POSITION, NAVIGATION AND TIMING

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Global Navigation Satellite System (GNSS)

This satellite based system is called the Global Navigation Satellite System or GNSS. GNSS comprises of following core systems.

- Global Positioning System (GPS) provided and maintained by US Department of Defence has been in operation since 1995
- Global Navigation Satellite System (GLONASS) has been provided and is being maintained by Ministry of Defence, Russian Federation.
- Beidou Navigation System by China. Two satellites were launched in 2000. It is a mix of Medium Earth Satellites and Geo-stationary satellites.
- Galileo, a civil system proposed by European Union with 30 Medium Earth Satellites by 2008

Global Navigation Satellite System (GNSS)

- GNSS provides the primary signals, which can be used by GNSS receiving equipment anywhere on the earth’s surface or in the space to derive position, navigation and timing services.
- RNSS does the same but over a limited portion of the globe.
- SBAS provide an integrity signal which alerts the GNSS receiving equipment if the GNSS or RNSS they are using exhibit a fault.
- SBAS are designed primarily for the safe navigation of commercial aircraft but have a wide range of other users, as SBAS also improves the accuracy of the user’s position

Global Navigation Satellite System (GNSS)

- GNSS comprise constellations of 24 to 32 mid-earth orbiting (MEO) satellites.

- RNSS constellations are smaller (3-7) and can be both MEO and geostationary (GEO) satellites.

- SBAS only consist of geostationary satellites.
  - An SBAS will typically broadcast from 2 or 3 GEO to provide area coverage and signal redundancy.
  - Most existing SBAS satellites (including WAAS, EGNOS and GAGAN) use commercial GEO communications satellites with an additional L-band payload for navigation services

Applications of GNSS

- Aviation is an example of an industry sector which has developed a range of specific skills in GNSS:
    - Pilot training in GNSS theory, use of airborne equipment and licensing, endorsement and flying currency requirements;
    - Engineers engaged to develop technical standards for radio frequency management, signal in space specifications and airborne equipment specifications;
    - Avionics technicians trained in the installation and maintenance of airborne equipment; and
    - Air Traffic Controllers trained in the use of GNSS technology for navigation and surveillance applications.
- The skill base associated with space and satellite technologies in the university and research sectors is broadly spread across geosciences, geography, geospatial, a variety of engineering sciences, electrical and IT, and the physical sciences.

Applications of GNSS

- existing SBAS in North America and Europe (WAAS and EGNOS) are used extensively by non-aviation users including marine and land transport, agriculture and the geospatial industry.
- For example, the EU estimates that of the 240,000 agricultural tractors expected to be fitted with GNSS by 2012 nearly 70% will be EGNOS capable.
- The economic benefits of EGNOS to agriculture alone are estimated at €6 Billion by 2030.

Global Positioning System (GPS)

- The first generation of a global space-based Positioning, Navigation and Timing (PNT) utility

  - is a critical component of transport, energy and communications infrastructures and

  - established itself as a key smart technology for increasing the productivity of ports, mines, farms and construction sites.

Decade ahead is for Multi constellation

- During this decade, PNT2.0 will emerge as a "system of systems"

- It will include an

  - upgraded GPS along with Global Navigation Satellite Systems (GNSS)

  - Regional Navigation Satellite Systems (RNSS) from Russia, Europe, China, India and Japan.

India – PNT infrastructure

- India under GNSS plan has invested in developing :
- GAGAN (GPS Based Geo Augmented Navigation) to primarily provide integrity, accuracy, availability and continuity to meet aviation standards and can be used for multi modal operations.
- IRNSS (Indian Regional Navigation Satellite Systems) mainly provided for defence applications.
- The infrastructure will provide huge business opportunities for both aviation and non aviation, defence and civilian utilities particularly in geo spatial applications.
- The PNT 2 investments will have tremendous opportunities covering from Australia to Africa under the footprint of Indian Satellites
- Taken up with neighbouring countries for extending GAGAN signals wherever Augmented signal footprint is available

Current PNT Service Providers

	USA	Russia	China[7]	EU	India	Japan
GNSS	GPS	GLONASS	Compass	Galileo		
RNSS			BeiDou		IRNSS	QZSS
SBAS	WAAS	SDCM	MASS	EGNOS	GAGAN	MSAS

Table 1: Current and planned PNT space assets

Sources of Error

- **Control Segment Errors**
  - **Satellite Clock Bias**
  - **Ephemeris prediction error**
- **Receiver Clock Bias**
- **Propagation uncertainty**
  - **Ionospheric Delay**
  - **Troposheric Delay**
- **Multipath and Receiver Noise**

Pseudo Range = Range + Receiver Clock Bias + Ephemeris & Clock Error + Ionospheric & Tropospheric Delay + Multipath & Receiver Noise

Probable Solutions

Control Segment Errors (Clock bias and Ephemeris Errors)

Correction can be provided by taking the observations at pre-surveyed stable points. By comparing the observed positional information as given by GPS configuration and the known accurate positional information got by survey, correction for both clock bias and ephemeris error can be know for each satellite.

Propagation Uncertainty (Ionospheric and Tropospheric delays)

By taking measurement on both L1 and L2 simultaneously, calculating the time difference between the receipt time of L1 and L2, a model can be created in terms of delay difference and ionopheric width.

