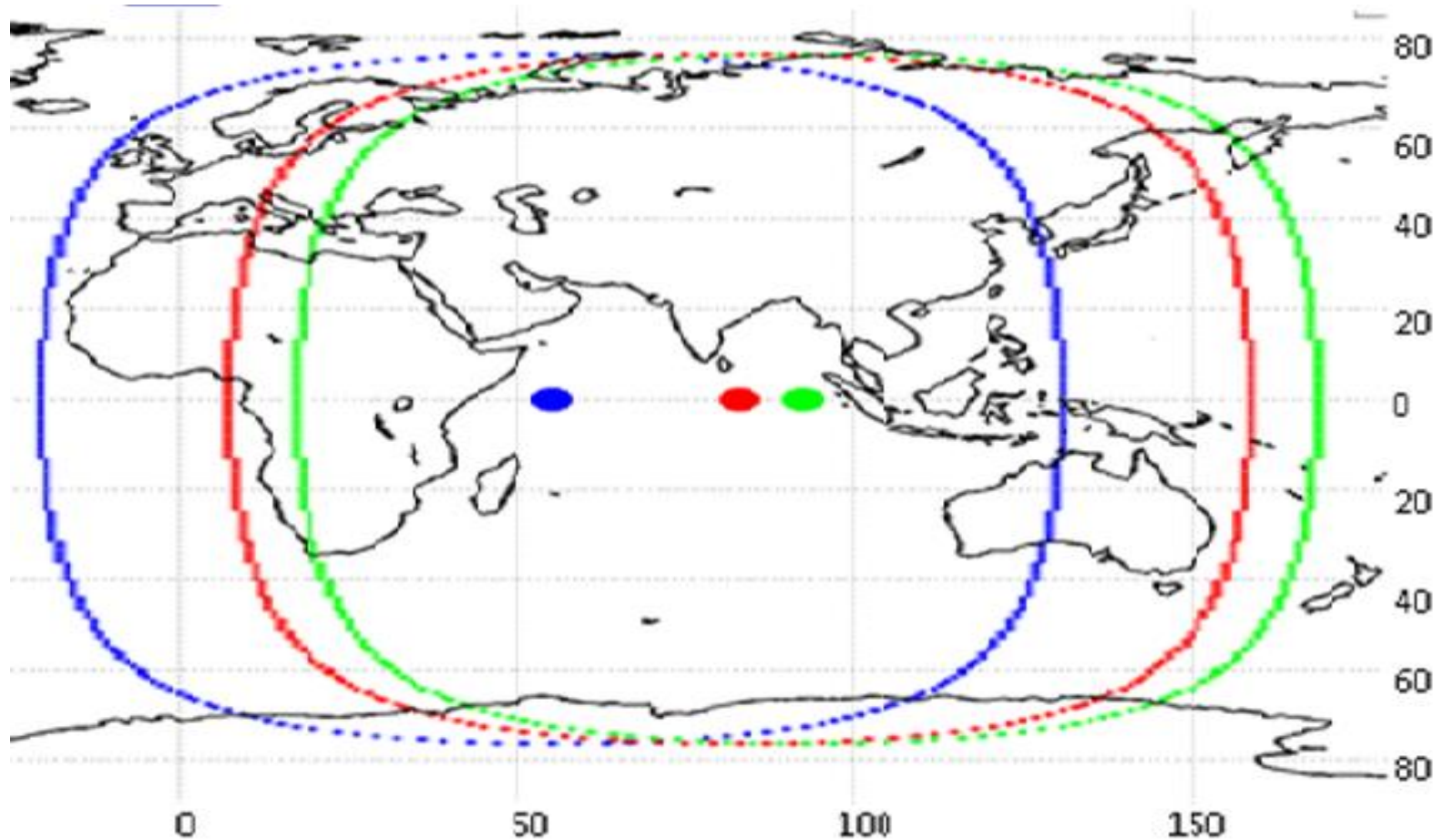
- **Up gradation due obsolescence and technological advancement**

Due obsolescence & technological advancement - GNSS reference receiver (GII ), Processors, Routers etc. are to be replaced which involves software changes as well. – AAI is planning to upgrade in phased manner.

