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## **PBN & SBAS(GAGAN) Implementation in India**



# WHY WE THOUGHT PBN AT INDIA ?





- The continuous growth of aviation; demanded more airspace capacity for operating flights efficiently.
- Diversity in topography of Indian airports i.e. from flat surfaces ZERO AMSL to HILLY terrain 11000 feet AMSL elevation.
- Therefore solution was only PBN based navigation.





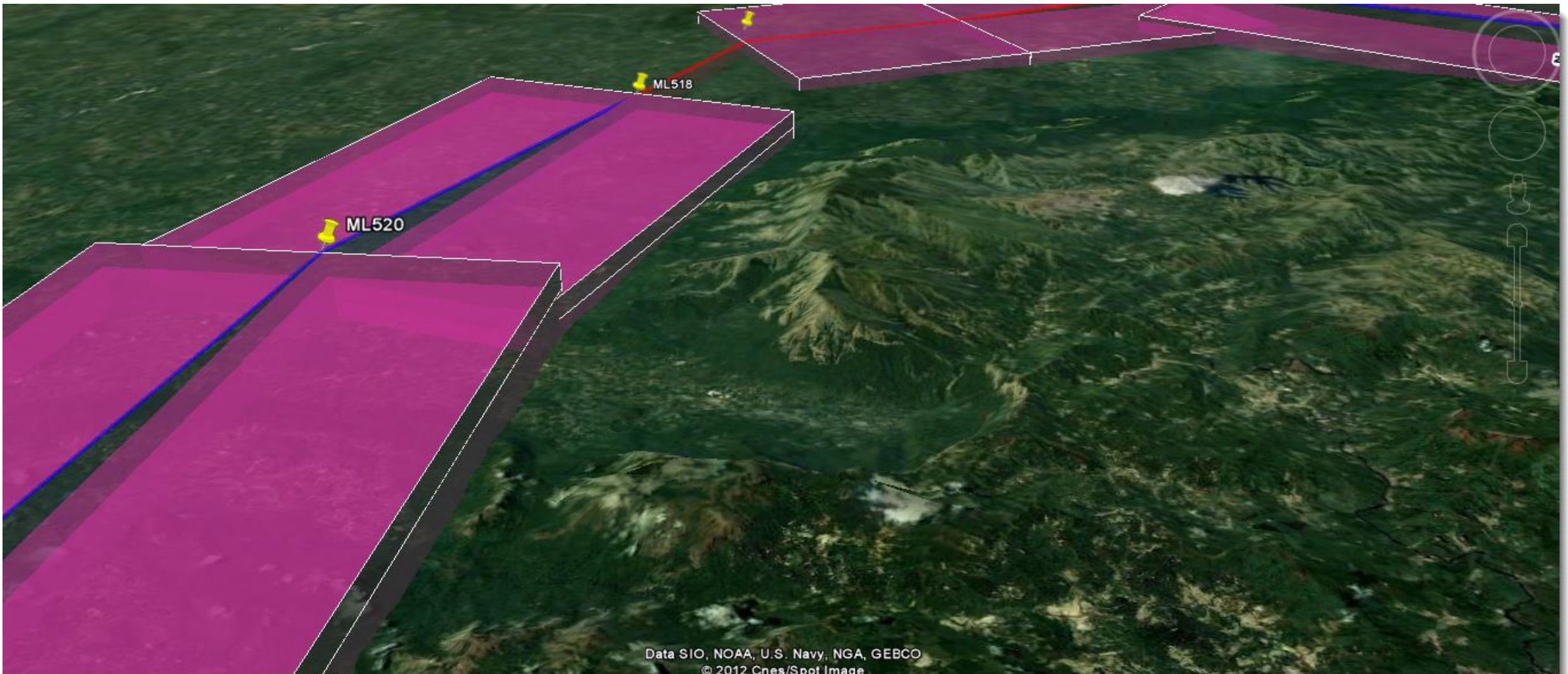
- INDIA'S ANSP provider AAI prepared PBN implementation plan in accordance with ICAO guidelines DOC 9613 and submitted to ICAO in 2011 which has been recognized as “ROBUST” plan.
- As per AAI'S PBN Implementation Plan, PBN SIDs and STARs, RNP APCH procedures will be implemented at all operational airports by 2016.



# Design Flexibility



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Data SIO, NOAA, U.S. Navy, NGA, GEBCO  
© 2012 Cnes/Spot Image

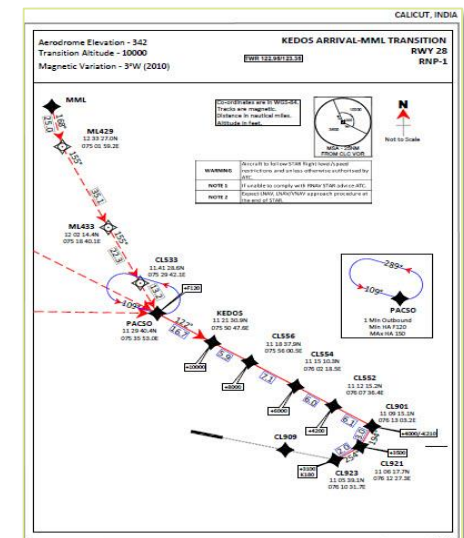


# Terminal Area



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- PBN RNAV1 SIDs & STARs have been implemented at 10 major airports so far : **Delhi, Mumbai, Chennai, Kolkata, Hyderabad, Bangalore, Trivandrum Ahmadabad Cochin ,Guwahati airport & recently at Defense controlled Goa.**
- Plan is to implement at 7 more airports by the end of this year at, **Calicut, Coimbatore, Nagpur, Jaipur, Mangalore and Varanasi airport**

