



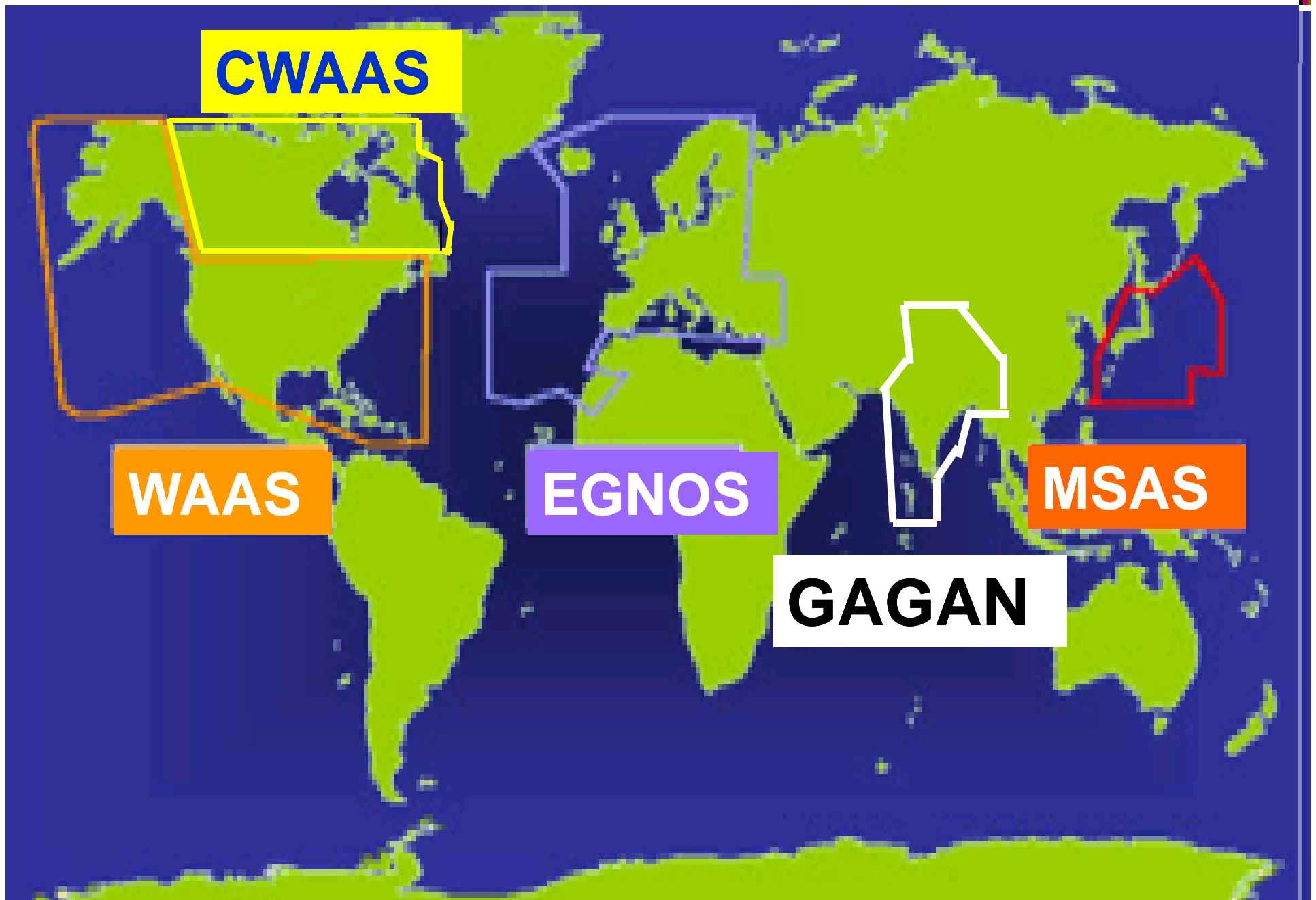
**Indian SBAS – GAGAN  
&  
PBN Implementation**



## GAGAN- INDIAN SBAS PROGRAM

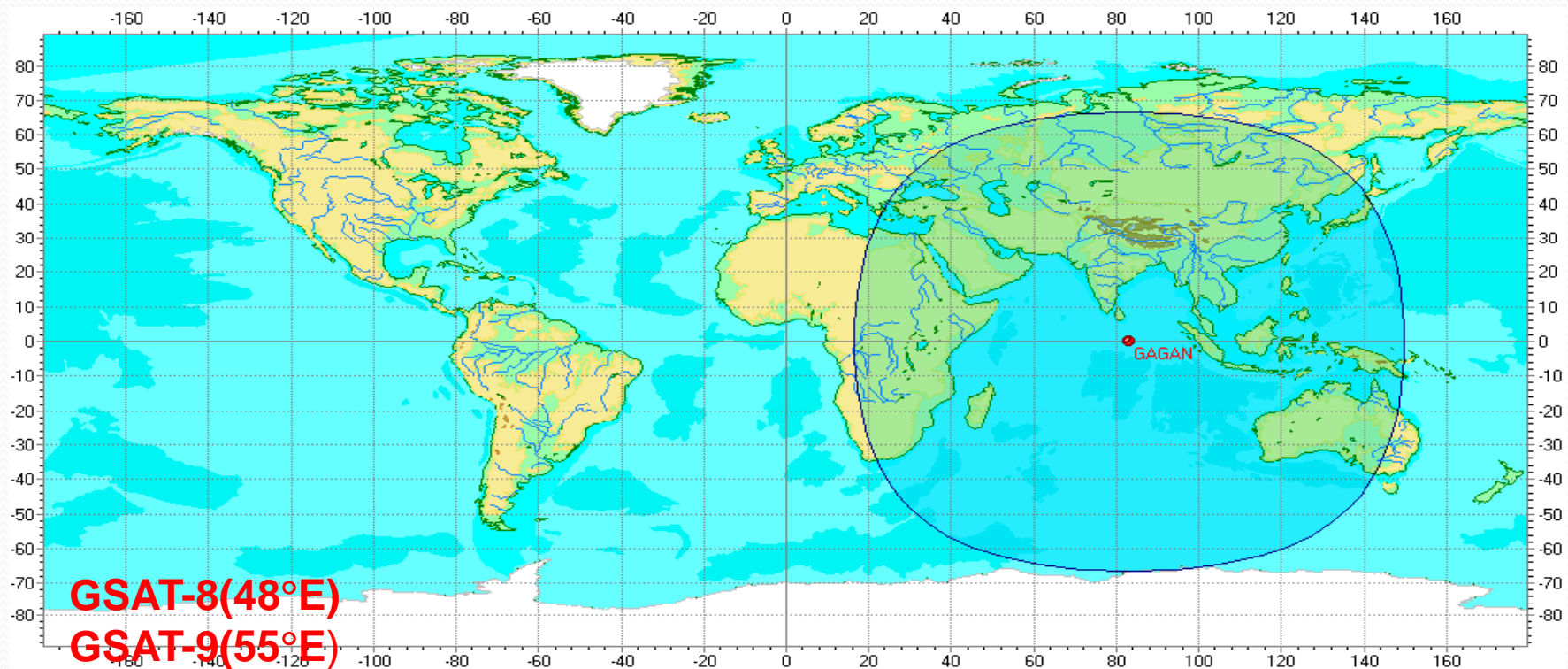
- **GAGAN** (*The sky*) - **G**PS **A**ided **G**EO **A**ugmented **N**avigation
  - is an overlay system built around the GPS
  - jointly Implemented by AAI & ISRO
- To be operational in 2013

# SBAS IN VOGUE



# GAGAN Coverage

- GAGAN will have two GEOs broadcasting corrections simultaneously with almost similar coverage area
- GAGAN will have an in-orbit spare GEO satellite which can be made operational incase of failure of any GEOs
- The PRN nos.(127 & 128) of the GEOs and their placement slots( $84^\circ$ ,  $48^\circ$ ,  $55^\circ$ )have already been obtained from competent authorities