Availability and Continuity

By providing ranging source in additional satellites, for example in the Geo-stationary satellites, the availability and continuity can be increased

Why Augmentation

Current GNSS core constellation cannot support Requirements for All Phases of Flight

- **Integrity is not Guaranteed**
  - ❖ All satellites are not monitored at all times
  - ❖ Time-to-alarm could be from minutes to hours
  - ❖ No indication of quality of service to the user

- **Accuracy is not sufficient**
  - ❖ Even after SA removal, Vertical Accuracy is more than 10m

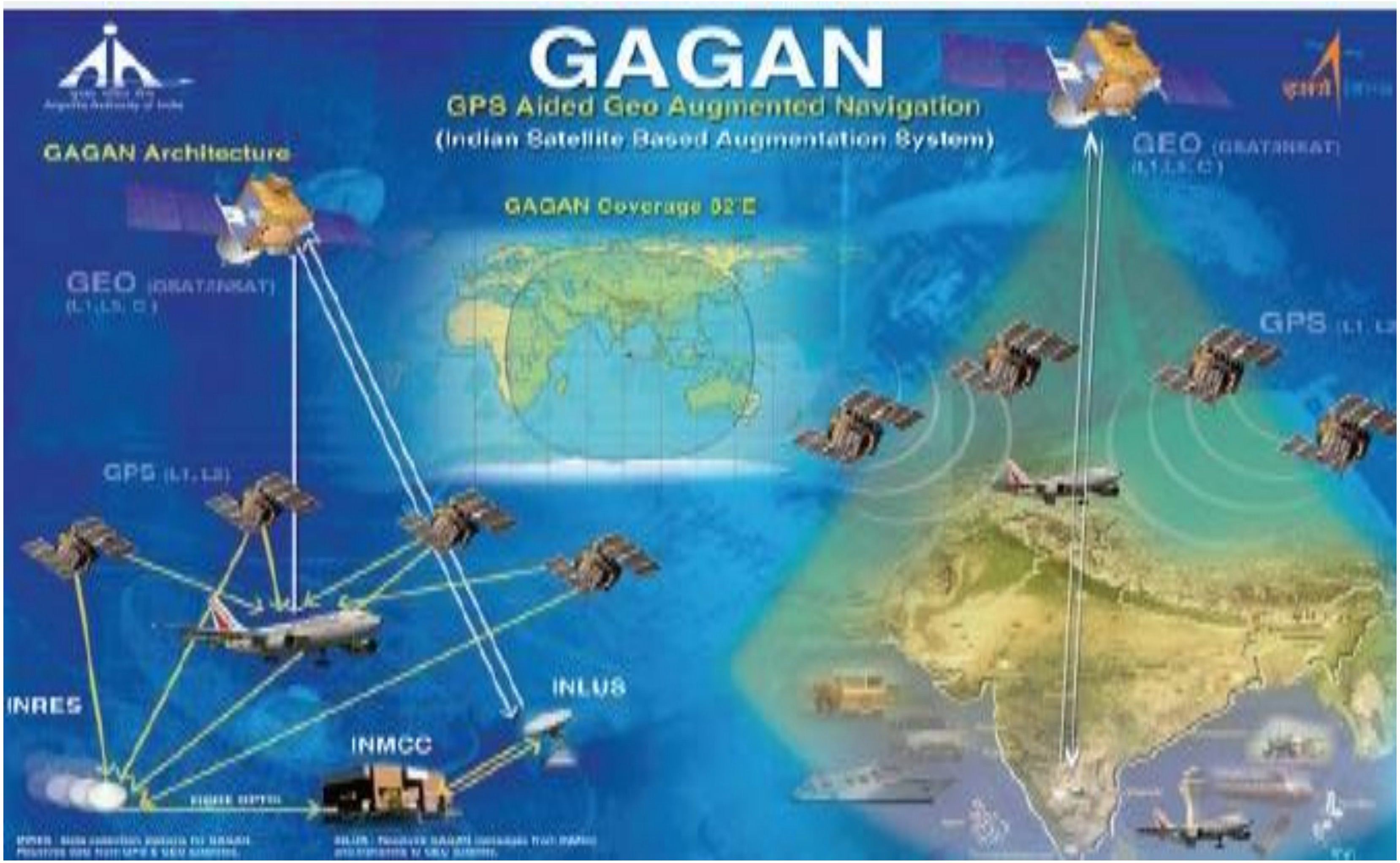
- **Availability and Continuity requirements must be met**

What Augmentations

- Space Based Augmentation System (SBAS)
  - WAAS, EGNOS, MSAS,SDCM
- Ground Based Augmentation System (GBAS)
  - LAAS
- Aircraft Based Augmentation System (ABAS)
  - RAIM

- Enhancements to Service
  - Integrity improvement by Real Time Monitoring
  - Accuracy improvement by Applying Corrections
  - Improvement of Availability and Continuity by increasing satellites

GAGAN- Indian SBAS



GAGAN – Indian SBAS Redefining Navigation

- AAI and ISRO signed an MoU for the implementation of GPS Aided GEO Augmented Navigation (GAGAN) on 25th August, 2001
- Project planned in two phases:
  - Phase I : Technology Demonstration System (TDS)
  - Phase II : Final Operation Phase (FOP)
- TDS phase was successfully completed in August' 2007
- FOP phase has commenced on 29.06.2009 and it will be completed by June'2013