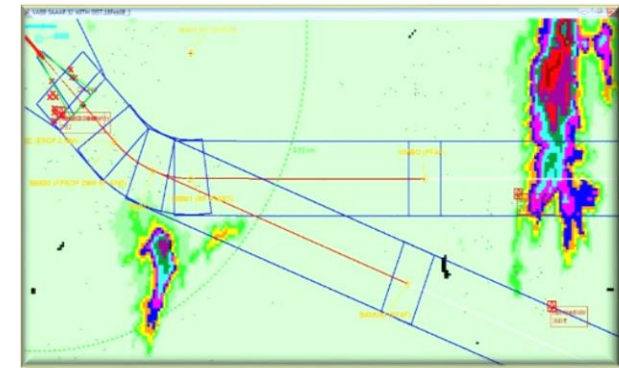
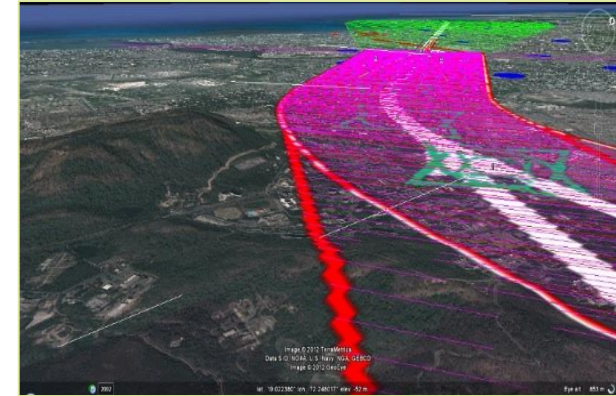


# APPROACH



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- **RNP APCH (LNAV, VNAV)-COCHIN AIRPORT– RWY27**
- **RNP- AR-MUMBAI AIRPORT –RWY32**  
(Presence of Trombay Hill, ILS was not proposed for RWY32 due un-reliability of ground based Nav-Aid signals)





- RNAV-5 Q routes have been implemented connecting cities **Delhi, Mumbai, Chennai, Trivandrum, Cochin, Calicut, Coimbatore, Ahmedabad, Vadodara.**
- **On-going Development**  
RNAV-2 routes under development between:
  - **Delhi-Bangalore, Hyderabad, connecting Colombo**
  - **Delhi-Kolkata connecting Dhaka**





# Benefits



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- Track miles savings resulting in fuel savings and emission reduction
- Design flexibility
- CDO and CCO enablers
- Segregated arrival/departure traffic flows thus enhancing safety
- Reduced pilot-controller communication
- Structured and predictable trajectories to enable energy management for fuel efficiency



# FUEL SAVINGS IN ENROUTE & TERMINAL AREA



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ATS Route	Fuel Savings/day (Kg)	Carbon emission reduction/day (Kg)	Remarks
RNAV 5	40,100	126,716	Q1 to Q13

Ahmedabad airport	853 arrivals	121,992 Kg	384,226 Kg
Mumbai airport	254 arrivals	32,727 Kg	103,088 Kg

*Based on actual fuel savings as intimated to ATC on R/T  
by the flight crew*





- Recently AAI has just completed an international project i.e. designing of conventional & PBN based SIDs, STARs and RNP AR approach for SHARAJAHA airport.

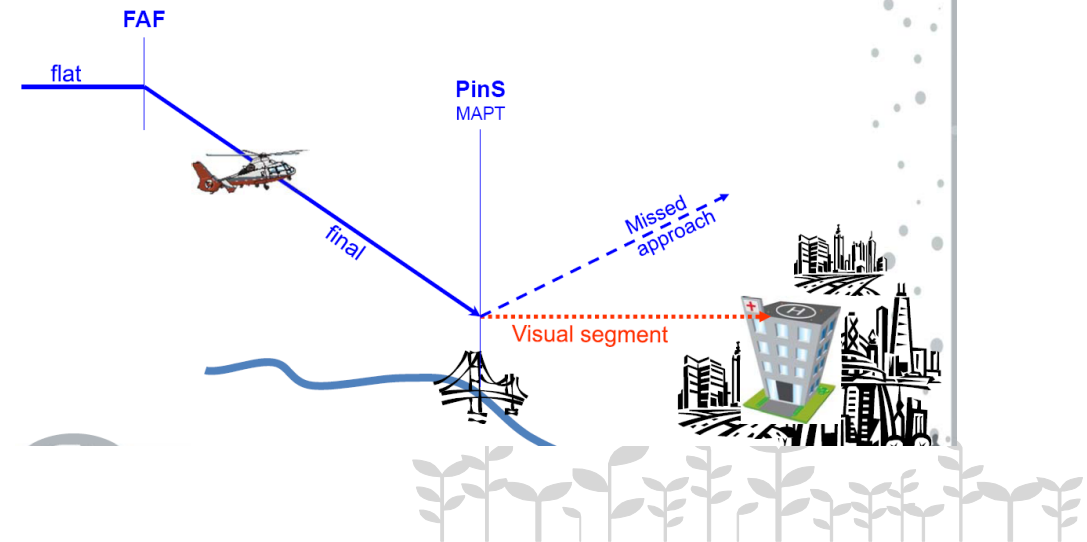
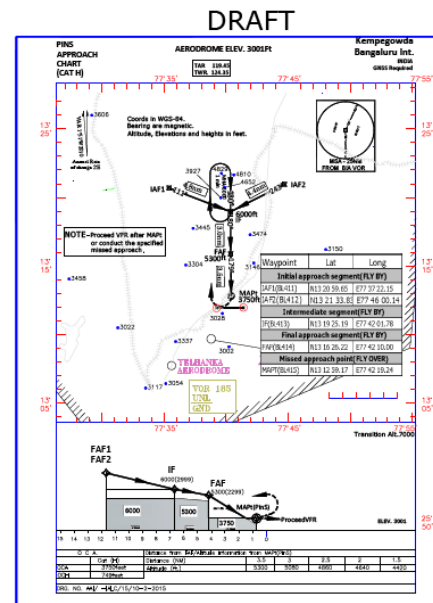


# PINS approach for HELICOPTERS



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- With the growth of H/C operations, AAI has designed PINs(sensor GNSS) approach for H/C at **MUMBAI,DELHI,BANGALURU & GUWAHATI** reducing delay for H/C operation.