- **Data links technology**

AAI is examining the feasibility of datalinks upgradation from TDM to IP based technology under AAI-FTI project.

# GAGAN GEO Satellites Coverage



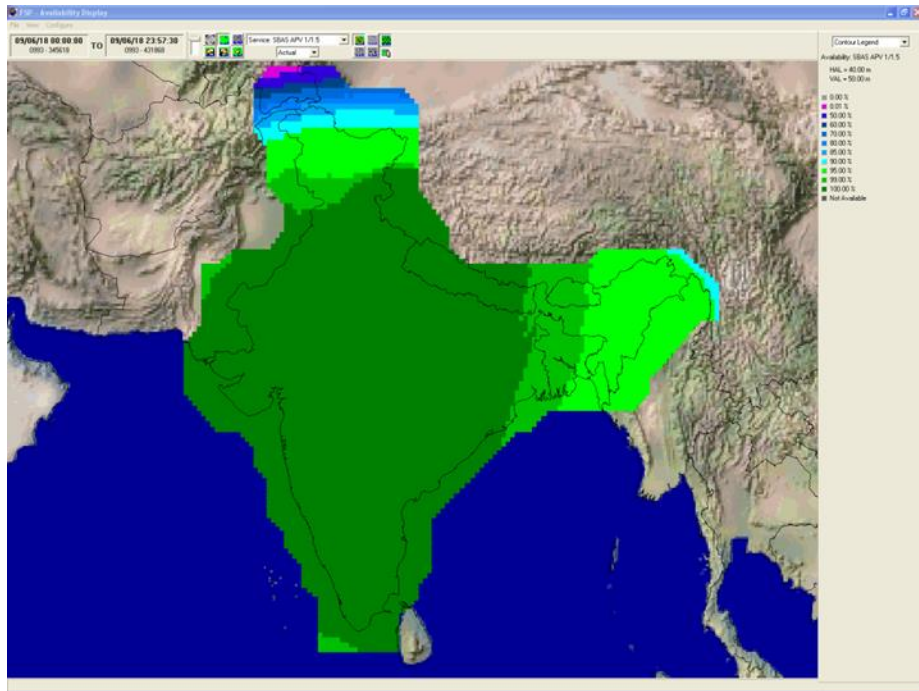
 GSAT8

 GSAT10

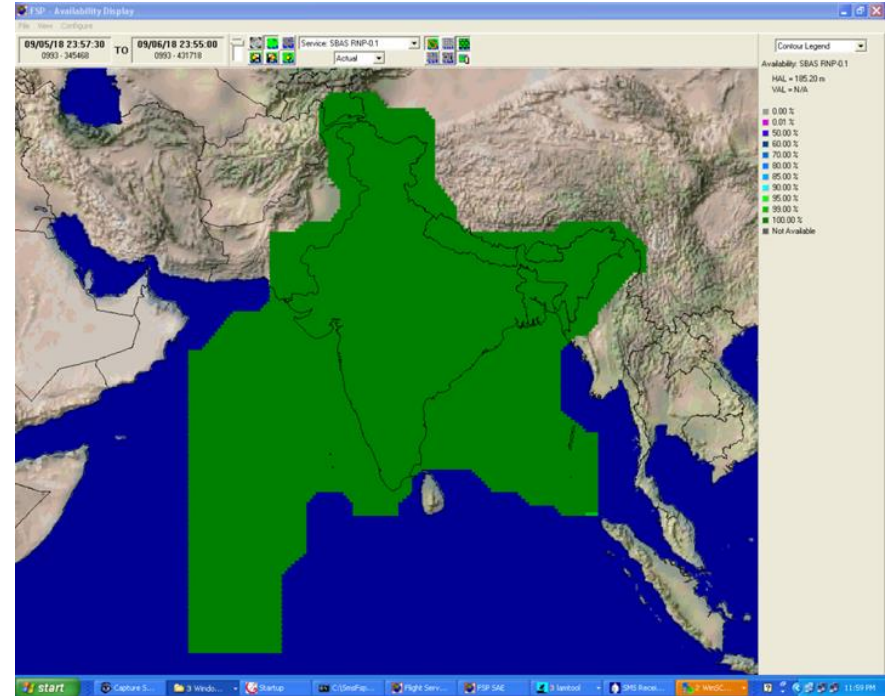
 GSAT15

# Typical availability of GAGAN APV 1 and RNP 0.1 service on a nominal day

## APV I

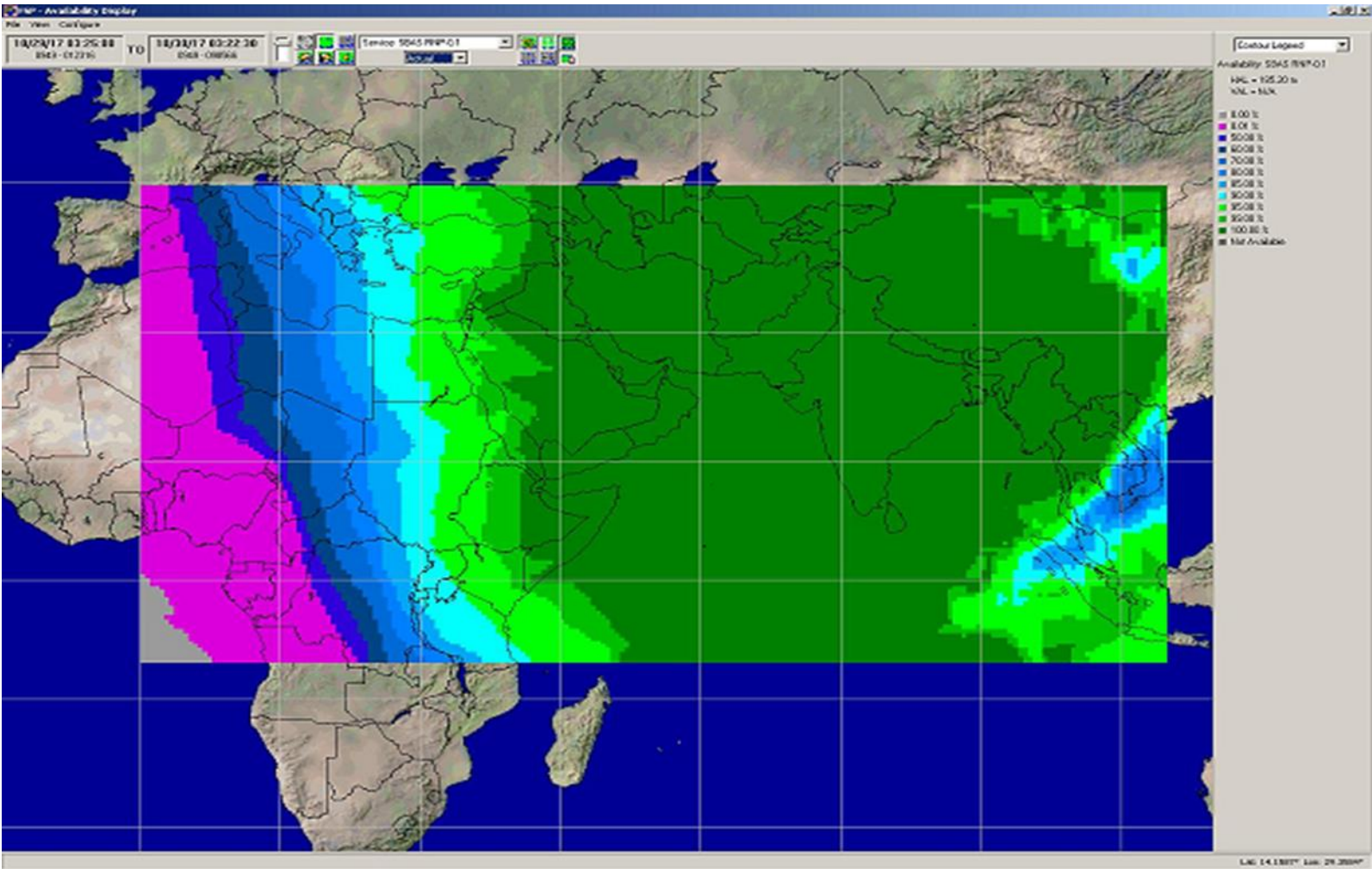


## RNP 0.1





# GAGAN RNP 0.1 service availability beyond the Indian Region

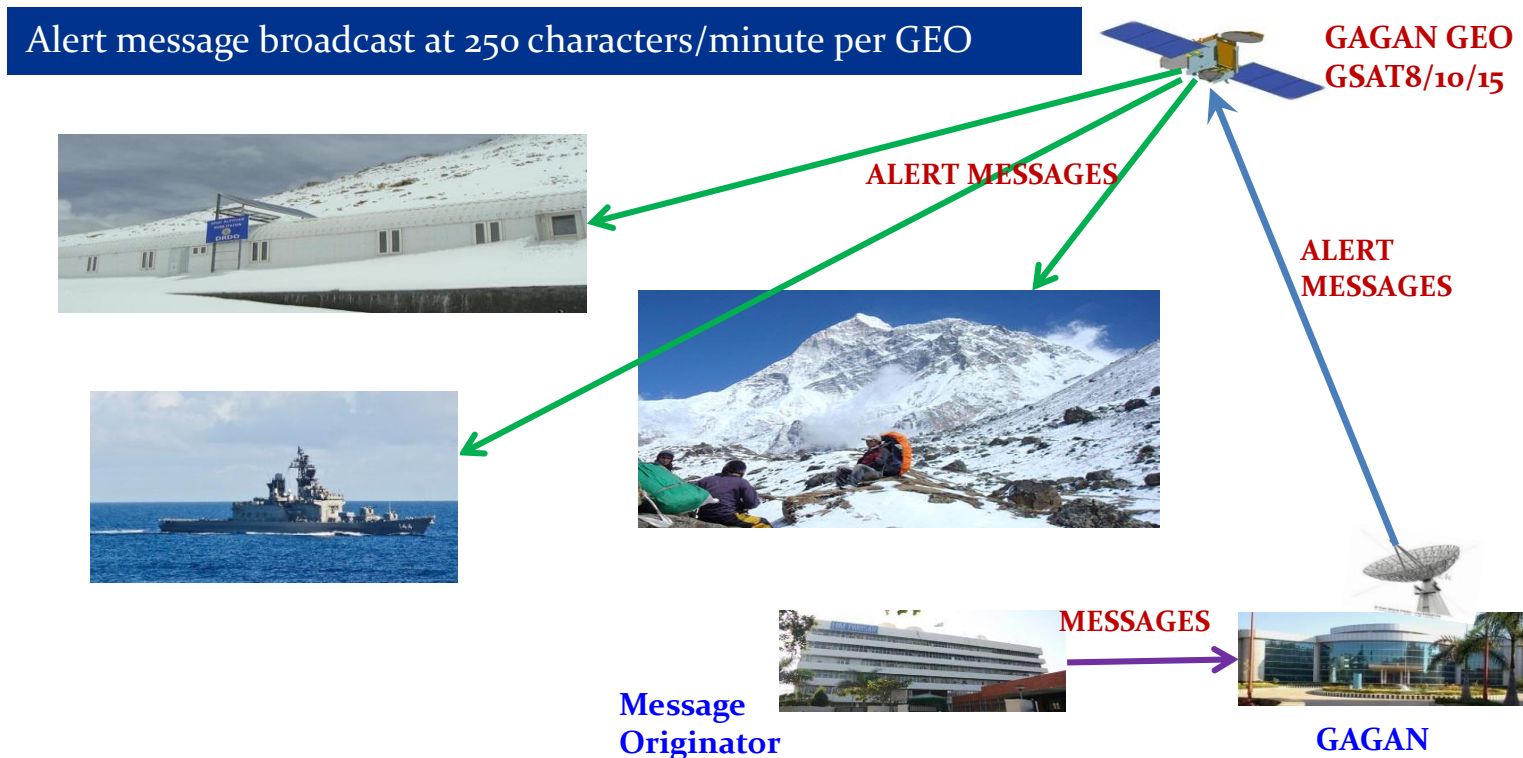