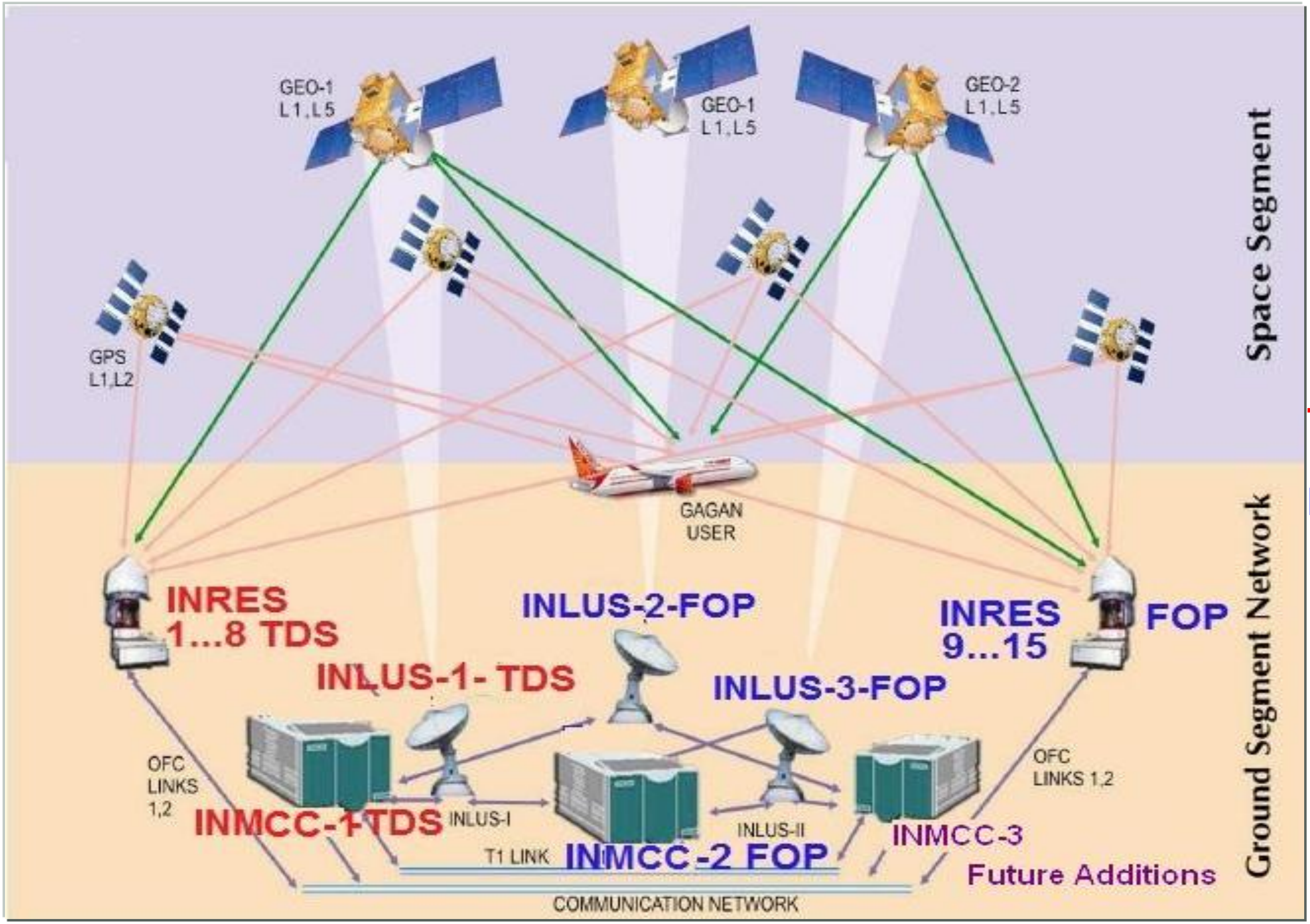
Advantage of SBAS (GAGAN) over Terrestrial Nav Aids

- ✓ Provides Navigational signal
  - At airports situated in difficult terrain such as Leh, Simla, Agatti etc.
  - At airports having insufficient land
  - At airports where it is un-economical to install terrestrial nav-aids
  - At unused / abandoned air strips / airports and helipads
  - In the oceanic areas
- ✓ Provides direct and multiple routes and approaches
- ✓ Sustain airport growth by making more land available for development & commercial exploitation

Current Status of GAGAN

- All Ground Equipments have been installed, tested and integrated with the Space Segment (GSAT-8) launched by ISRO.
- GAGAN Signal-in-Space is available for non-aviation users.
- AAI is continuously interacting with other organization like Railways, Shipping, Transport,NHAI, and Survey of India etc. for effective use of GAGAN signals
- Gagan user meet jointly with ISRO and involving all stake holders conducted in Feb 2012; more such meets in future
- GAGAN Certification activities are in process. The certified GAGAN Signal will be available to aviation users by July 2013 after launch of 2nd GEO satellite (GSAT-10) in July 2012.
- ATS Procedures using GAGAN signals are under preparation
- Approval by DGCA after Safety assessment
- System Validation- DO-178B Standards;Signal validation by Type 0 messages
- Flight trials by authorized pilots using certified multimode receivers;
- Promulgation of procedures for civil aviation use