# ANS PLAN vis a vis ASBU BLOCK-0



ANS Strategic Plan Operational Objectives		Short Term	Medium Term	Long Term
PBN Implementation	Enroute	Reduced Horizontal Separation ( RHS); RNP 10 in Oceanic; RNAV-5 in continental	RHS; RNAV 5; RNAV 2	RNP 4; RNP 2
	TMA	RNAV 1 SID/STAR; RNP 1 SID/STAR; Precision APP, APV;LNAV CCO/CDO	RNAV 1 SID/STAR at all airports; RNP 1 SID/STAR at all possible airports; Precision APP, APV;LNAV RNP 0.3 ( for helicopters) CCO/CDO	RNAV 1 SID/STAR at all airports; RNP 1 SID/STAR at all possible airports; Precision APP, APV;LNAV RNP 0.3 ( for helicopters) CCO/CDO
	Airspace	Non-Exclusive	Non-exclusive	Non-Exclusive/ Exclusive

AAI is marching along with the ASBU BLOCK-0 PLAN







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# GPS Aided GEO Augmented Navigation (GAGAN)





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## GAGAN

- India's **FIRST** satellite navigation system developed jointly by AAI & ISRO
- **4<sup>th</sup> SBAS in the World**
- **3<sup>rd</sup> to achieve Approach with Vertical Guidance Certification**
- **1<sup>st</sup> system developed in Equatorial Region making India the leader in Asia Pacific Region**

**PROVIDES**

**APV 1 & RNP 0.1 SERVICE IN INDIAN FIR**

**GAGAN PROGRAMME, INDIA**

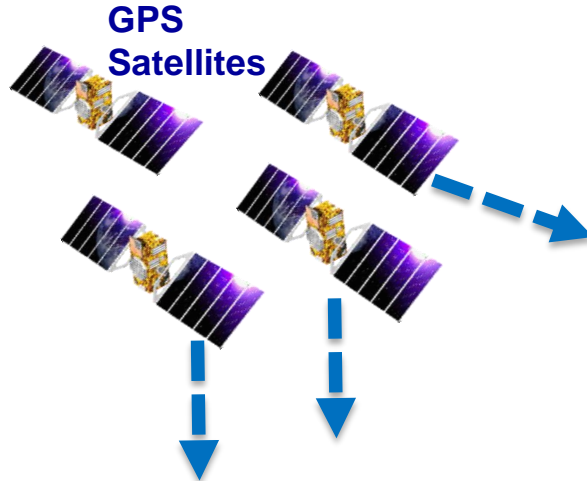




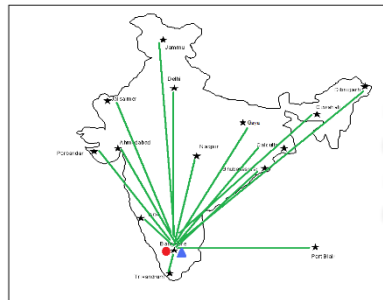
# GAGAN ARCHITECTURE



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GPS Satellites



15 Ground Reference Stations located at various airports collect data from GPS and forward to Indian Master Control Centres

GSAT-8 (PRN-127)

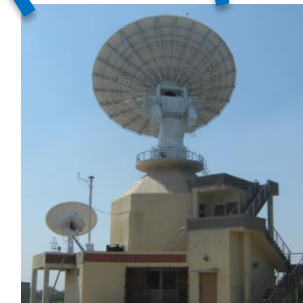


2 Indian Master Control Centres receiving data from reference stations and provide Ionospheric, Clock and Ephemeris corrections and send it to Uplink stations



GSAT-10 (PRN-128)

Both Geostationary satellites (GSAT-8 & GSAT-10) send correction messages to Users



3 Indian Land Uplink Stations uplink correction messages to 2 Geostationary satellites (GSAT-8 & GSAT-10)







# GAGAN Accomplishments



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- In 2013, India became the fourth country in the world to have the capability of SBAS through GAGAN for enroute operations.
- With the certification of GAGAN for approach and landing operations (APV 1) on 21<sup>st</sup> April 2015, GAGAN has become the third country in the world to have such capabilities apart from WAAS of USA and EGNOS of Europe.
- GAGAN is the first system in the world to have implemented in the equatorial ionospheric region. GAGAN ionospheric algorithm known as Multi-Layer Data Fusion (MLDF 4) was developed by ISRO.