## **GAGAN Services expansion - Possible support by AAI to interested countries**

1. GAGAN GSAT 8/10/15 foot print extends from Africa to Australia.
2. GAGAN system has capability to cater 45 reference stations. At present 15 reference stations are connected.
3. Utilization of AAI SBAS infrastructure can be considered by the countries within GAGAN GEO coverage for implementing RNP 0.1/APV I service with minimal expenditure.
4. AAI, as GAGAN service provider has the capability to :
  - install reference stations
  - train personnel
  - integrate reference station data with Indian Master Control center
  - uplink the same via GSAT 8/10/15 for SBAS services over the selected country
  - Support in testing, SIS validation, documentation, certification etc. activities.
5. GAGAN will support in cooperative development of future SBAS standards

# AAI initiative in non aviation application of GAGAN

AAI implemented an innovative application viz. “GAGAN Message Service” by the use of SBAS message type 63 to broadcast short messages through three GAGAN GEO satellites. This service can be used as a last mile connectivity to broadcast oceanic & meteorological information, alert/ early warning messages on the occurrence of natural disaster, calamity, search & rescue, relief & humanitarian related messages for the safety of life within GAGAN coverage area.



# How GMS works ?

Agencies responsible for forecasting on occurrence of natural disasters (MESSAGE ORIGINATORS)

SASE

INCOIS

IMD

GMS Servers

GAGAN System

Firewall

GAGAN GEO  
PRN 127

GAGAN  
GEO  
PRN 128

GAGAN GEO  
PRN 132

Text Messages  
250bits/Sec (MT63)

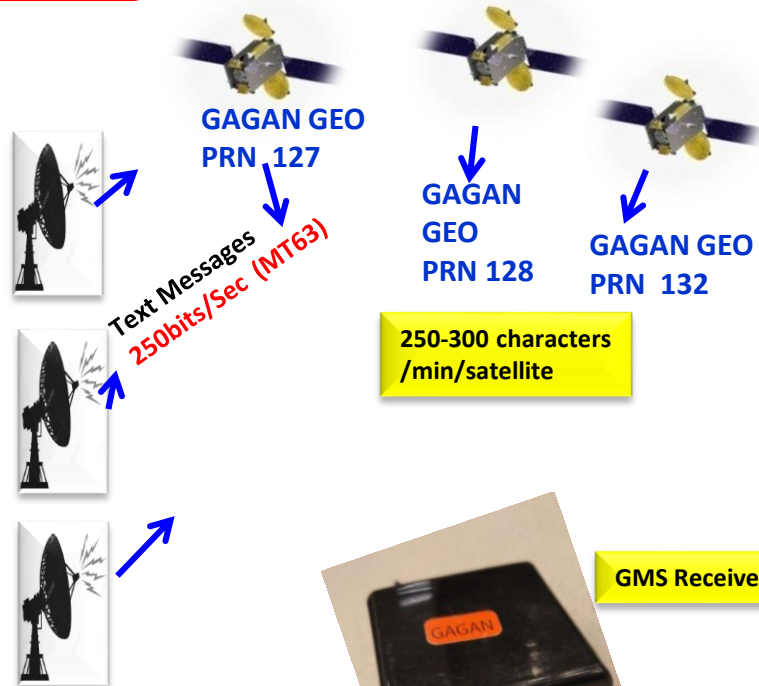
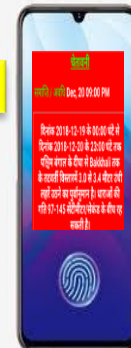
250-300 characters  
/min/satellite

