Satellite Positioning

GE-703

Fundamentals of Satellite Positioning Systems (GNSS)

TU Institute of Engineering (IOE)
पश्चिमाञ्चल क्याम्पस
PASHCHIMANCHAL CAMPUS

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Objectives

- To outline main concepts of GPS/GNSS and enable students to access receiver characteristics,
- To analyze GNSS receiver data and
- Conduct static and kinematic surveys.

Textbooks and References

1. M. E. Canon, ENGO 561 Lecture Notes Space and Inertial Positioning, Winter 1995, University of Calgary
2. B. Hofmann-Wellenhof, H. Lichtenegger and J. Collins, Springer-Verlag, New York, GPS Theory and Practice
3. Guide to GPS Positioning, Canadian GPS Associates
4. Selected technical papers as recommended by the Geomatics Department
5. Gilbert Strang-Linear Algebra, Geodesy and GPS 1997
6. NAVSTAR Global Positioning System Surveying – American Society of Civil Engineers 2000
7. Pradip Mishra and Per Enge, Ganga-Jamuna Press, Lincoln, Massachusetts USA – Global Positioning System 2012

Contents

Fundamental Problem

How to know your location precisely?

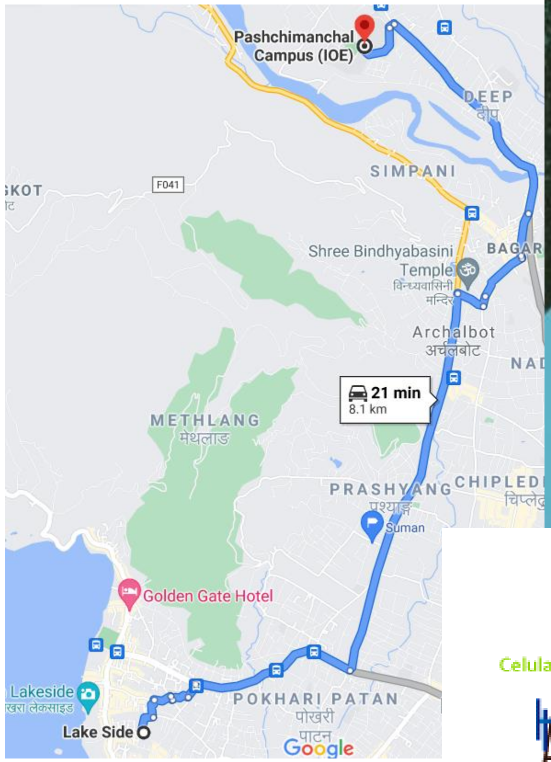
- In any condition
- At any time
- Anywhere on earth (at least outdoors)

How to navigate to the destination?

- Guidance or Navigation

How to synchronize time globally?

- Mobile phone
- Financial Institutes
- Data Centers / Substations



Navigation Types

- Landmark-based Navigation
  - Stones, Trees, Monuments
    - Limited Local use
- Celestial-based Navigation
  - Stars, Moon
    - Complicated, Works only at Clear Night
- Sensors-based Navigation
  - Dead Reckoning
    - Gyroscope, Accelerometer, Compass, Odometer
    - Complicated, Errors accumulate quickly
- Radio-based Navigation
  - LORAN, OMEGA
    - Subject to Radio Interference, Jamming, Limited Coverage
- Satellite-based Navigation or GNSS
  - TRANSIT, GPS, GLONASS, GALILEO, QZSS, BEIDOU (COMPASS), IRNSS
    - Global, Difficult to Interfere or Jam, High Accuracy & Reliability