# GAGAN CERTIFICATION PRINCIPLES



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- **Safety Certification:**

- *Achieved through:*

- *Safety Assurance process;*
- *P(HMI) Integrity Analysis;*
- *FMEA; Fault Tree Analysis;*
- *Performance Analysis;*
- *Test and Validation.*

- **Operational Certification:**

- *Achieved by :*

- *ensuring that all system integration requirements have been complied with ICAO requirements,*
- *validating the System is working properly within the service area*
- *ensuring that equipments function within the limits*
- *providing sufficient Training of the operation and maintenance team*
- *ensuring proper procedures are in place and being followed.*





# GAGAN CERTIFICATION PRINCIPLES



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- **Service Certification**

- *Achieved through:*

- *ensuring a proper and reliable operation GAGAN service by monitoring daily, weekly, monthly and quarterly performance reports.*
    - *To assure this certification the necessary training to the operators is to be ensured.*

- **Security Certification:**

- *to confirm Vulnerability assessment on GAGAN Architecture,*
  - *Define threat Characterizations,*
  - *Risk assessments for each threat*
  - *Mitigated risks to an acceptable level of safety.*





# RAIM Prediction for RNP Operations



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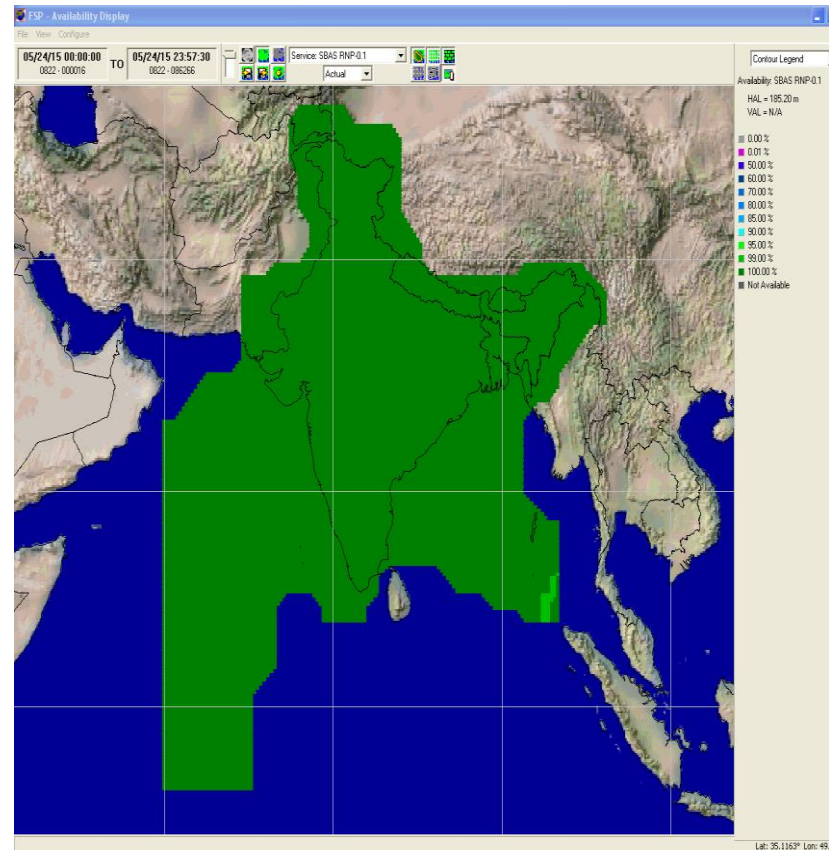
- To meet the requirement of RAIM prediction, online **GPS VISIBILITY PREDICTION TOOL** has been developed by AAI.

<http://59.144.72.85/gagan/tools/gps-visibility/MainFile.html>

- RNP Service map is also available with prediction for ensuing 24 hrs.

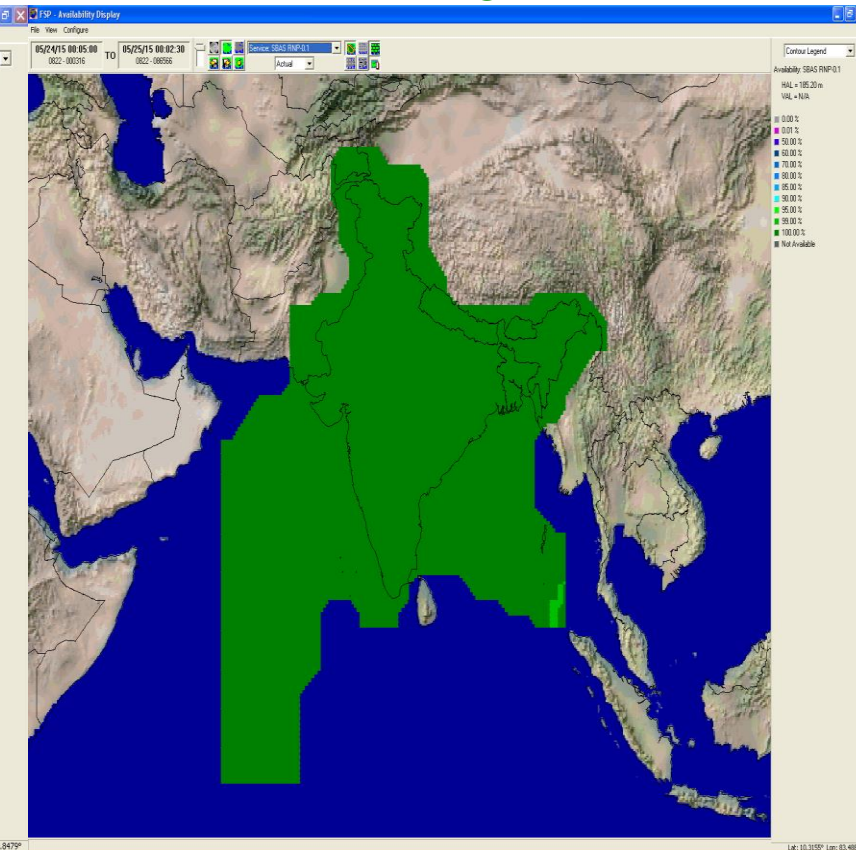
<http://59.144.72.85/gagan/content/rnp-service>