# GAGAN – Ground Segment Elements



INMCC



INRES Antenna



11 Mtr Antenna Subsystem



INLUS - RF Subsystem



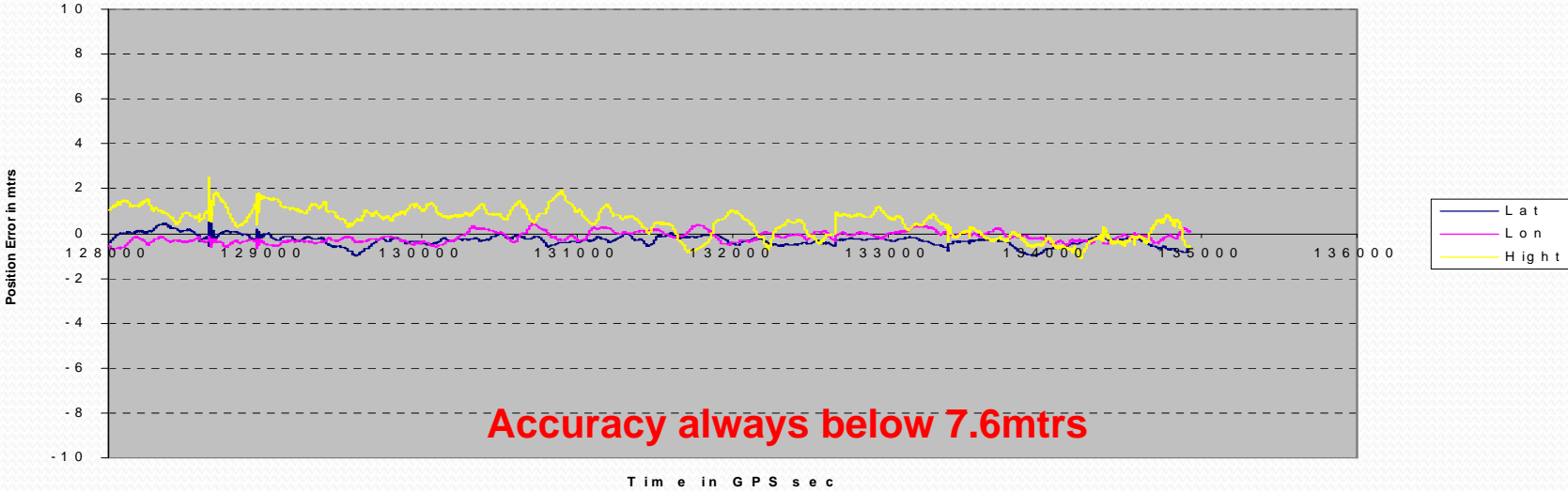
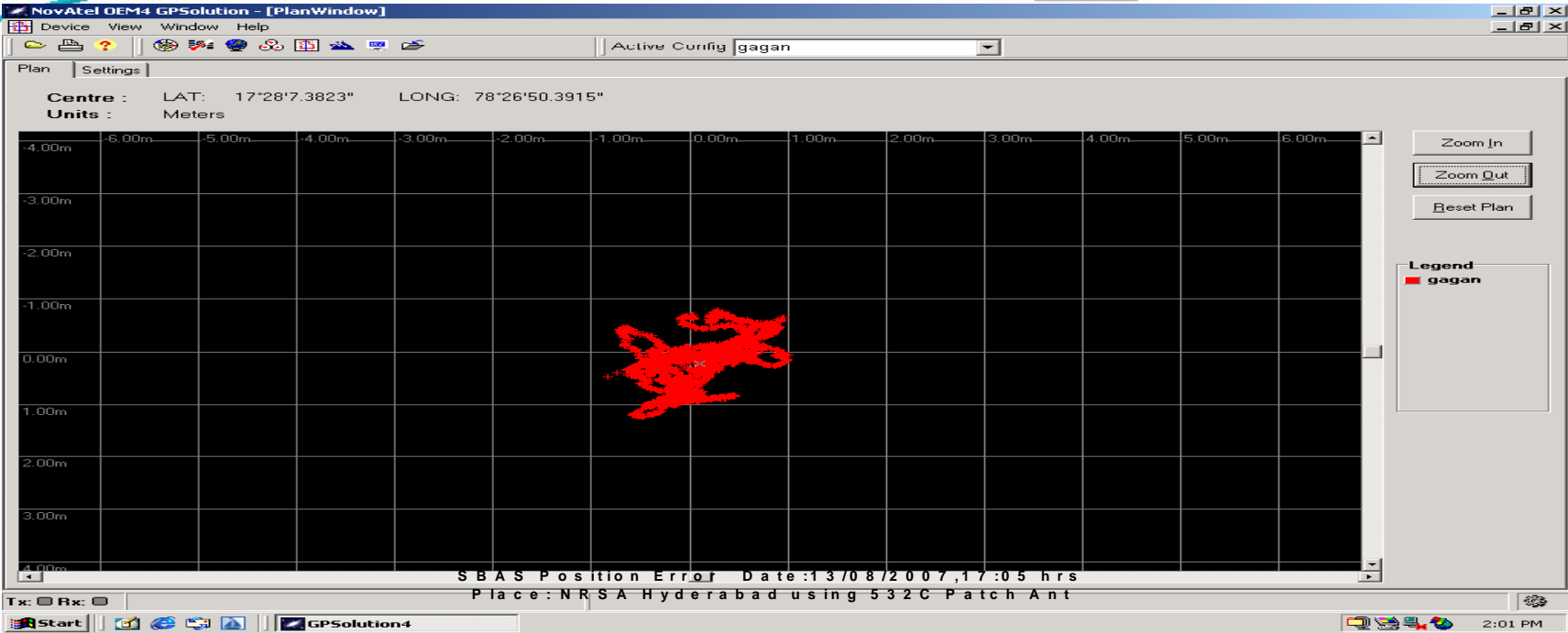
INREE

# Flight Plan (Dynamic Test) using DGPS Stations established by NRSA

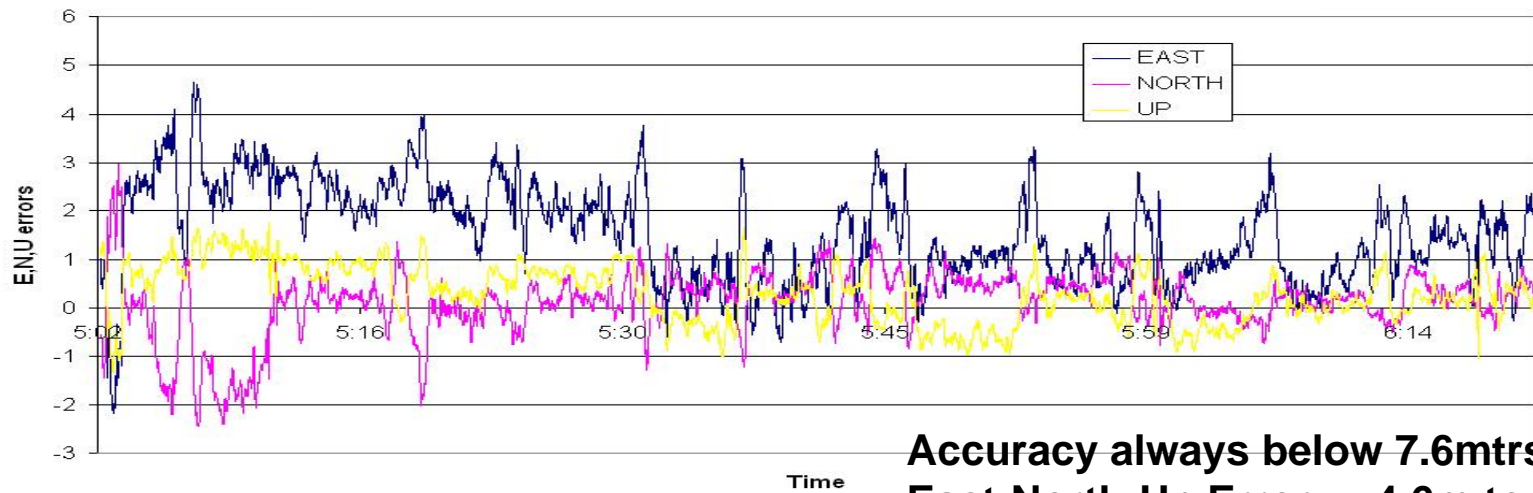
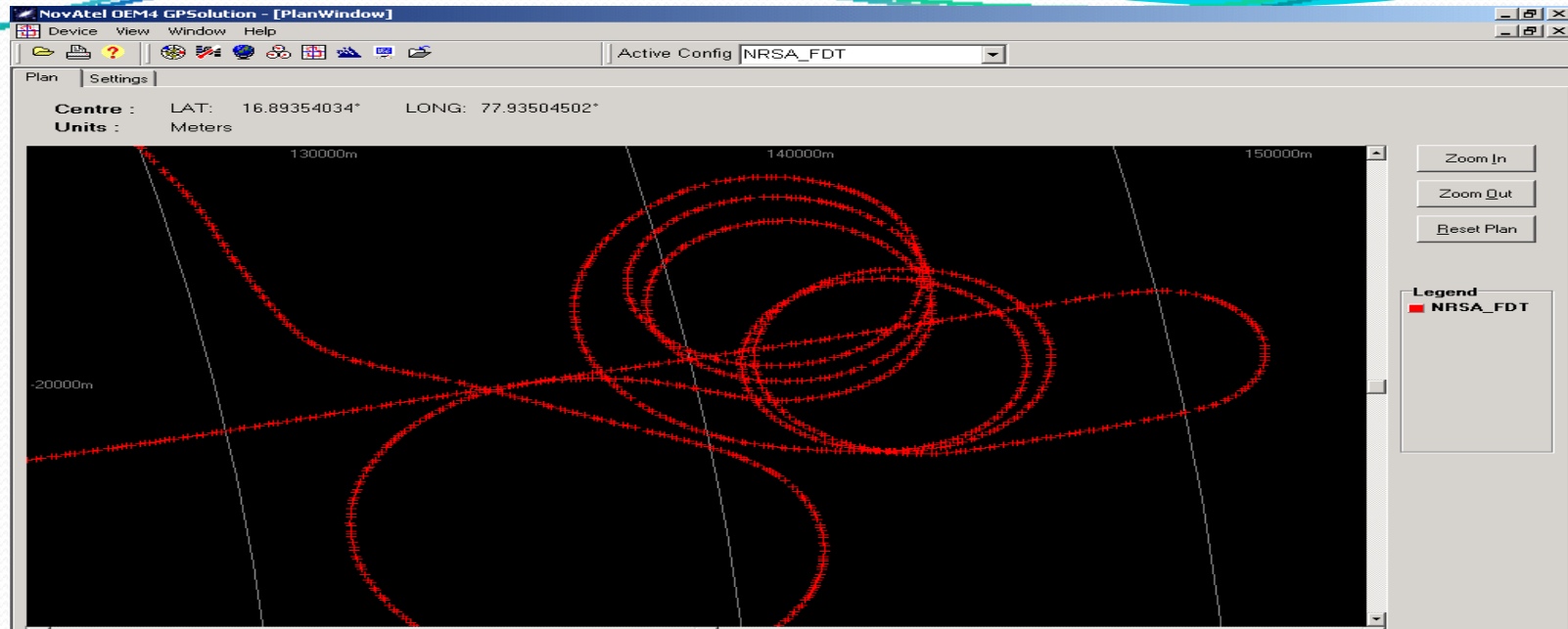
- HYDERABAD (VOHY)
- SHADNAGAR
- NAGAR KURNOAL
- ENIGANNOOR
- ANANTHPUR
- HINDPUR
- BANGALORE (VOBG)