GNSS

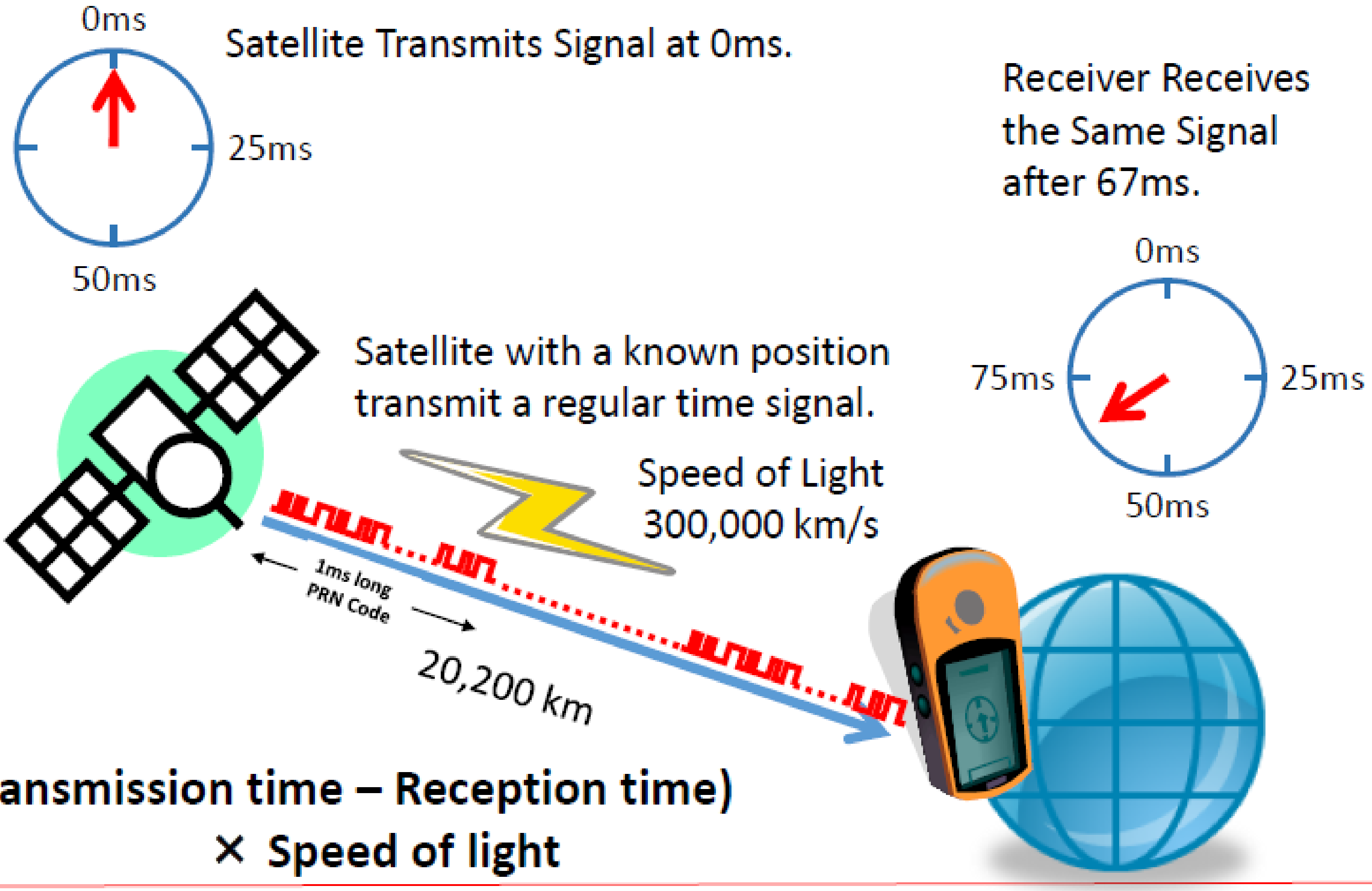
- Global Navigation Satellite System (GNSS) is the technical interoperability and compatibility between various satellite navigation systems like GPS, GLONASS, GALILEO, BeiDou, QZSS, NAVIC to be used by civilian users without considering the nationalities of each system in order to promote the safety and convenience of life.
- GNSS is the standard generic term for all navigation satellite systems.
- The main application of GNSS is to determine the position in the Global reference system any where any time on the Globe in a simple, fast and cost-effective manner.

- Global Constellation
  - GPS USA
  - GLONASS, Russia
  - Galileo, Europe
  - BeiDou (COMPASS) / BDS, China
- Regional Constellation
  - QZSS, Japan
  - NAVIC (IRNSS), India

Global availability 24/7
Signals are available free of charge
Receivers are getting smaller and cheaper
Great potential when combined with other data

GNSS: How does it work?