PRN-127



24-MAY-2015

PRN-128



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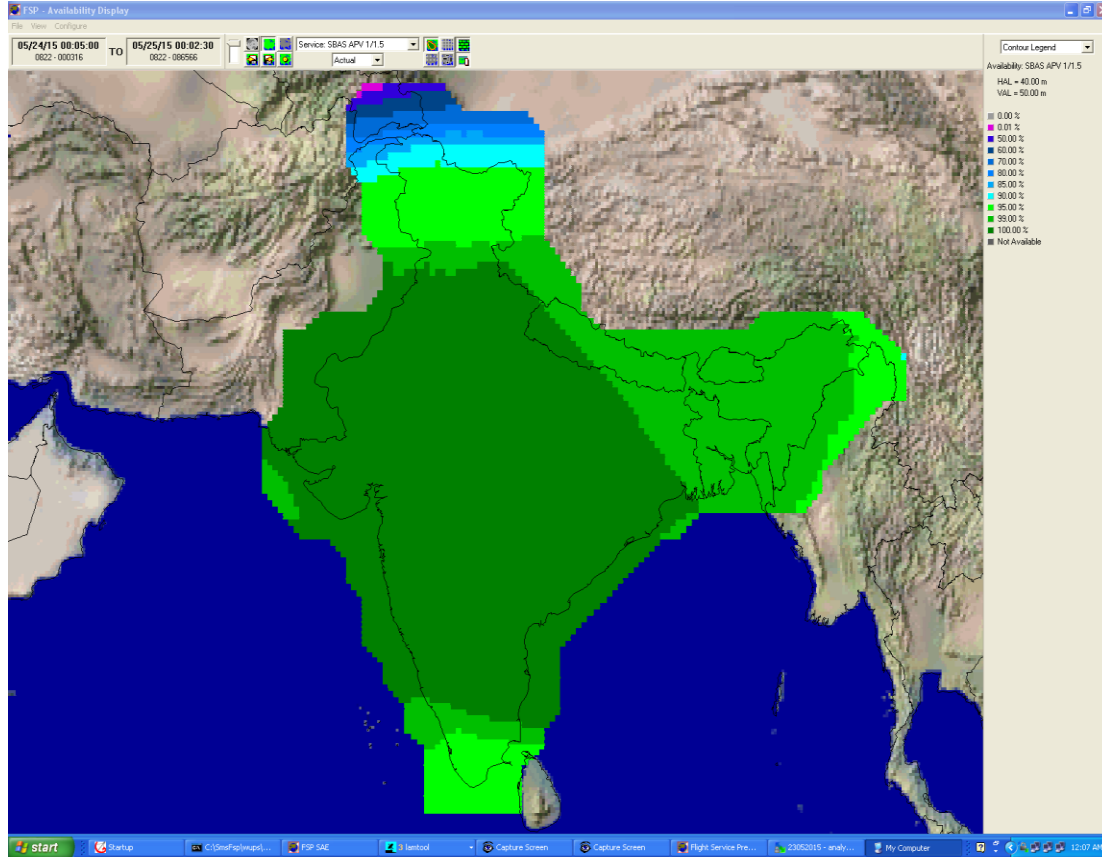


# Typical APV1 performance



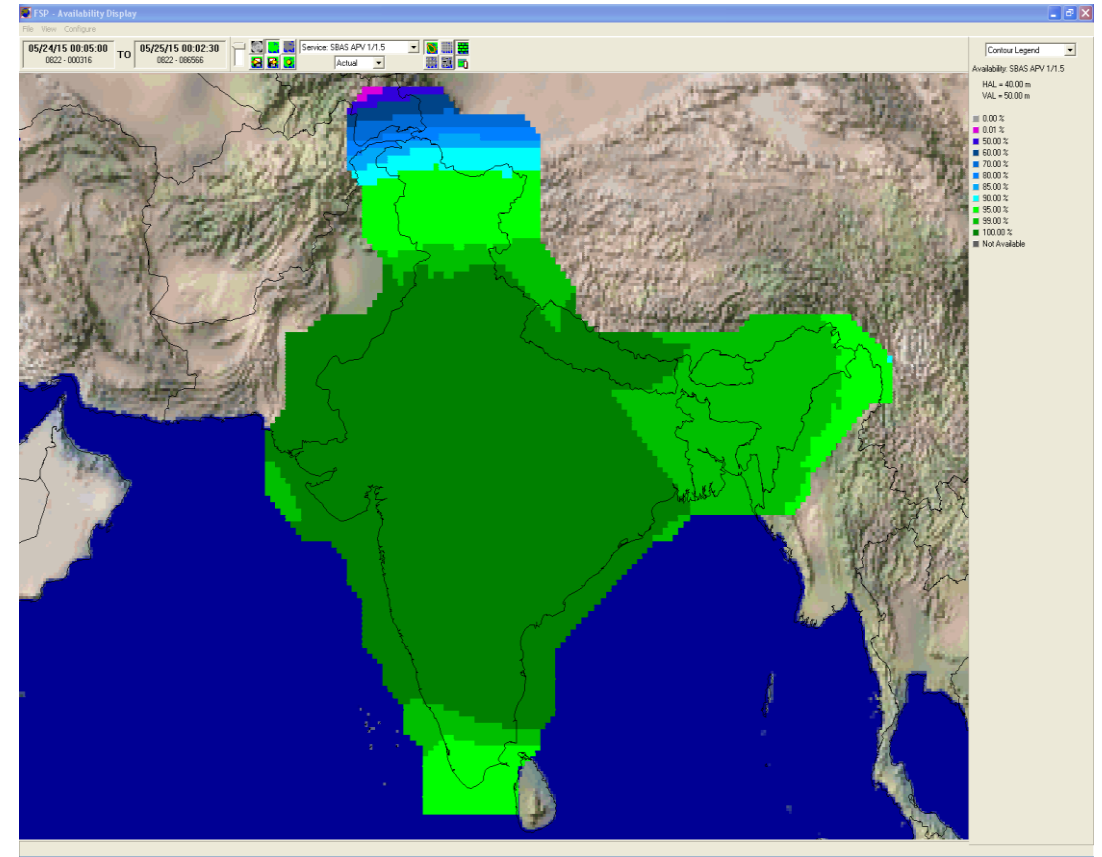
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# Benefits of LPV