GMS Receiver

Bluetooth/ Wifi

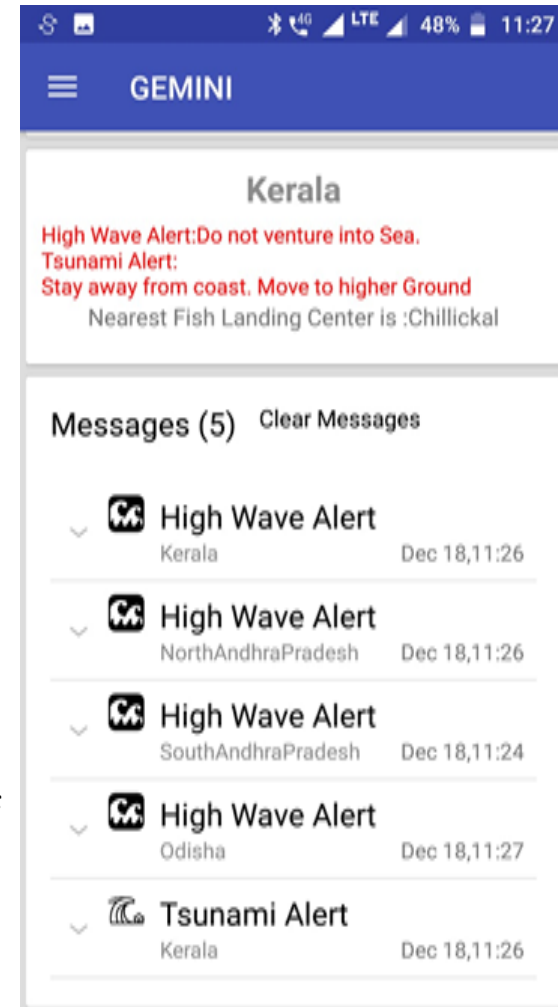
GMS receiver receives the message from satellite, filters out non GMS messages and gives GMS messages to smart phone through Wi-Fi/Bluetooth.

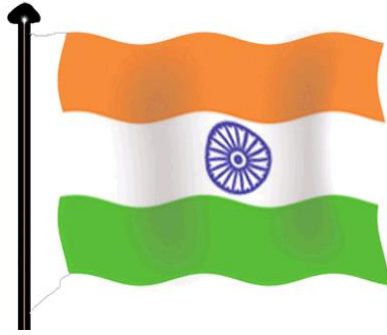
Users



# GAGAN broadcasted messages on Smart Phone

1. Developed a proto type GMS receiver by one of the GNSS receivers manufacturing agency to receive and process the contents of MT- 63 SBAS message broadcasted by three GAAGN GEO satellites.
2. User can connect the receiver through Wi-Fi/Bluetooth to an Android based mobile and an app decodes the MT-63 message contents and display the same along with location information.
3. Successfully completed the field trails of GMS service for the use of fisherman in deep seas at six different Indian sea cost locations during December 2018 by using the prototype GMS receiver and mobile with an app. developed by message originator.
4. Planning to operationalize the GMS services for the benefit of fishing community of deep seas.
5. Benefit of GMS is timely & effective last mile reach, mainly to the areas where there is no coverage of mobiles services for broadcast of alert/early warning messages and information related to forecast of Meteorological, Avalanche, Landslides etc.





**Thank you**



Airport	VELH	SBAS APV 1/1.5	05/24 12:57	05/24 13:25	00:27
Airport	VEMR	SBAS APV 1/1.5	05/24 12:57	05/24 13:27	00:30
Airport	VIAR	SBAS APV 1/1.5	05/24 12:57	05/24 13:12	00:15
Airport	VIBR	SBAS APV 1/1.5	05/24 12:57	05/24 13:15	00:17
Airport	VEAT	SBAS APV 1/1.5	05/24 13:00	05/24 13:22	00:22
Airport	VECC	SBAS APV 1/1.5	05/24 13:00	05/24 13:20	00:20
Airport	VELP	SBAS APV 1/1.5	05/24 13:00	05/24 13:27	00:27
Airport	VILD	SBAS APV 1/1.5	05/24 13:00	05/24 13:12	00:12
Airport	VEBS	SBAS APV 1/1.5	05/24 13:07	05/24 13:12	00:05
Airport	VGHY	SBAS APV 1/1.5	05/24 16:10	05/24 16:17	00:07

NOTAM

Issue New NOTAM

6 of 90

ID: 0003822N

A) VEGT  
 B) 1905241255  
 C) 1905241322  
 E) SBAS UNAVBL FOR SBAS APV 1/1.5  
 1905241255 TIL 1905241322

- Issue
- Defer
- Restore
- Print

New: 90 Issued: 0 Deferred: 0 Expired: 37

Past Actual