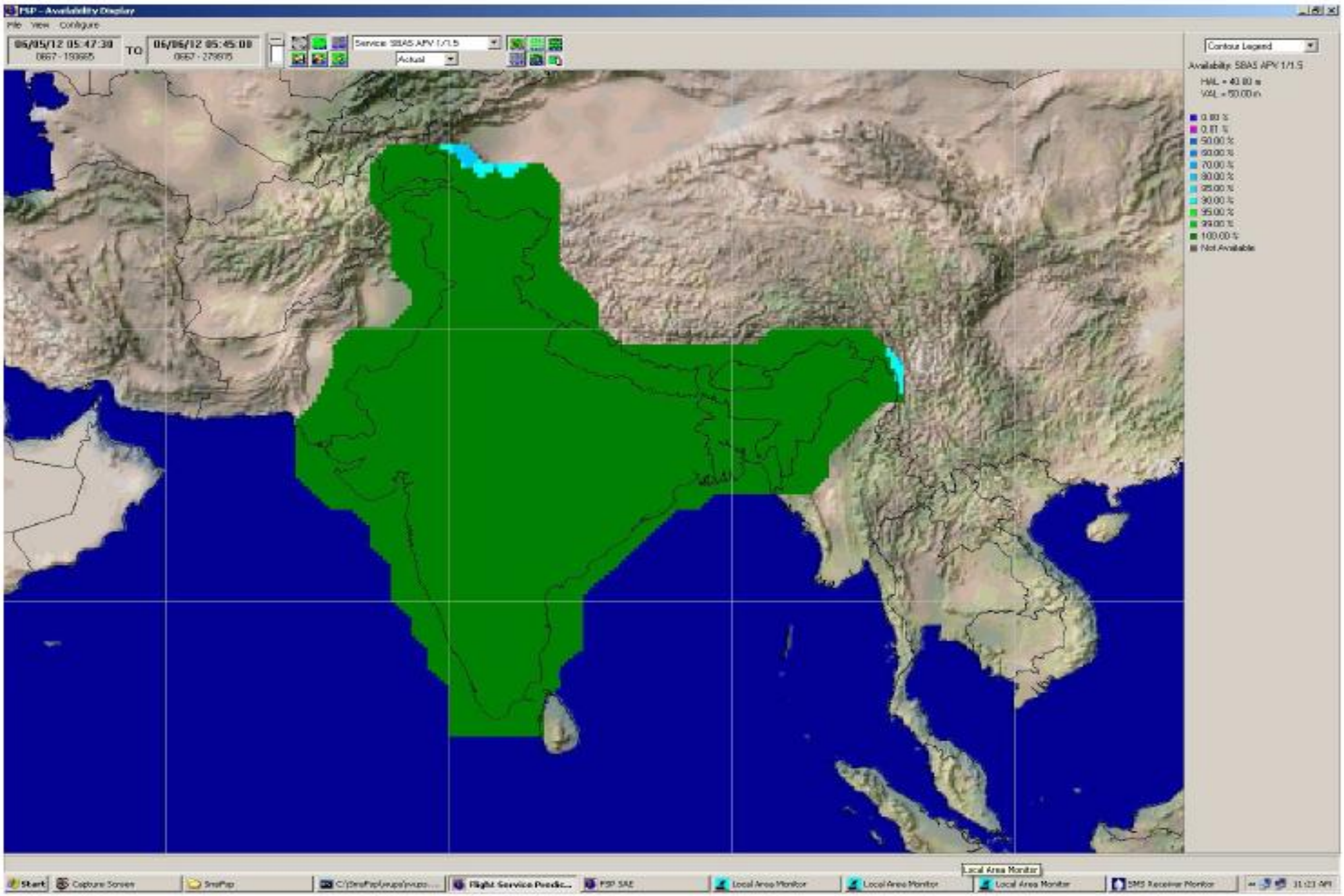
GAGAN Architecture



TDS

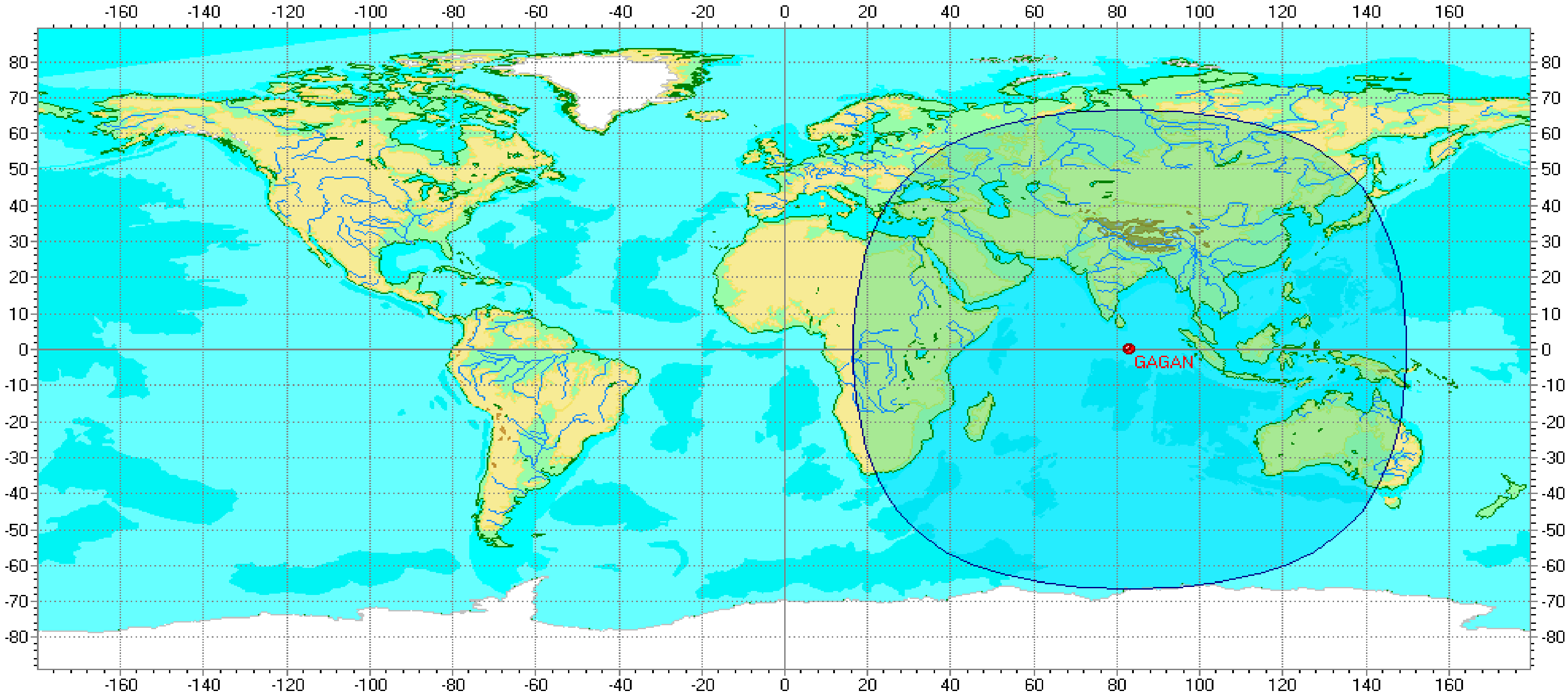
FOP

GAGAN Service (APV 1.0/1.5) over Indian Airspace as on 06/06/2012



GAGAN Coverage Area

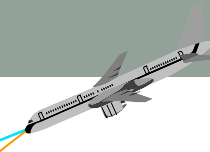
- GAGAN will have two GEOs broadcasting corrections simultaneously with almost similar coverage area. GSAT – 8 has been launched and GSAT-10 is planned to be launched in July 2012.
- GAGAN will have an in-orbit spare GEO satellite which can be made operational incase of failure of any GEOs
- GAGAN Signal-in-Space is available for non-aviation users.