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- GAGAN geostationary satellites provide ranging sources to supplement the GPS signals.
- Augmented signal is accurate enough to permit use of GPS as primary means of navigation.
- Requirement of RAIM prediction is eliminated thus reducing flight dispatch and pilot workload.
- Unlike Baro-VNAV, vertical path is not affected by temperature extremes.
- Provides a cost-efficient opportunity for airports to gain ILS-like approach capability without any ground infrastructure requirements.
- Eliminates siting constraints of navigation facility, maintenance and associated restrictions on airport development.
- Onboard SBAS receiver integrated with FMS is required to use SBAS signals for LPV.





# GAGAN – RNP APCH (LPV) Procedures



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- RNP APCH (LPV) procedures are being developed for better access to non-ILS runways and enhanced access to medium/small airports
- Typical comparison of minima in case of Medium airport – Ahmedabad and small airport - Belgaum:

Airport	Runway	Conventional Procedure OCH/Minima			Indicative LPV OCH/Minima	
		Procedure	Height	Minima	Height	Minima
Ahmedabad	05	VOR	450Ft	1700M	276Ft	800M
	23	ILS	241Ft	750M	NA	NA
		VOR	541Ft	1800M	541Ft	1800M
Belgaum	26	VOR	919Ft	4300M	269Ft	1300M

O C A. (H)		
CATEGORY OF AIRCRAFT	A/B	C/D
LPV	440(260)	460(280)
LNAV/VNAV	480(300)	500(320)
LNAV	660(480)	660(480)

FAS Data Fields - VAAH - LPV RWY05	
Operation Type	0
Service Provider Identifier	3
Airport Identifier	VAAH
Approach Performance Designator	0
Route Indicator	Z
Reference Path Data Selector (RPDS)	
Reference Path ID (Approach ID)	G05A
LTP/FTP Latitude	230357.4325N
LTP/FTP Longitude	0723720.6465E
LTP/FTP Ellipsoidal Height	+00026
FPAP Latitude	230518.4665N
FPAP Longitude	0723847.2300E
Threshold Crossing Height (TCH)	50
TCH Unit Selector	F
Glide Path Angle (GPA)	03.00
Course Width at Threshold	105.00
Length Offset	0305
Horizontal Alert Limit (HAL)	40.0
Vertical Alert Limit (VAL)	12.0
Precision Approach Path Point Data CRC Remainder	?????

- RNP APCH Chart depicts all three lines of minima:





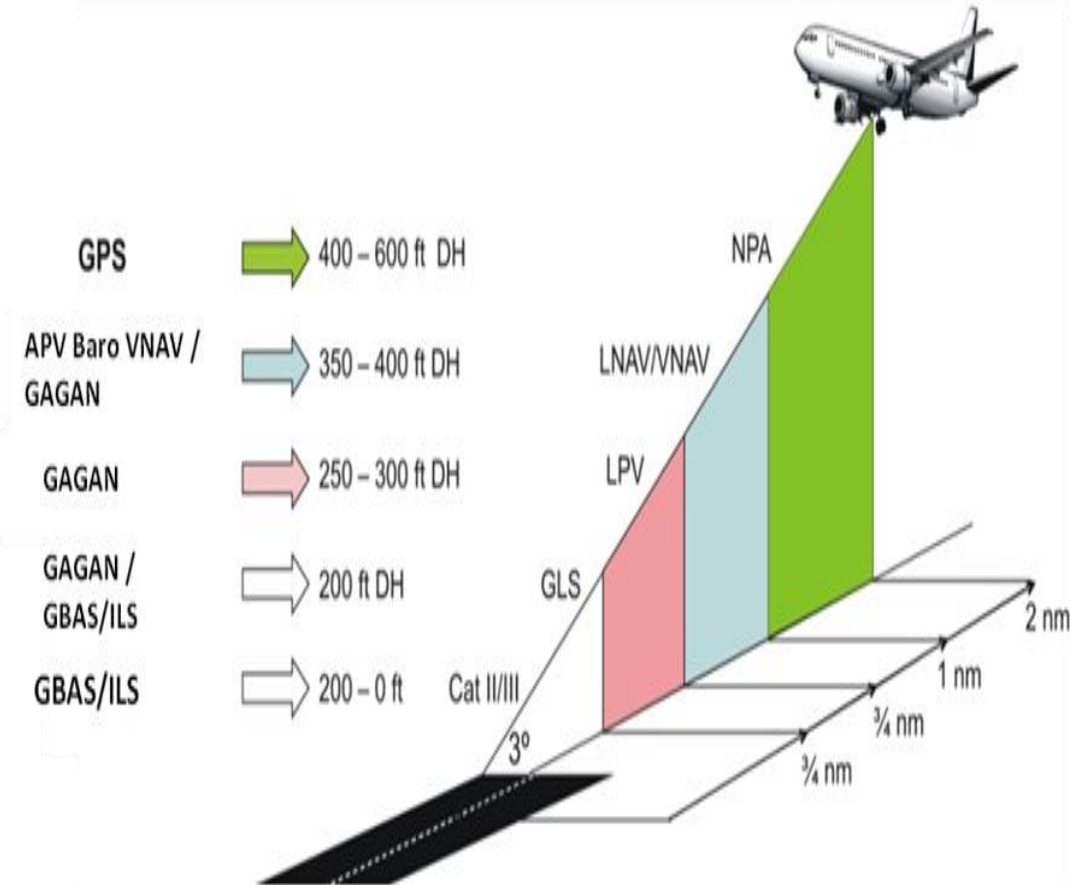


# GAGAN Implementation Plans-AAI



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- **For Runways equipped with ILS:**  
Alternative to ILS, when ILS becomes unserviceable or under maintenance.
- **At runways not equipped with ILS** or at terrain constrained airports where ILS installation is not practicable, GAGAN approaches will provide the requisite vertical guidance.
- **At small airports** where only few aircraft movement exist.
- **At new airports** where traffic density is expected to be **less than 10 movements**.