# Static Test results



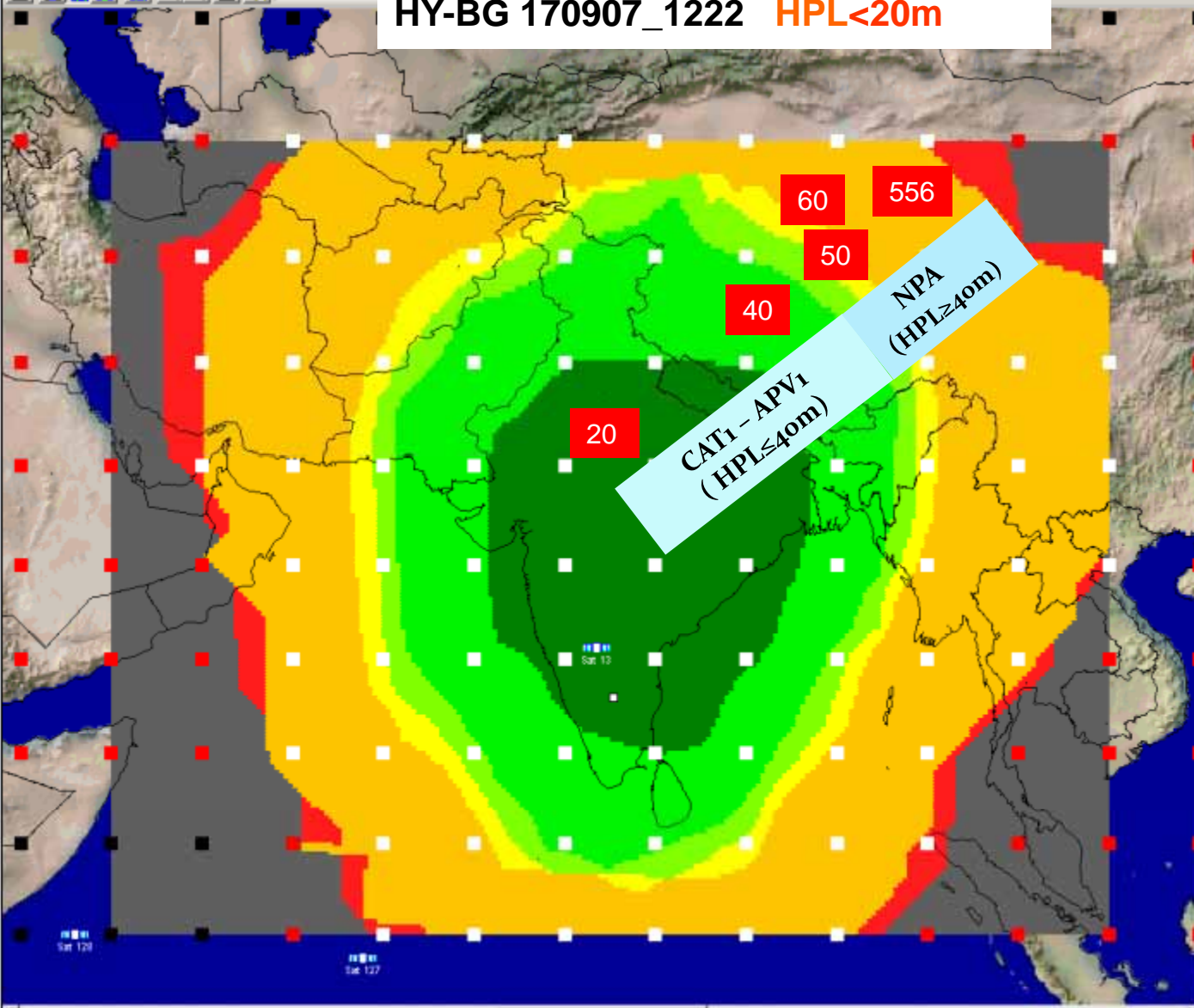
# Dynamic Test results



**Accuracy always below 7.6mtrs**  
**East-North-Up Error : +4.6m to -2.5m**



HY-BG 170907\_1222 HPL<20m



Show Color Legend

- No Data
- Outside GEO Footprint (INSAT1)
- < 20.0000
- < 40.0000
- < 50.0000
- < 60.0000
- < 556.0000
- Out of Range

# ICAO Service level : parameters

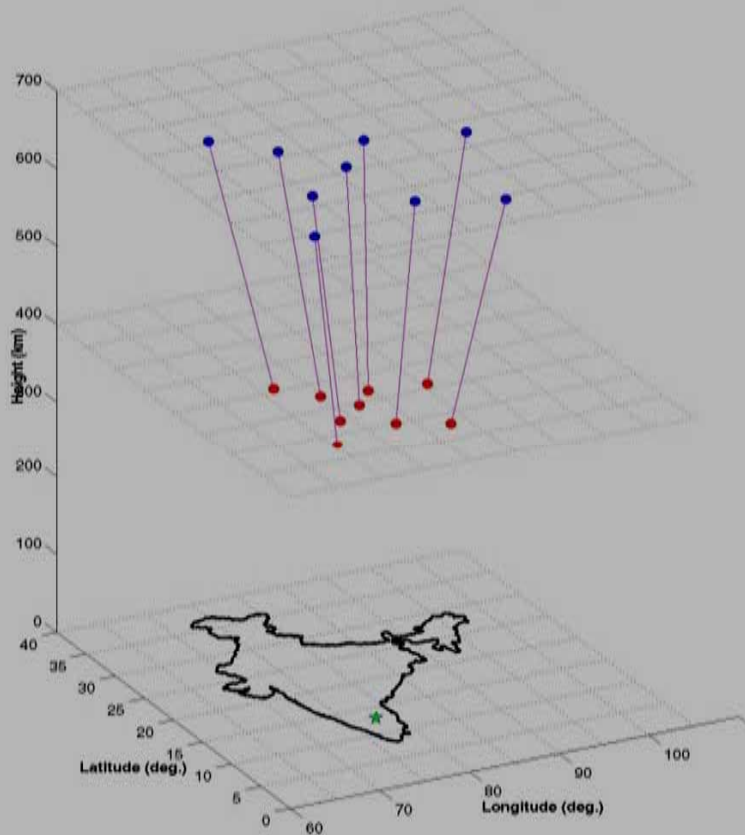
<i>Level of Services</i>	<i>Accuracy</i>	<i>TTA</i>	<i>Integrity</i>	<i>HAL</i>	<i>VAL</i>
En-Route	3.7 Km (H)	5 min	$1 \times 10^{-7}/h$	4NM	N/A
En-Route Terminal	0.74 Km (H)	15S	$1 \times 10^{-7}/h$	1 NM	N/A
<b>NPA / LNAV (RNP 0.3) MSAS</b>	<b>220 m (H)</b>	<b>10 S</b>	<b><math>1 \times 10^{-7}/h</math></b>	<b>556m</b>	<b>N/A</b>
<b>RNP 0.1 (Initial Level of Service for GAGAN FOP)</b>	<b>72 m (H)</b>	<b>10 S</b>	<b><math>1 \times 10^{-7}/h</math></b>	<b>185m</b>	<b>N/A</b>
APV1.0 (LNAV/VNAV*)	16 m (H) 20 m V	10 S	$1 \times 10^{-7}/app$	40m(556m*)	50 m
<b>APV1.5 (LPV) (Final Level of Service for GAGAN FOP)</b>	<b>16 m (H) 20 m V</b>	<b>6S</b>	<b><math>1-2 \times 10^{-7}/ app</math></b>	<b>40m</b>	<b>50 m</b>
APV 2	16 m (H) 8 m V	6S	$1-2 \times 10^{-7}/ app$	40m	20 m
<b>CAT 1 (LPV200) WAAS</b>	<b>16 m (H) 4 m (V)</b>	<b>6S</b>	<b><math>1-2 \times 10^{-7}/ app</math></b>	<b>40m</b>	<b>15-10 m</b>

## GAGAN Service levels

<b>Approach Category</b>	<b>Flight Phase</b>	<b>Accuracy</b>	<b>Time to Alert</b>	<b>HAL</b>	<b>VAL</b>	<b>Expected Date of Completion</b>
<b>RNP 0.1</b>	<b>En-route</b>	<b>85 m</b>	<b>N/A</b>	<b>185 m</b>	<b>N/A</b>	<b>June 2013</b>
<b>APV 1.5</b>	<b>Precision Approach</b>	<b>7.6 m</b>	<b>6 sec</b>	<b>40 m</b>	<b>50 m</b>	

# GAGAN MLDF Algorithm

Instantaneous IPP Distribution for Bangalore INRES



IPPs delay and confidence at 250 km shell height

GIVD and sigma fit computation at 250 km shell height

IPPs delay and confidence at 450 km shell height

GIVD and sigma fit computation at 450 km shell height

Transform/ Scale

Data Fusion

GIVD, GIVE at 350 km shell height

**GIVE  
MONITOR**

## MLDF (Multi Layer Data Fusion):

- New Multi layer Grid Based Model that minimizes limitations of single layer model
- Uses Data Fusion Technique for lesser GIVE
- Provides GIVD, GIVE at 350 km (as per MOPS) – THIS MODEL DOES NOT CALL FOR MOPS



## ICAO Approach Types

- Non-Precision Approach (NPA)
  - Lateral Guidance Only
- Approach with Vertical Guidance (APV)
  - Lateral and Vertical Guidance
  - Two Types –
    - APV/Baro-VNAV
    - APV-I and II supported by SBAS
- Precision Approach (PA)
  - Lateral and Vertical Guidance
  - Levels of Performance (Cat I, II and III)



## APV based on SBAS

- As a backup when ILS is unserviceable or withdrawn to maintain arrival capacity
- Improve flexibility of approach procedure design, provide APV on secondary runways
- Sites with environmental constraints

## Implementation Methodology

- Identify Airport and Operator and try to implement an APV procedure. Initially this will be done for a sample set of airports.
- Procedures will be designed and flight demonstrations performed.
- Flight Checks will be performed to ensure:
  - Path Definition is correct
  - Required obstacle clearance is available
  - GNSS & SBAS coverage is available
- Procedures are promulgated.