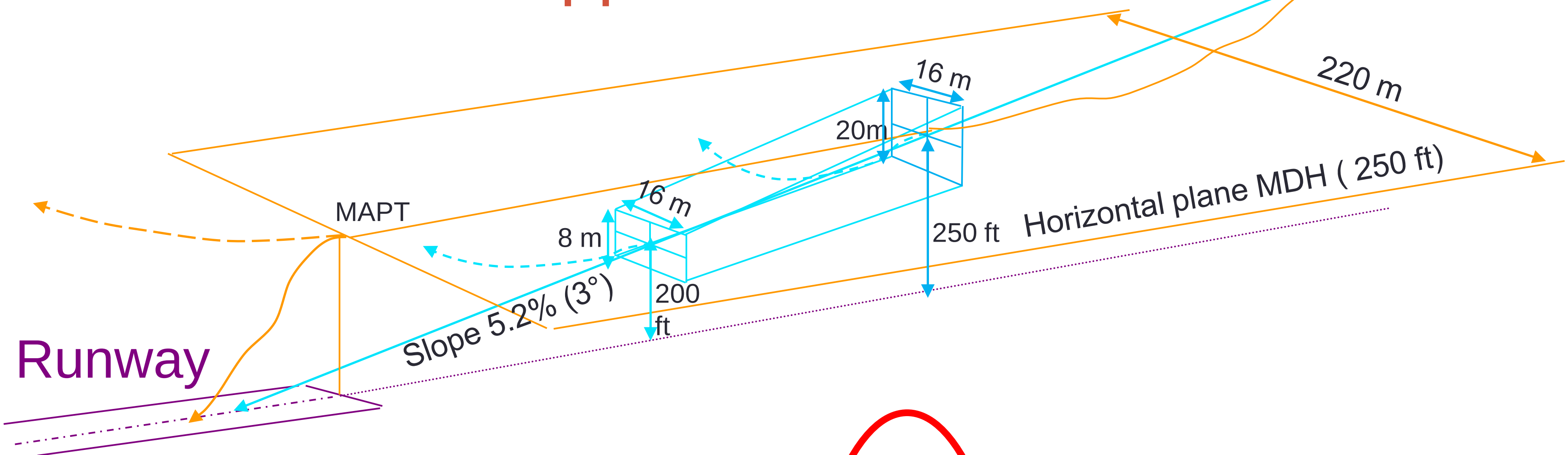


ICAO Service level : parameters

Level of Services	*Accuracy*	*TTA*	*Integrity*	*HAL*	*VAL*
En-Route	3.7 Km (H)	5 min	$1x10^{-7}$/h	4NM	N/A
En-Route Terminal	0.74 Km (H)	15S	$1x10^{-7}$/h	1 NM	N/A
NPA / LNAV (RNP 0.3) MSAS	**220 m (H)**	**10 S**	**$1x10^{-7}$/h**	**556m**	**N/A**
RNP 0.1 ***(Initial Level of Service for GAGAN FOP)***	**72 m (H)**	**10 S**	**$1x10^{-7}$/h**	**185m**	**N/A**
APV1.0 (LNAV/VNAV*)	16 m (H) 20 m V	10 S	$1x10^{-7}$/app	40m(556m*)	50 m
APV1.5 (LPV) ***(Final Level of Service for GAGAN FOP)***	**16 m (H) 20 m V**	**6S**	**1-$2x10^{-7}$/ app**	**40m**	**50 m**
APV 2	16 m (H) 8 m V	6S	1-$2x10^{-7}$/ app	40m	20 m
CAT 1 (LPV200) WAAS	**16 m (H) 4 m (V)**	**6S**	**1-$2x10^{-7}$/ app**	**40m**	**15-10 m**

Final Approach Procedure





APPROCH CATEGORIES		CAT I	APV2	APV1	NPA
Accuracy	Horizontal	16 m		16 m	220 m
	Vertical	4 à 6 m	8 m	20 m	Not applicable
Alarm Limit	Horizontal	40 m		40 m	
	Vertical	10 à 15 m	20 m	50 m	Not applicable
DH/MDH (mini)	Vertical	200 ft	200 ft	250 ft	250 ft
Horiz. Visi. (mini)	With Land. lights	550 m	550 m	T.B.D	1200 m
	Without Land. lights	1000 m	1000 m	T.B.D	1800 m
Protection areas		reduced (ILS)	near ILS	near ILS	Important => Mimima if obstacles
Slope		5.2% (3°)	5.2%(3°)	5.2% (3°)	Descent + stabilization => CFIT risk
Integrity/continuity of service		yes	yes	yes	not

Benefits of GAGAN to Civil Aviation Sectors

- Save operators time and money by managing climb, descent and engine performance profiles
- Improve the efficiency and flexibility by increasing the use of operator-preferred trajectories
- Improve airport and airspace access in all weather conditions, and the ability to meet the environmental and obstacle clearance constraints.

Benefits of GAGAN to Civil Aviation Sectors…

- Enhance reliability and reduce delays by defining more precise terminal area procedures that feature parallel routes and environmentally optimised airspace corridors. save operators time and money by managing climb, descent and engine performance profiles
- Offer high position accuracies over a wide geographical area like the Indian airspace.
- Provide navigation over oceanic regions

Applications of GAGAN to Non-Aviation Sectors…

- NAVIGATION
  - SPACECRAFT
  - AIRCRAFT
  - SHIP
  - SURFACE TRANSPORT & RAILWAYS
- GEOGRAPHIC DATA COLLECTION
  - MAPPING
  - SURVEYING
  - ENGINEERING
- SCIENTIFIC RESEARCH
  - ATMOSPHERIC STUDIES
- GEODYNAMICS
  - CRUSTAL MOVEMENTS
  - CRUSTAL DEFORMATIONS
- MILITARY

- NATURAL RESOURCE AND LAND MANAGEMENT
  - GIS INGEST
  - FOREST MENSURATION
  - TOWN PLANNING
  - FLEET MOVEMENT
  - ROUTING/ALIGNMENT
- AGRICULTURE
  - PRECISION FARMING
- EMERGENCY RESPONSE
  - SEARCH AND RESCUE
- BUSINESS SOLUTIONS
  - LOCATION BASED SERVICES
    - MOBILE
    - TOURISM
    - RETAILING

… MANY MORE

AREAS OF RESEARCH & DEVELOPMENT IN POSITIONING AND TIMING SYSTEM

SCIENCE

- IONO-TROPO MODELLING IN THE EQUATORIAL REGION IN L-BAND
- RADIO OCCULTATION STUDIES FOR NEAR EARTH ATMOSPHERIC TEMPERATURE PROFILE

APPLICATIONS

NEW APPLICATION AREAS:

- TELECOMMUNICATION
- VEHICLE TRACKING
- TIMING, BANKING & GRID SYNCHRONIZATION
- PRECISION FARMING
- INTELLIGENT HIGHWAY SYSTEM
- SURVEYING
- NAVIGFATION FOR CIVIL AVIATION

TERRESTRIAL FRAME FOR GLOBAL MAPPING

- SEAMLESS MAPPING

REAL-TIME WEATHER FORECASTING

PLATE TECTONICS

. MONITORING THE HEALTH OF TALL BUILDINGS/TOWERS, LONG BRIDGES

TECHNOLOGY

- PRECISION ORBITS
- TIME SYNCHRONISATION
- DEVELOPMENT OF NAVIGATION SOFTWARE
- ATOMIC CLOCK – RUBIDIUM, CESIUM, HYDROGEN MASERS
- ISOFLUX ANTENNAS FOR SPACECRAFT
- DUAL RECEIVERS (GPS+GLONAAS, GPS+GALILEO)
- ACCURATE ESTIMATE OF PHASE DELAYS ONBOARD SATELLITE

AREAS OF RESEARCH & DEVELOPMENT

Ionospheric Study

- Understanding the behaviour of the ionosphere in this region is essential for GAGAN Project.
- GAGAN project has carried out substantial studies in the area by installing TEC receivers at 26 airports all over the country.
- The results has indicated the occurrence of high ionospheric gradients and ionospheric depletion bubbles and high scintillations. These are different from the ionospheric behavior in the mid-latitude region.

Ionospheric Study – IGM MLDF Model for GAGAN

- An Unique IGM-MLDF (ISRO GIVE Model- Multi Layer Data Fusion) Algorithm developed for the GAGAN to meet the challenges posed by Indian sub continent and other Equatorial Ionospheric Anomaly regions
- MLDF set the evaluation criteria parameters for Availability, Continuity, Integrity & Accuracy, as per the specifications of annex 10
- Extensive study of the ionospheric delay variation and the scintillation done in conjunction with academic institutions like Andhra University, Calcutta University, Dibrugarh University etc.,

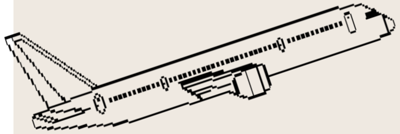
Area of Research & Development

- Academic community can take the opportunity of availability of GAGAN Signal for:
  - Ionospheric Studies.
  - Iono-tropo modeling in equatorial region in L-Band.
  - Radio occultation studies for near earth atmospheric temperature profile for research and development
  - Geodynamic studies

THE MISSION

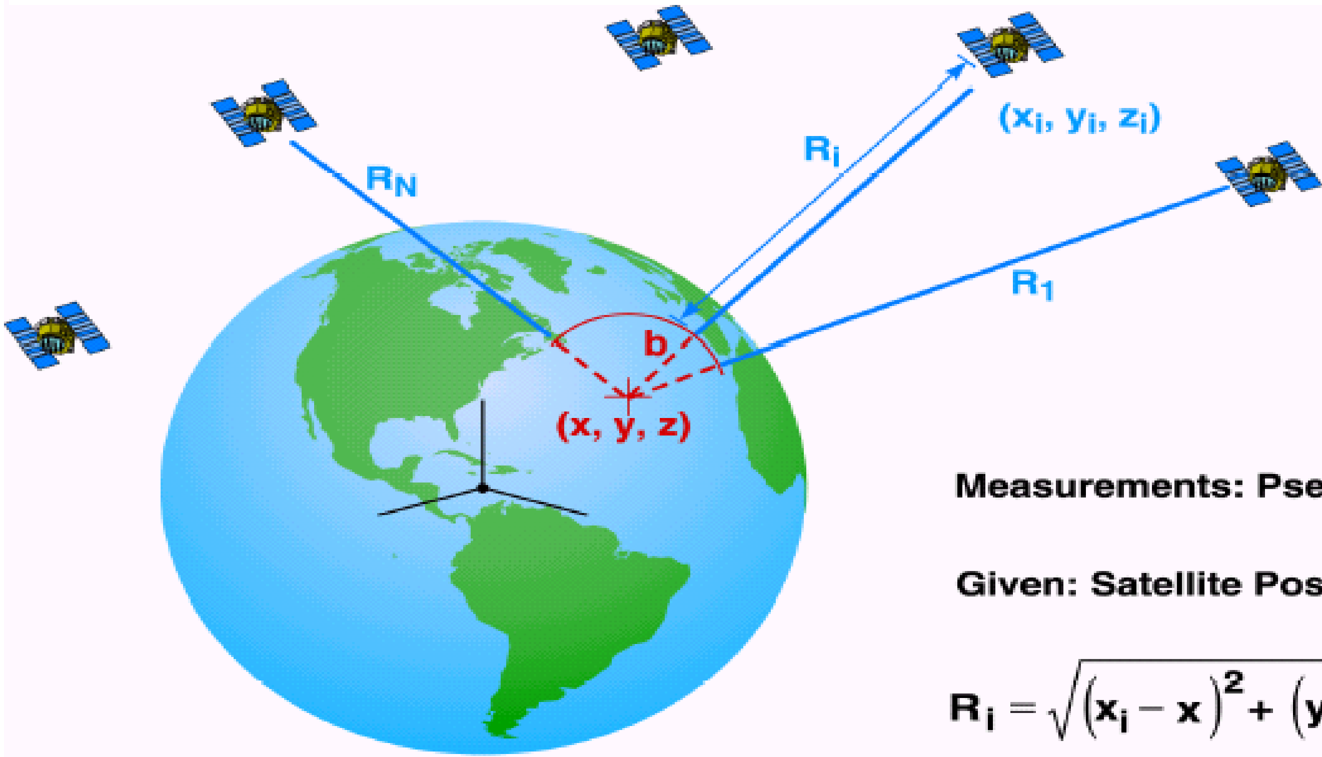
- Translate vision into reality for the benefit of all the Aviation and Non Aviation Stakeholders .

Together, we can do it.



THANKS FOR YOUR ATTENTION.