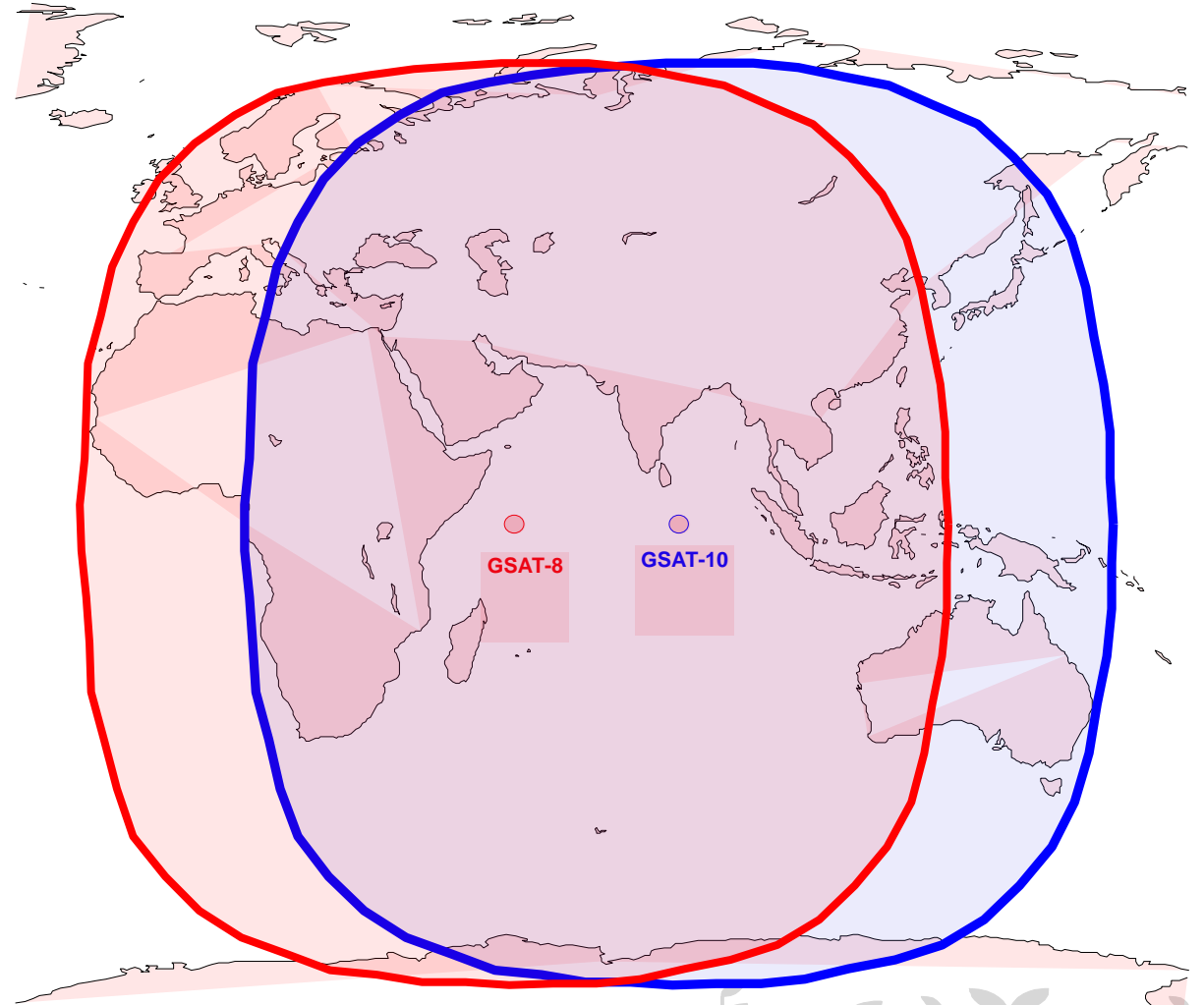


# GAGAN GEO FOOTPRINT



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- GAGAN GEO footprint expands from Africa to Australia and have expansion capability for seamless navigation services for the region.
- GAGAN is also interoperable with other SBAS systems like WAAS, EGNOS and MSAS.





# GAGAN Expansion Possibilities



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This study shows the RNP 0.1 given the GAGAN system for corrections for the surrounding areas beyond the GAGAN FIR.

The region that is studied includes the SAARC nations (Afghanistan, Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan, and Sri Lanka), Saudi Arabia and Oman and the eastern area towards the Philippines.