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# **PBN Implementation in India**



## PBN Implementation - 1

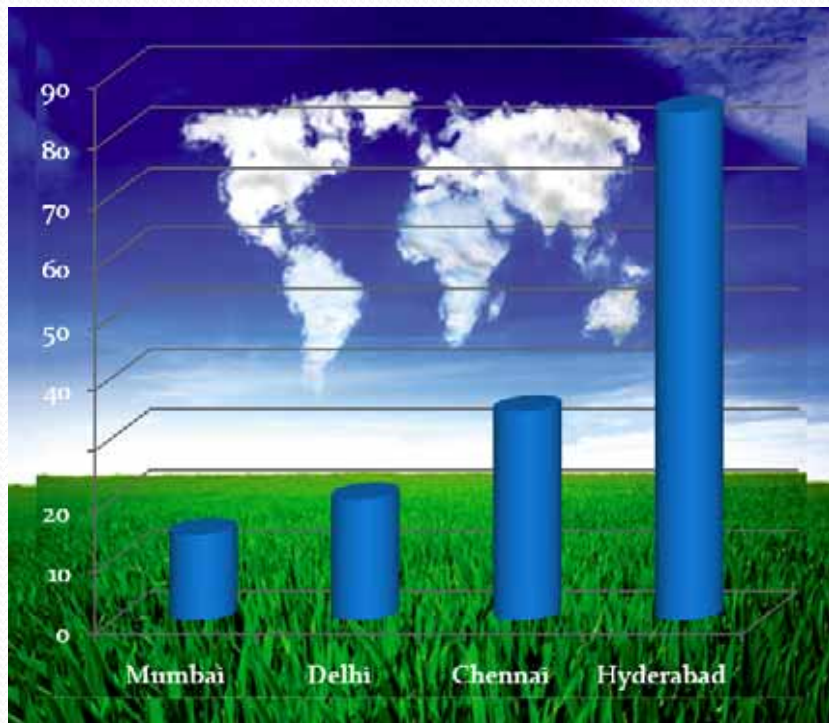
- RNAV-1 SIDs and STARs implemented at:
  - New Delhi, Mumbai & Ahmadabad in 2008
  - Chennai in 2009
  - Hyderabad International in 2010
  - Kolkata & New Delhi (Revised) in 2011



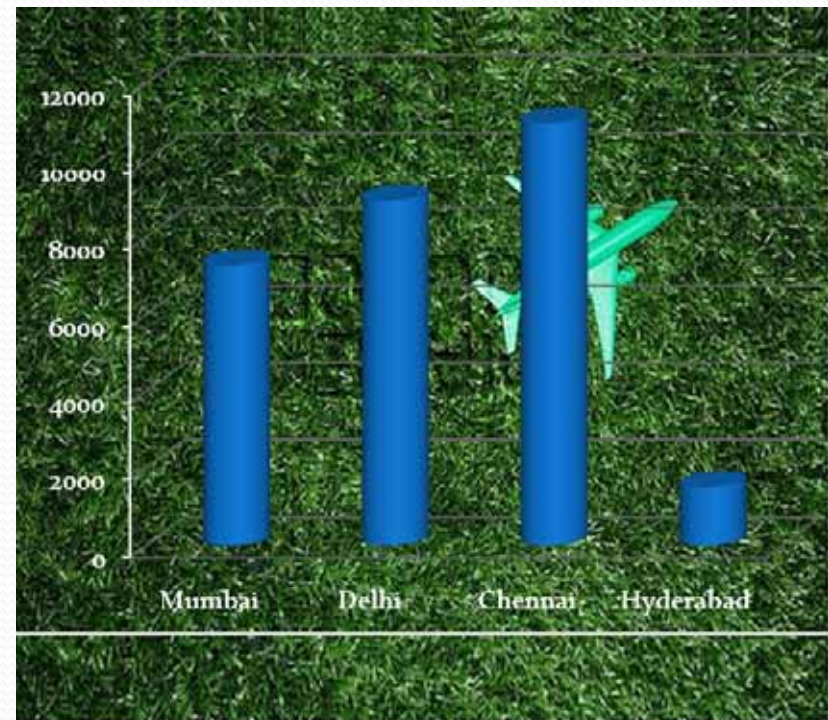
## PBN Implementation - 2

- RNP-1 STARs and Baro-VNAV Approach procedure to be implemented in 2011:
  - Cochin International (*Jointly done by DGCA, AAI & Quovadis*)
- RNP-1 SID & STARs and Baro-VNAV Approach procedure:
  - Calicut
  - Coimbatore
- Baro-VNAV Approach procedures:
  - Bangalore International (Rwy 09/27)
  - Hyderabad International (Rwy 09/27)
  - Ahmadabad International (Rwy 05/23)
  - Mumbai International (Rwy 09/14/27)