GNSS
Position Estimation by Trilateration



Measurements: Pseudoranges $\{R_i\}$

Given: Satellite Positions $\{(x_i, y_i, z_i)\}$

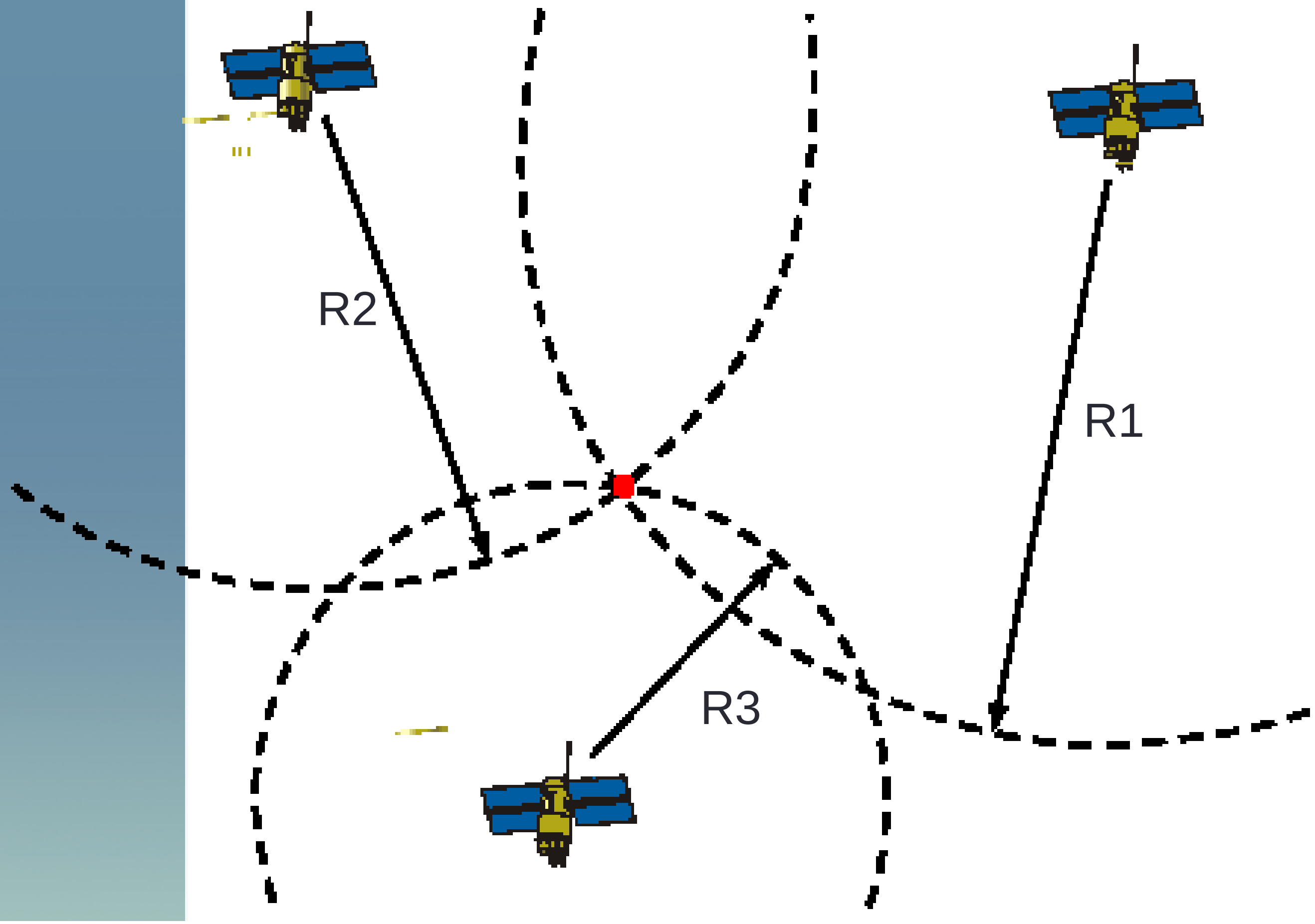
$$R_i = \sqrt{(x_i - x)^2 + (y_i - y)^2 + (z_i - z)^2} - b$$

$i = 1, 2, \ldots, N$

Unknown: User Position (x, y, z)