Determine the Distance using Radio Wave



Distance = (Transmission time – Reception time)
× Speed of light

GPS

History of GPS

1957 1. Satellite (Sputnik)

1958 Start of NNSS-TRANSIT (Navy Nav. Sat. System)

1964 Start of project Timation (GPS)

1967 1. Satellit in orbit (NAVSTAR7/GPS)

1973 Positioning possible

1997 System fully operational

Operators

DoDefence

DoTransportation

DoCommerce

DoState

DoInterior

DoJustice

DoAgriculture

Joint Chief of Staff

NASA

System Parameters

- 24 satellites
- 6 orbits with 4 satellites each, inclination 55°
- Orbit height ~ 20.000 km, time of circulation ~ 12h
- Life expectancy of satellites 10 years
- (current average 12 years, maximum 15 years)
- Limiting factor: Clock (Passive Hydrogen Maser + Rubidium Clock, 2 each, 1 each necessary)
- Satellite mass 2.03t, power supply min. 1.14kW
- Solar generators with 13.4m2

GPS Constellation
GPS satellites are positioned in precise, circular orbits 18,000 kilometers (11,000 miles) above the Earth. They orbit once every 12 hours.

Problems

- Bad signal-to-noise ratio, improvement by stronger signals not possible (GPS secondary user of frequencies)
- Shadowing effects by trees, buildings an mountains
- Sole means of navigation in land traffic problematic
- Update rates of 1 to 50Hz possible – not enough for highly dynamic movements with fast rotation

Goals

Navigation service for US troops.

Real-time 3D positioning unaffected by radio interference.

Operational at all time and weather between reasonable degrees of latitude.

Today: 95% civilian users.

1st commercial GPS receiver

Layout Decisions

User only receiving, not sending.

Position determined in receiver (satellites not involved).

System still operational when ground control stations destroyed (atomic war).

GLONASS

A space-based satellite navigation system operated by the Russian Aerospace Defense Forces. It provides an alternative to Global Positioning System (GPS) and is the second alternative navigational system in operation with global coverage and of comparable precision.

History of GLONASS

Development parallel to GPS

1960's: CIKADA-system (Doppler navigation like TRANSIT)

1970's: Start of GLONASS

12.10.1982: First satellite in orbit

18.01.1996: System operative

Designed during the cold war

Operational after the cold war!

Uragan-M
the second generation of GLONASS satellites

GLONASS System Parameters

- 24 satellites in 3 orbits (8 satellites in each orbit)
- 64,8° inclination, repetition of ground trace every 17 orbits (8 days) → better availability in high latitudes than GPS
- Orbit height: 19 100km
- Orbit time: 11h16m
- Average satellite life expectancy 3 years
- Satellite mass 1,48t
- Power supply 1,6kW from 17.5m2 solar panels
- Satellites have reflectors on surface → positioning from the ground with laser possible