Saudi Arabia, Oman

SAARC Countries

Malay, Philippines





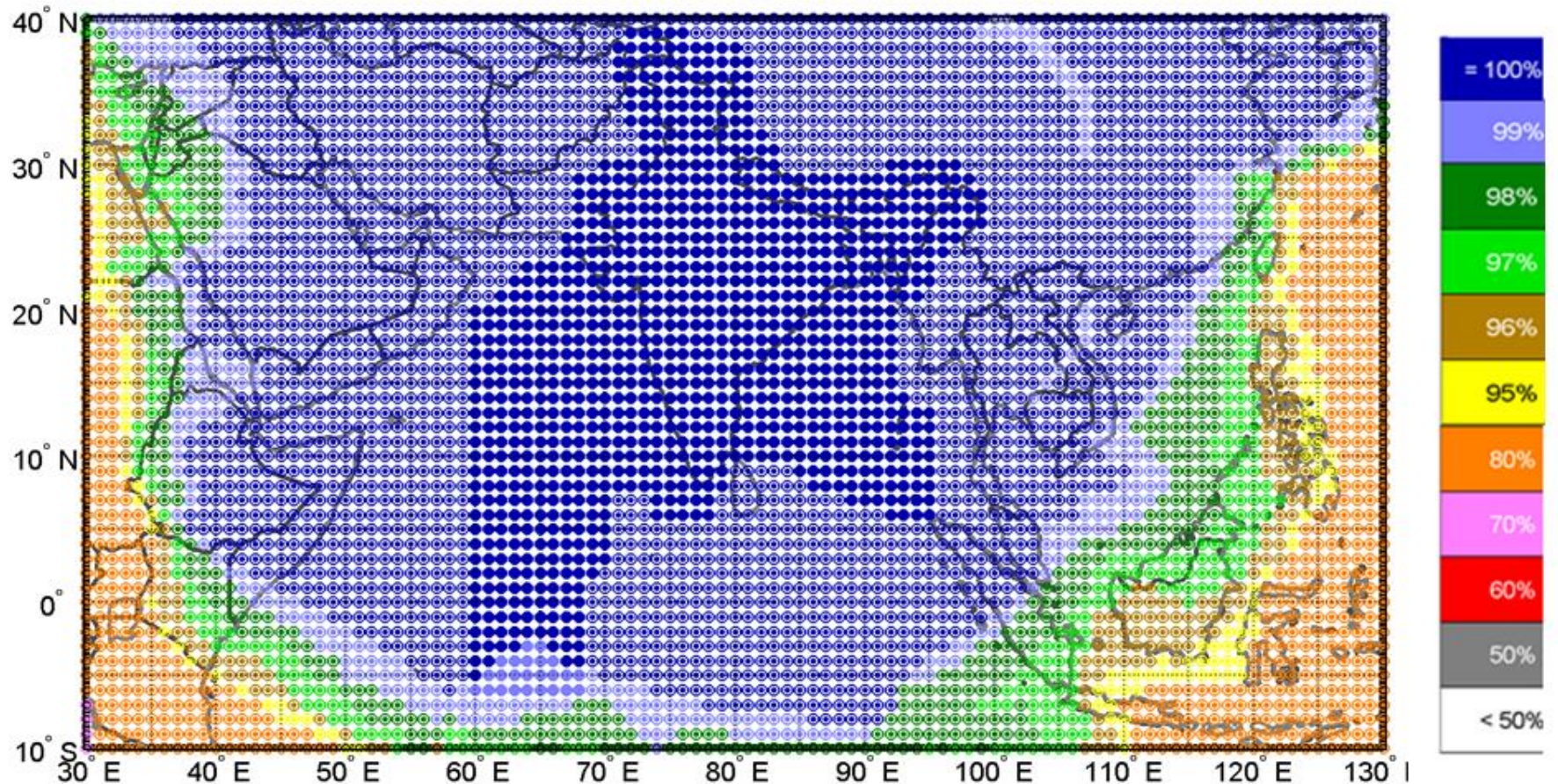


# GAGAN RNP 0.1 Coverage



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- Distribution of the RNP 0.1 for the current GAGAN 15 station configuration.
- The scale shows that 100% region reaches parts of Africa to the west and parts of Asia to the east.



Above availability is optimistic as it is based on user geometry based on the satellite constellation and the UDRE is modelled by the satellite geometry as opposed to the broadcast UDRES







## Opportunities for Neighbouring States



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- GAGAN Signals are available from Africa to Australia through two GEO satellites GSAT-8 & GSAT-10.
- GAGAN system has capability to cater 45 reference stations.
- The signals from Indian GEOs are capable of providing service to all neighboring countries such as Myanmar, Bangladesh, Nepal, Bhutan, etc., and countries of South East Asia, such as Thailand, Indonesia, Malaysia, Singapore and others over Australia and Africa falling within GEO foot print subject to installing Indian Reference Stations (INRES) at strategic locations within the states.





# Opportunities for Neighbouring States



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- AAI, as GAGAN service provider has the capability to :
  - install reference stations,
  - train personnel
  - integrate reference station data with Indian Master Control center and
  - uplink the same via GEOs GSAT 8 &10 for SBAS services over the selected country.
- Neighbouring states can take advantage of GAGAN signals to implement the RNP 0.1 and APV 1 service in the respective states with minimal expenditure.







# Expected Benefits to States



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- **Benefit to Myanmar, Thailand, Bangladesh, Nepal, Indonesia, Malaysia etc.:**
  - Sets a framework for expansion to countries including definition of expansion tasks and risks with the ICAO vision of ASBU
  - Demonstrates the performance benefit of GAGAN and low cost to expand to full national coverage.
  - Bring to bear the training capacity acquired by India
  - Sharing of India's Space segment resources
  - Meets ICAO RNAV goal over Burma.
- **Benefit to India**
  - Helps AAI to expand GAGAN to neighboring countries
  - Demonstrates improved GAGAN performance over East India which is a performance problem area

- **Projected number of sites**

Myanmar	5 sites
Thailand	7sites
Bangladesh	1 site
Nepal	1-2 sites
Indonesia	7 sites
Malaysia	6 sites





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**Thank You**