Receiver Clock Bias b

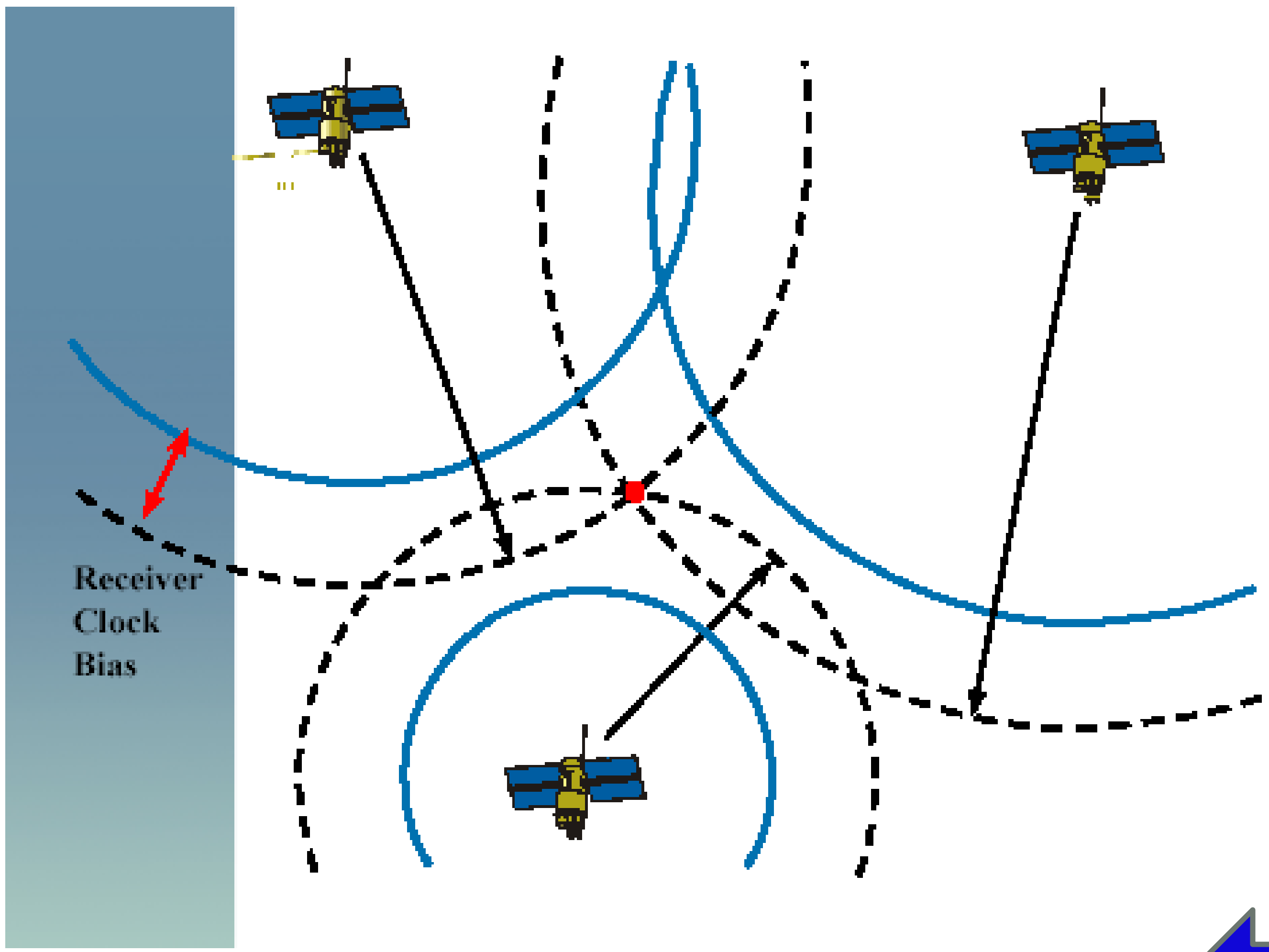
Navigation by Trilateration



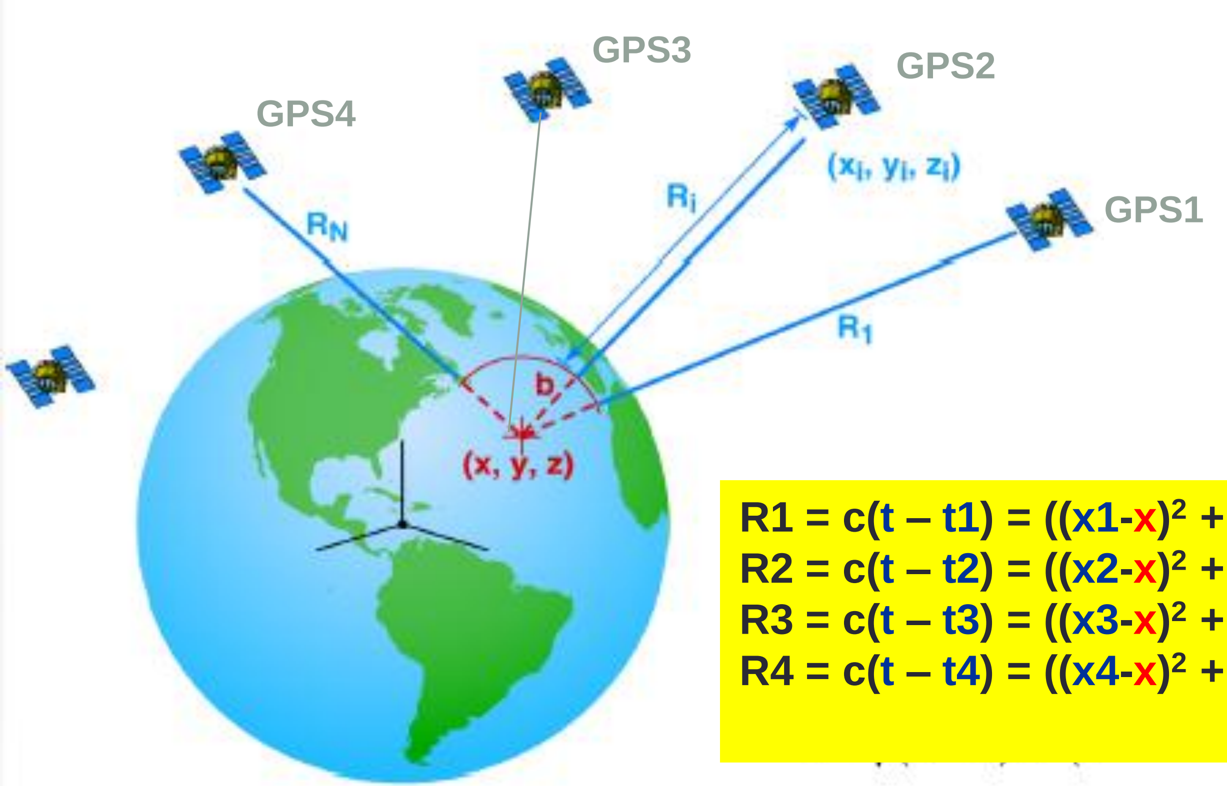
The signal is time stamped so it is possible to know at what time it started from the GNSS Satellite. The distance Ri is measured in terms of the time difference between the start of the e.m. signal from the GNSS satellite and time of its receipt in the Receiver. Knowing three RIs, we can calculate x, y and z

Or Ri = c(t – ti)
Where t = time of receipt of signal in Rx
& ti = time of start of signal from i[th] satellite

Navigation by Trilateration



Navigation by Trilateration



$$R1 = c(t - t1) = ((x1-x)^2 + (y1-y)^2 + (z1-z)^2)^{1/2} - b$$
$$R2 = c(t - t2) = ((x2-x)^2 + (y2-y)^2 + (z2-z)^2)^{1/2} - b$$
$$R3 = c(t - t3) = ((x3-x)^2 + (y3-y)^2 + (z3-z)^2)^{1/2} - b$$
$$R4 = c(t - t4) = ((x4-x)^2 + (y4-y)^2 + (z4-z)^2)^{1/2} - b$$