# Benefits

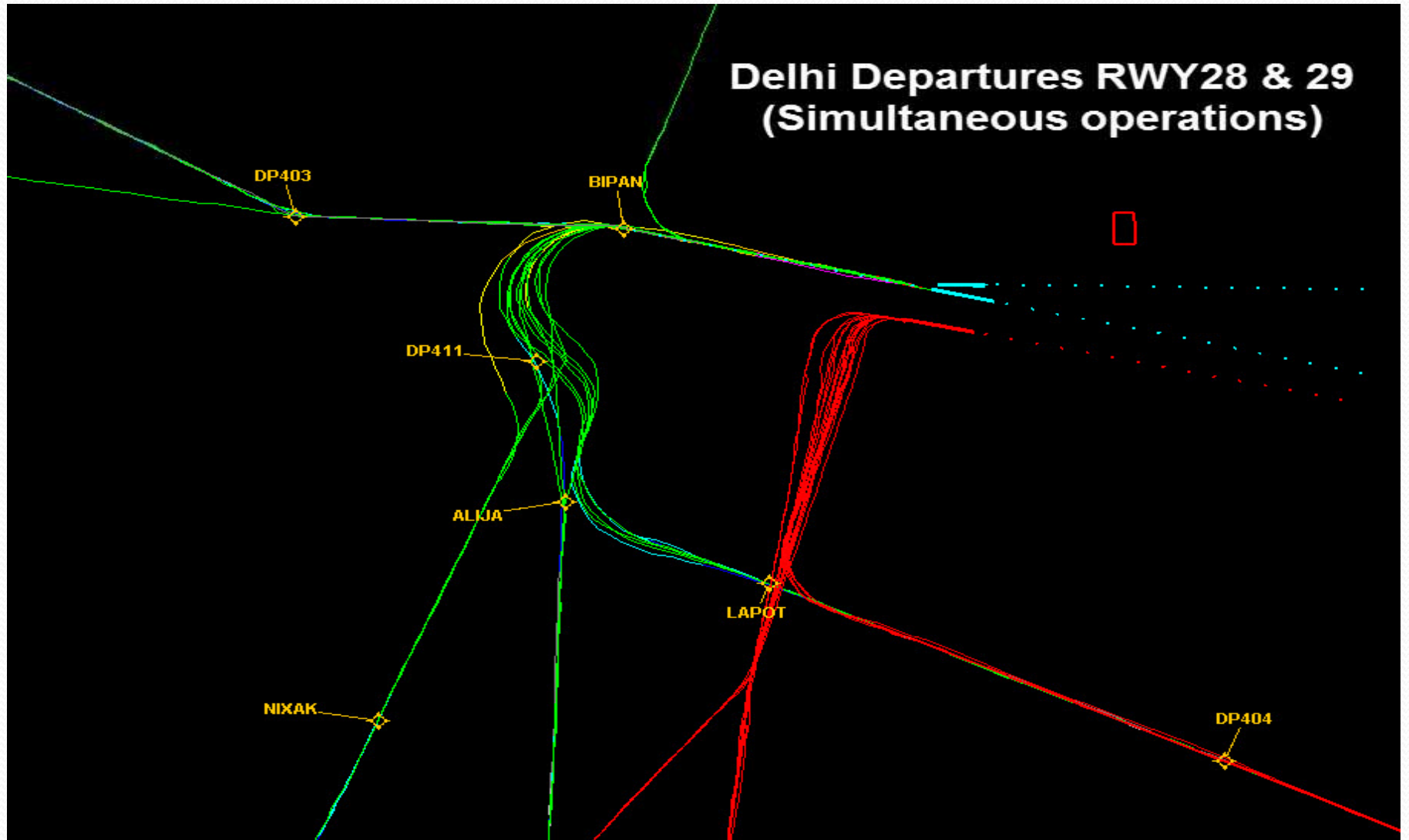


Track Miles saved per day

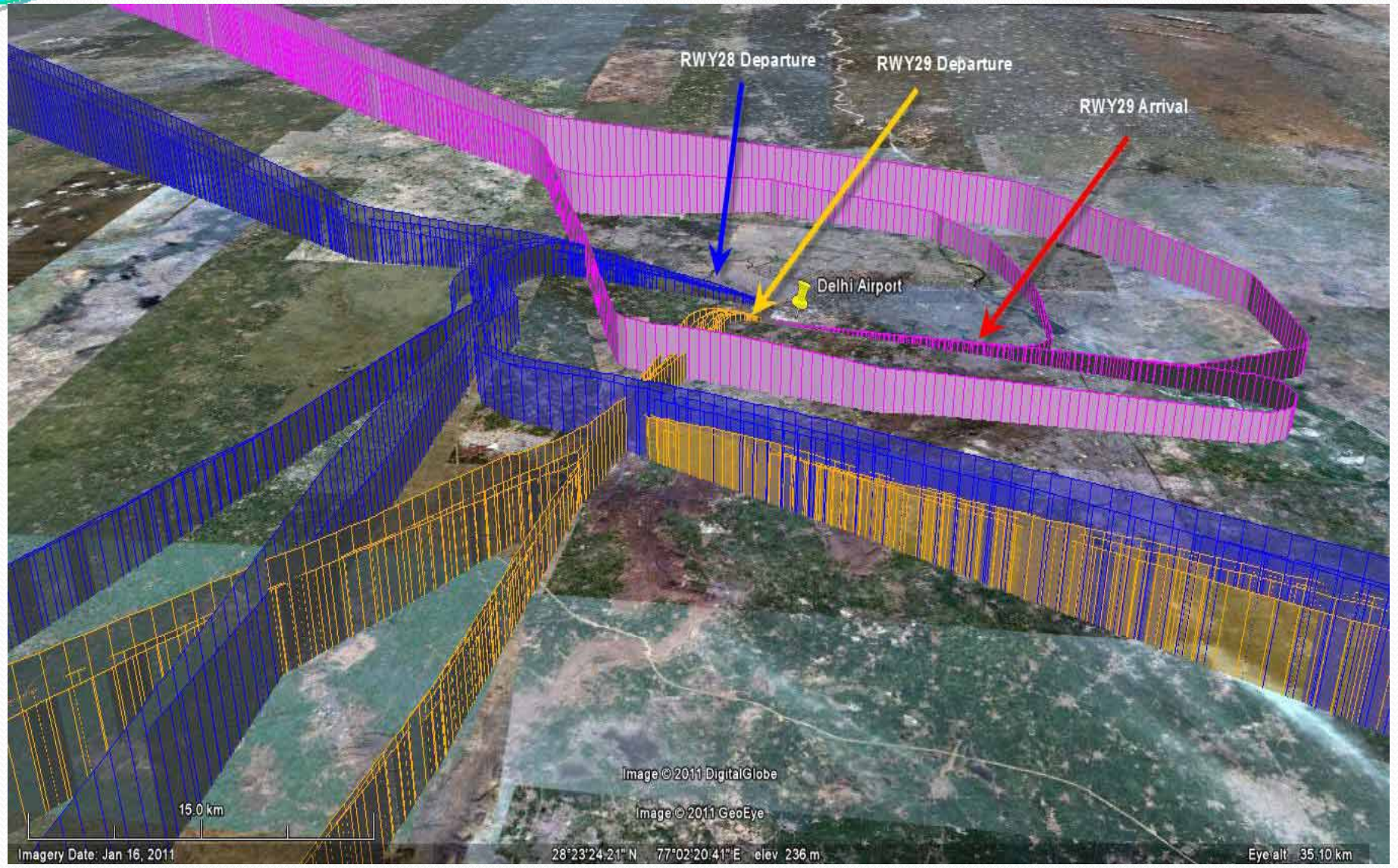


Kilo-liter of fuel saved per annum

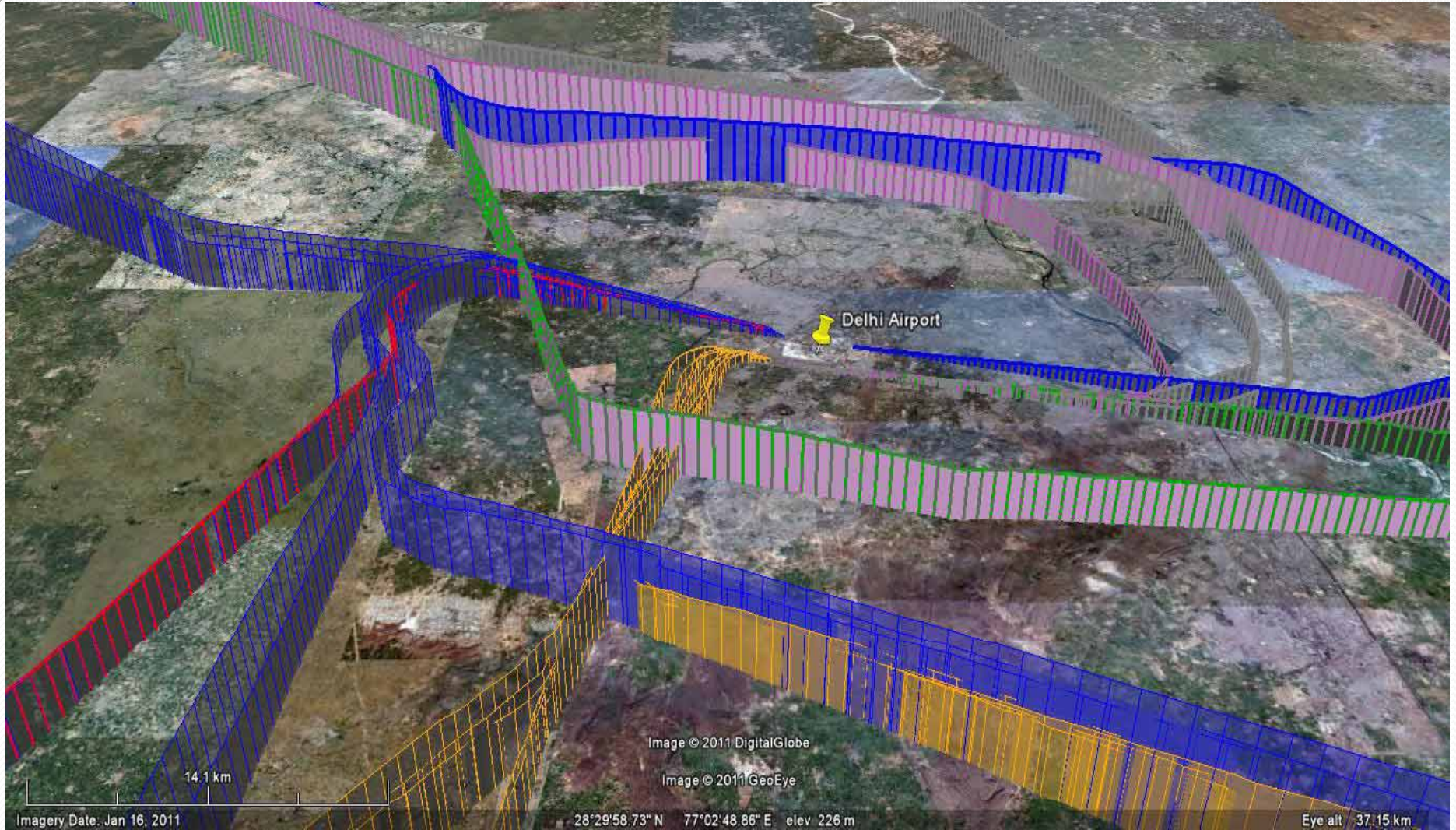
# Delhi-Simultaneous Departure RWY28 & 29



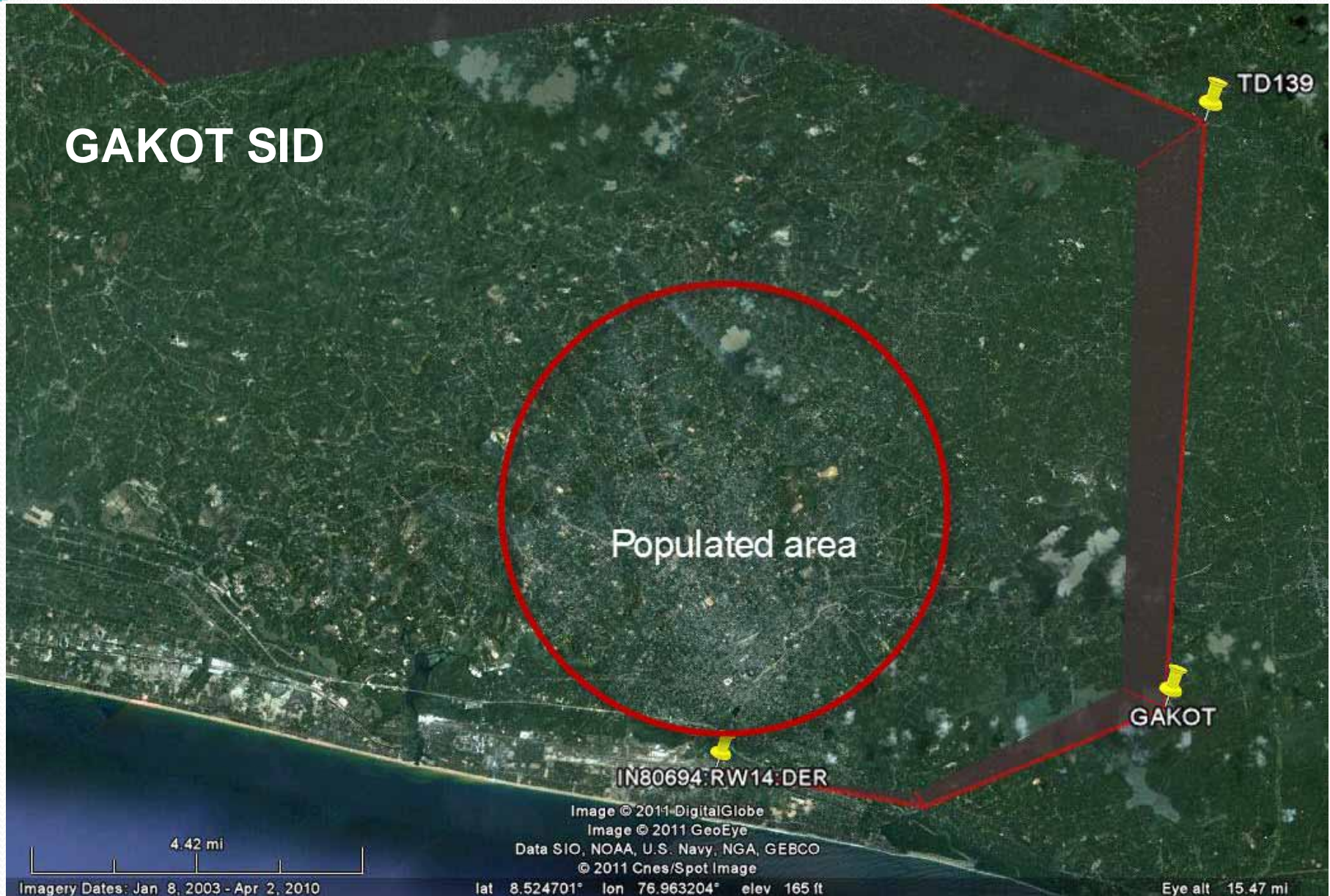
# Delhi SID-STAR Interaction



# Delhi SID-STAR interaction

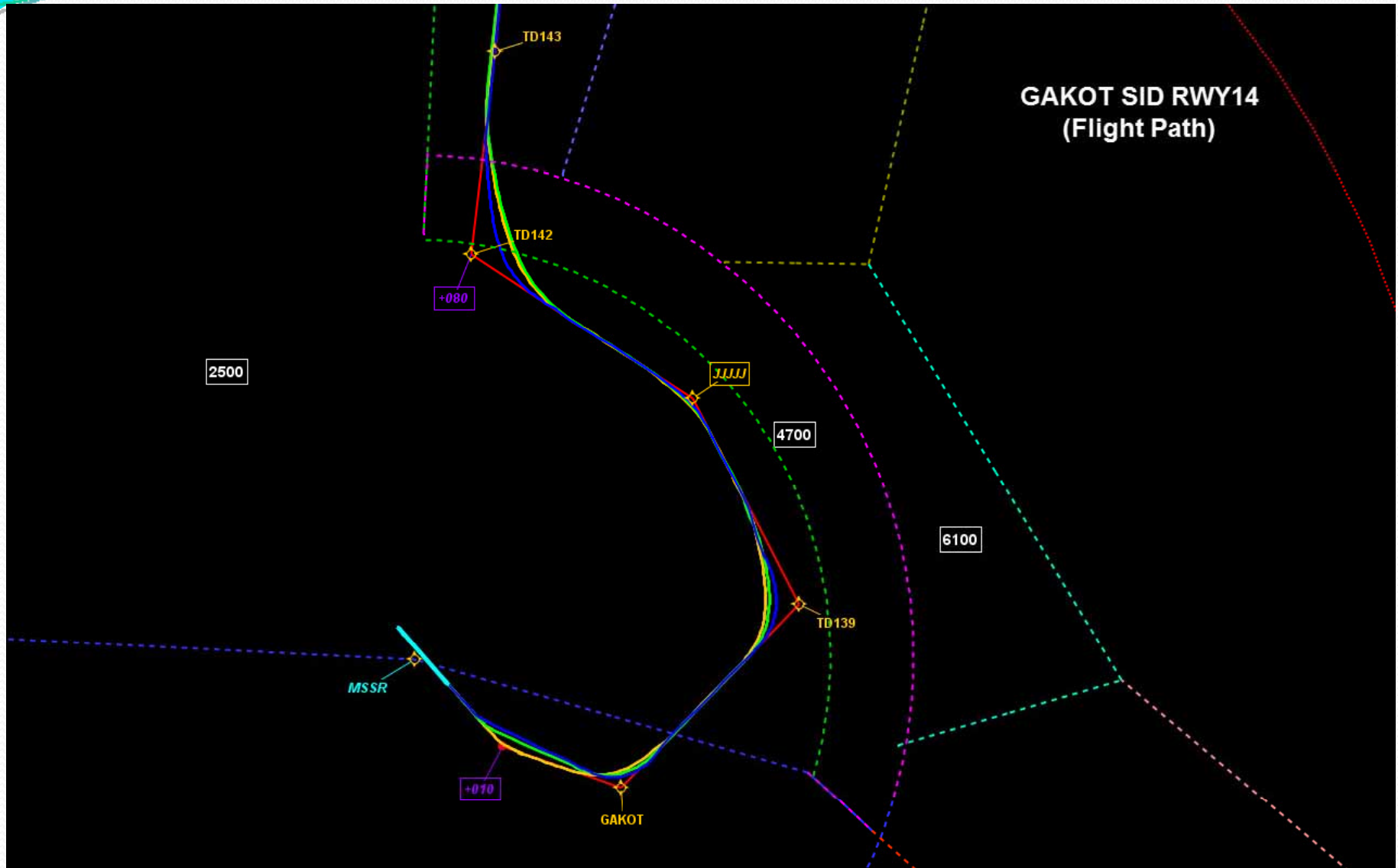


# Thiruvananthapuram RNAV-1 development

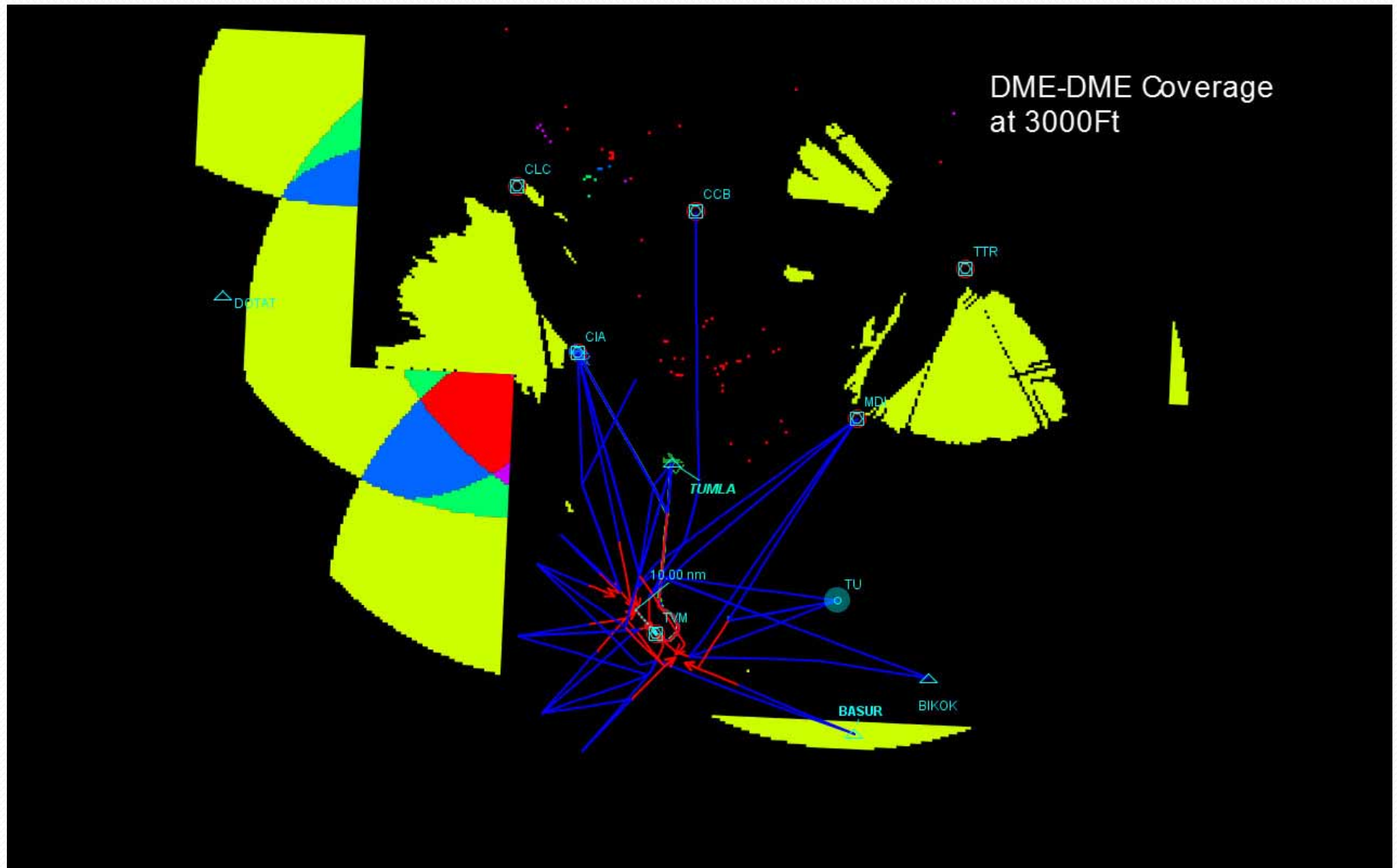




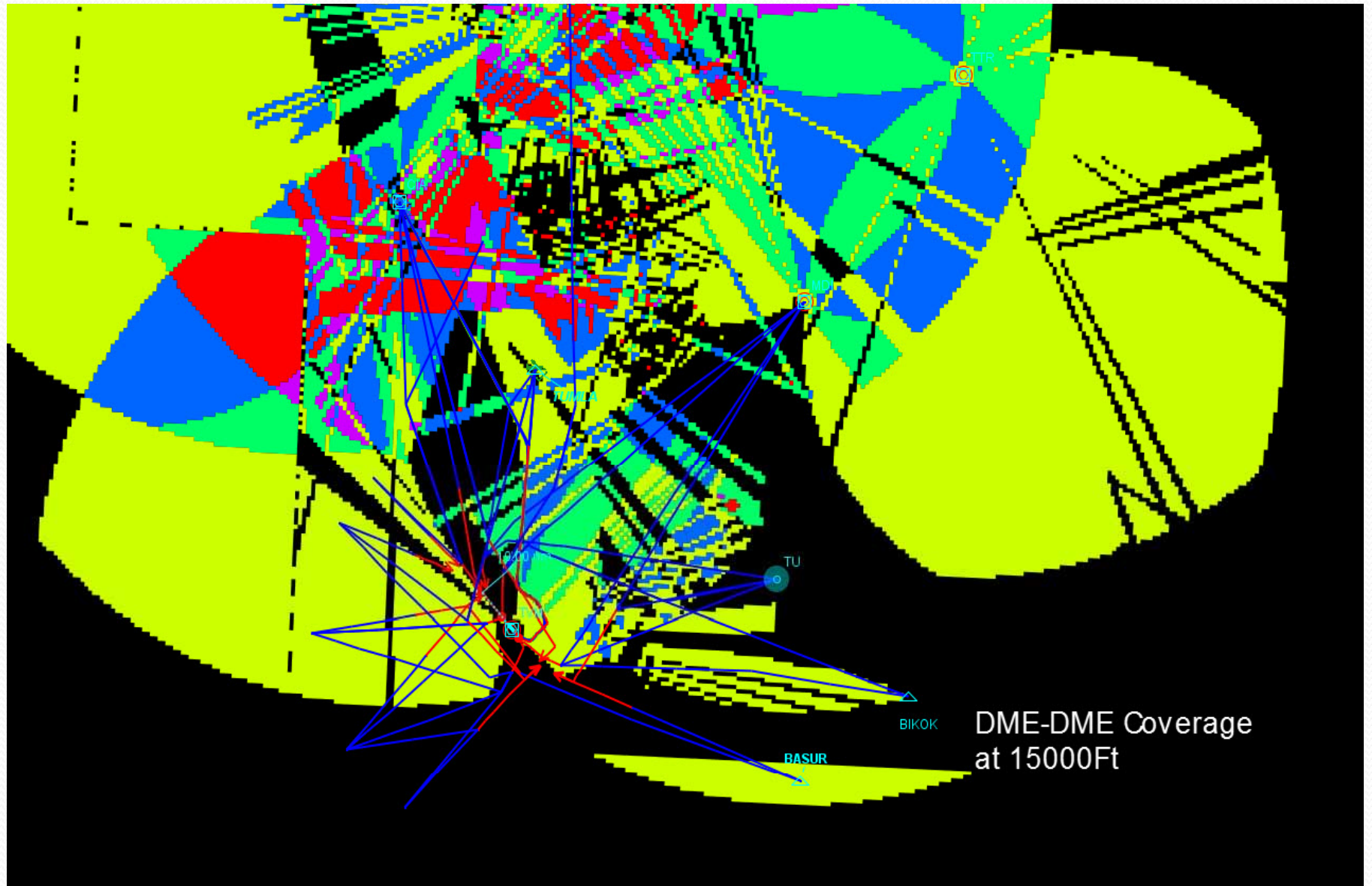
# Thiruvananthapuram RNAV-1 development



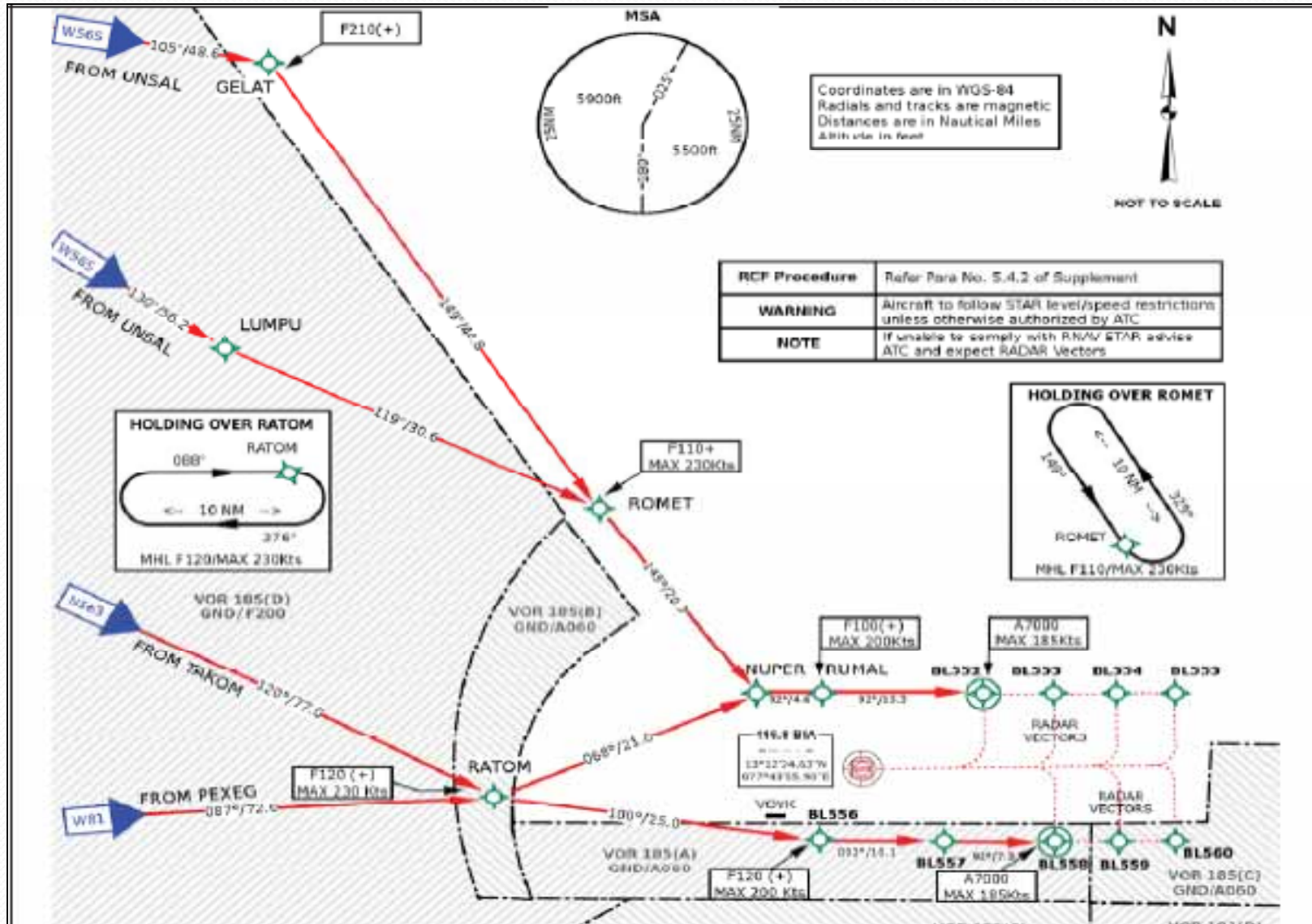
# DME-DME Coverage Analysis-1



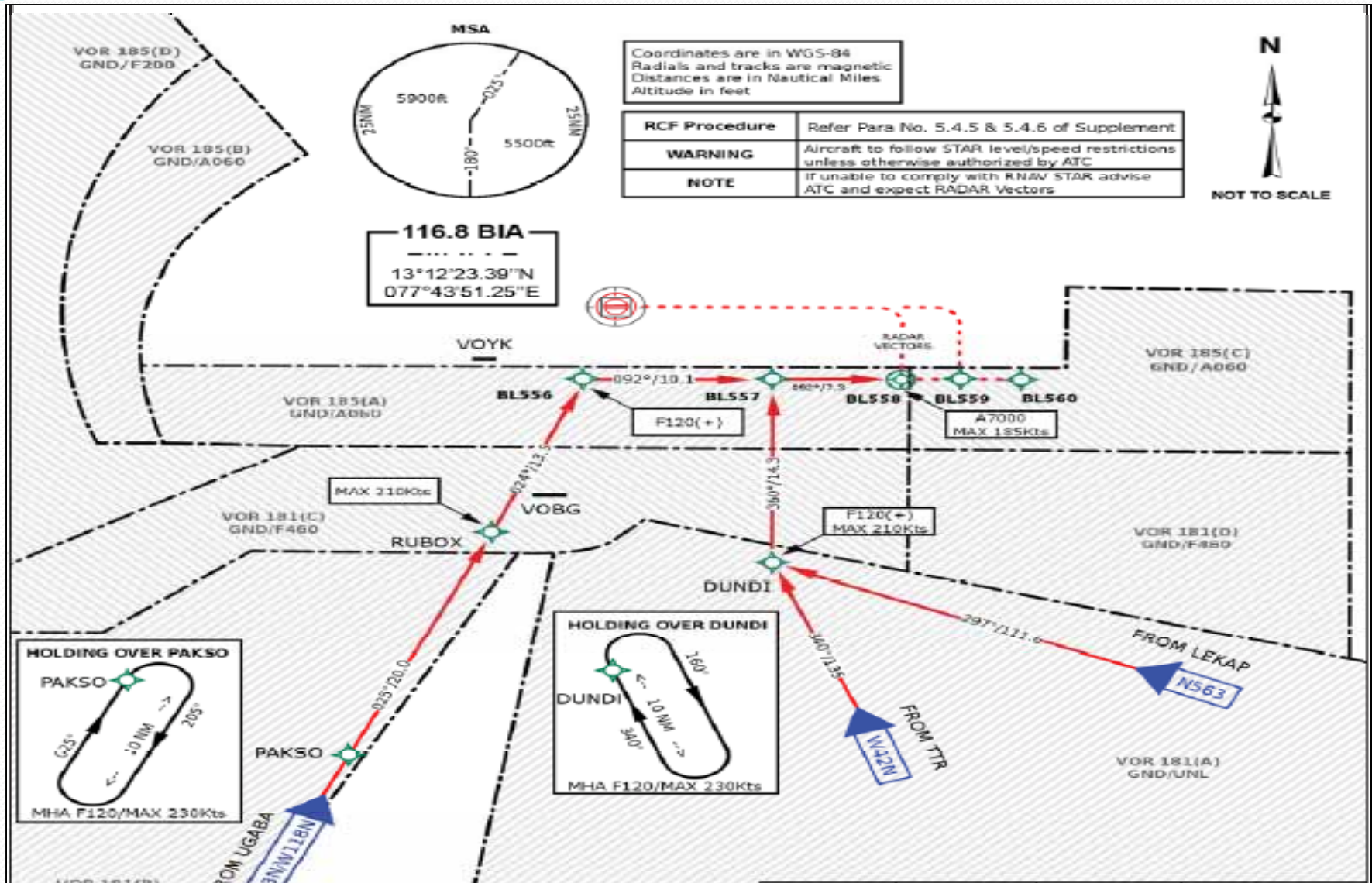
# DME-DME Coverage Analysis-1



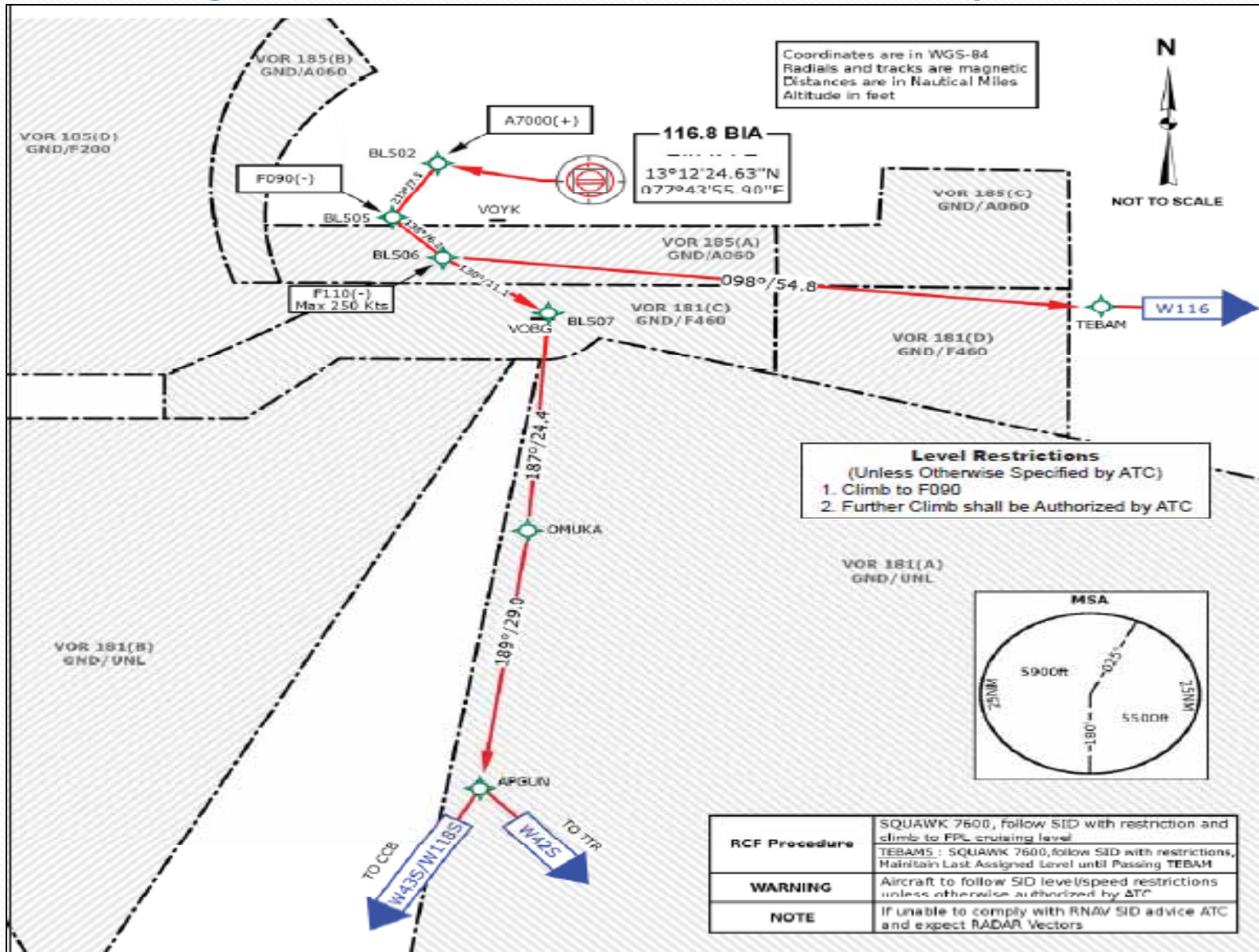
# Bangalore International RNAV-1 Implementation



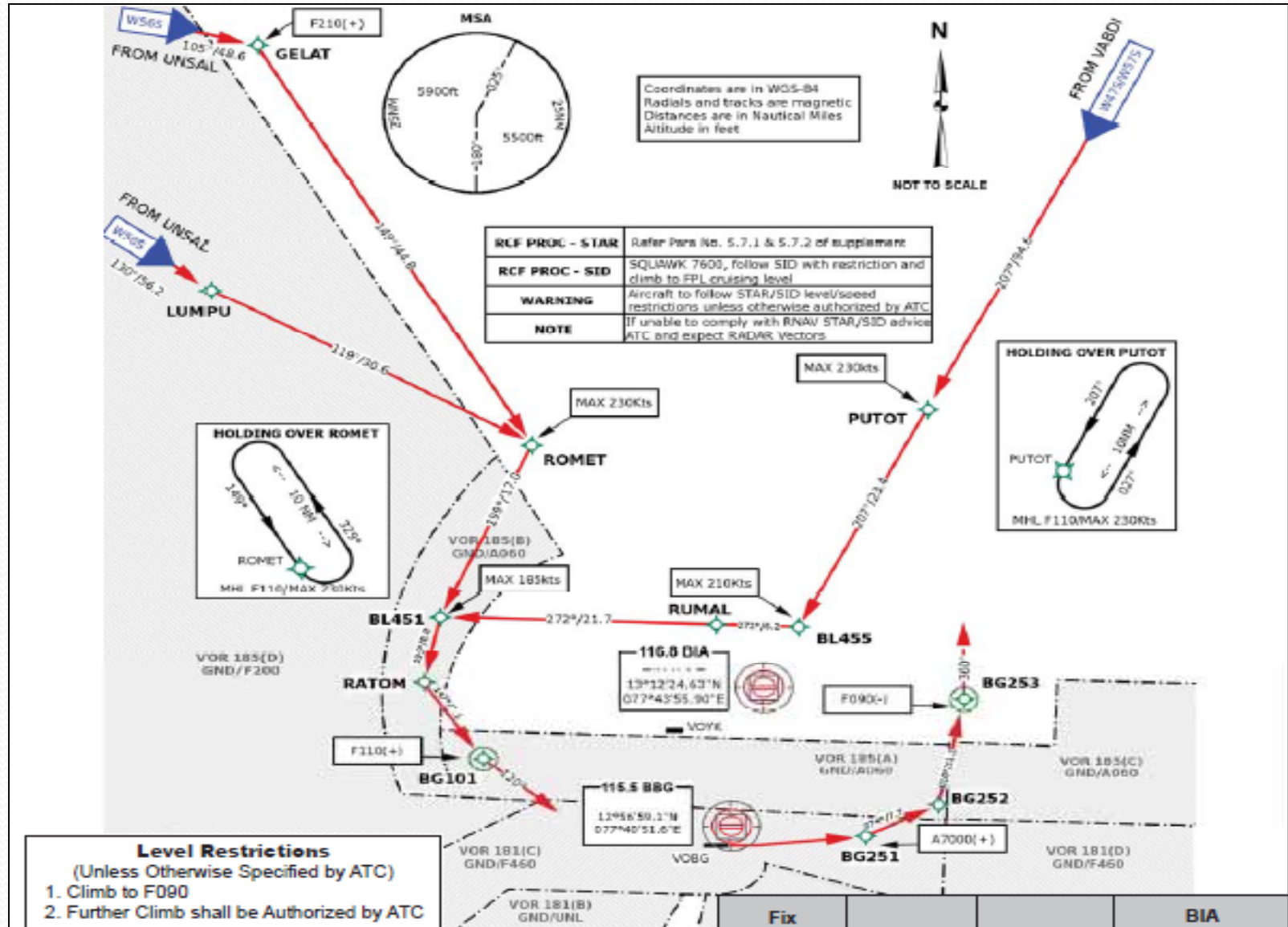
# Bangalore International RNAV-1 Implementation



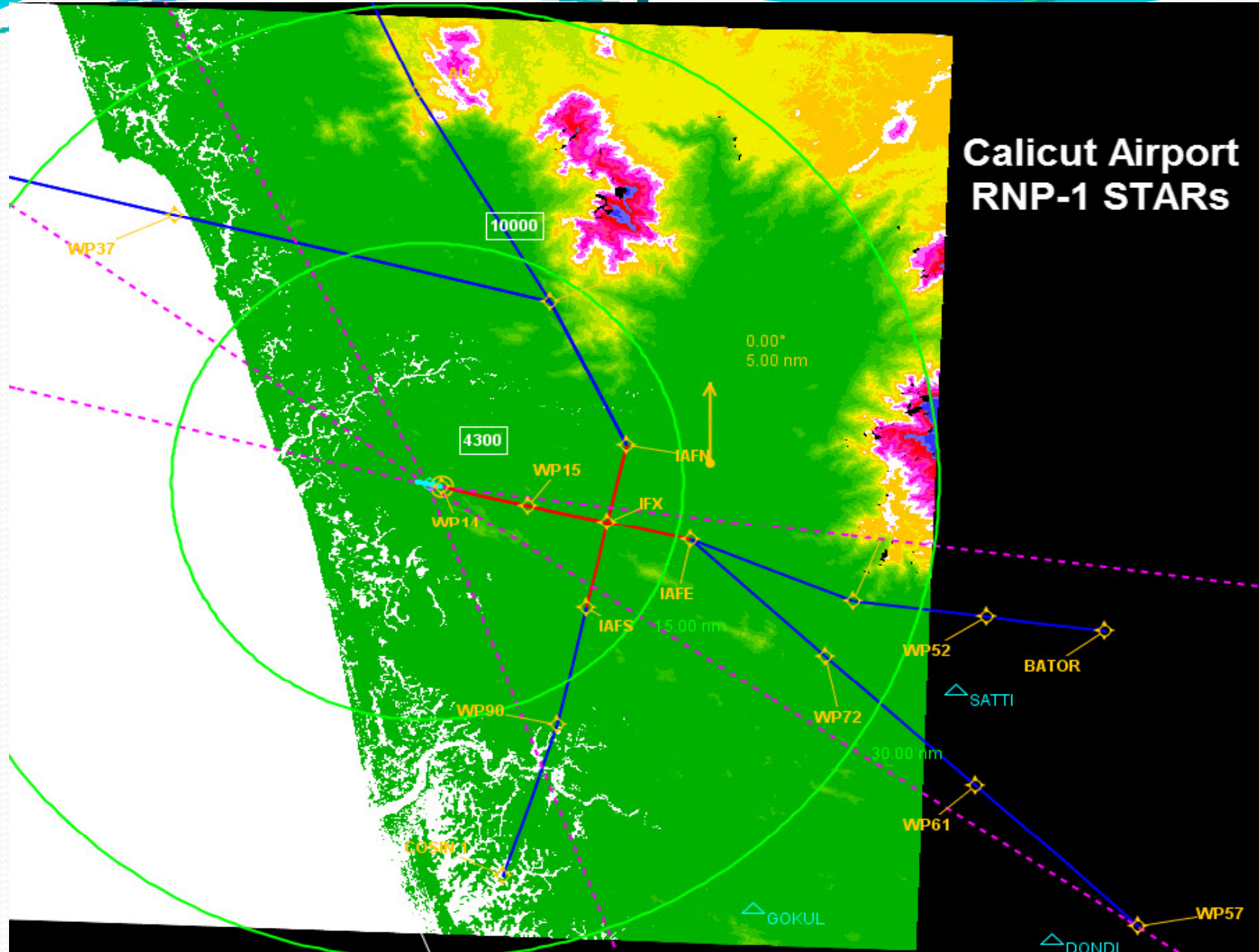
# Bangalore International RNAV-1 Implementation



# Bangalore International RNAV-1 Implementation



# Calicut Airport RNP-1 STARs







# Summary

- PBN procedures provide design flexibility thus making flight paths and climb/descent profiles efficient.
- Consistency of flight tracks and management of vertical profiles can be use to optimize airspace usage.
- Accuracy of flight RNAV flight paths have provided the flexibility to the designer to overcome environmental and/or terrain constraints in the airspace.



THANK YOU