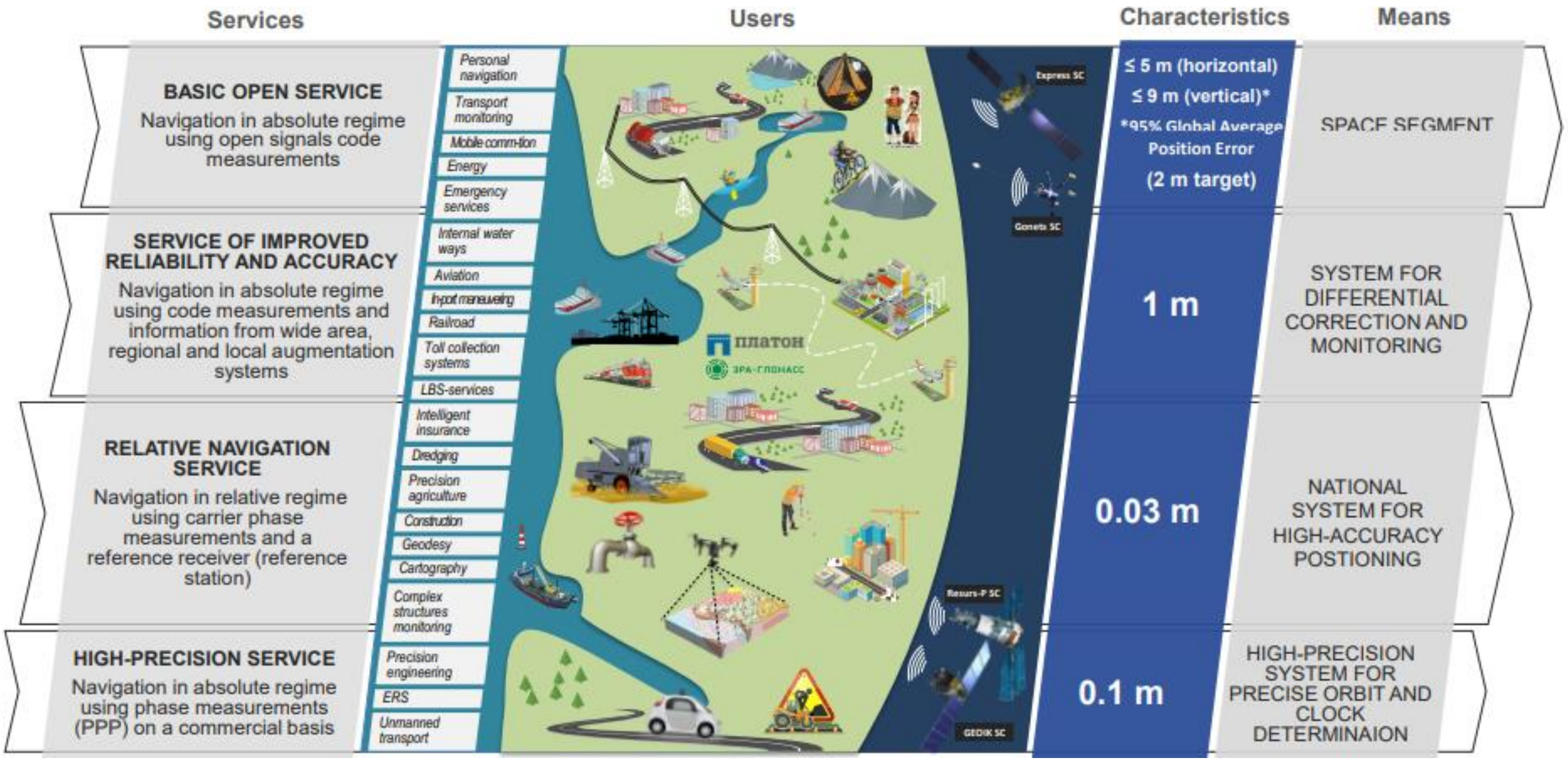
GLONASS

Differences to GPS

- ✓ Each GLONASS satellite has its own frequencies for sending
- ✓ Frequency Division Multiple Access instead of Code Division Multiple Access like in GPS
- ✓ Explicitly open for civilian users .Topic of unauthorized use of signals never had a high priority
- ✓ Never artificial deterioration of results like with SA
- ✓ unknown if due to technical reasons or as a political decision
- ✓ 2-frequency receivers for GLONASS are available

A model of a GLONASS-K satellite displayed at CeBit 2011

GLONASS Civil Services



Galileo

Galileo is the global navigation satellite system (GNSS) that is currently being created by the European Union (EU) and the European Space Agency (ESA).It is named after the Italian astronomer Galileo Galilei.

History

- **1999:** Different concepts proposed (from Germany, France, Italy and the United Kingdom) for Galileo, compared and reduced to one
- **17. Jan. 2002** a spokesman for the project stated that, as a result of U.S. pressure and economic difficulties, "Galileo is almost dead.
- EU and ESA agreed in **March 2002** to fund the project, pending a review in **2003**
- Test satellites launched in **2005** (GIOVE-A) and **2008** (GIOVE-B)
- **April 2008:** Galileo Implementation Regulation approved

Signature of the Galileo Ground Mission Segment contract and Galileo Ground Control Segment Contract

International Partners

China (since **2003**)

Israel (since **2004**)

Ukraine (since **2005**)

Morocco (since **2005**)

South Korea (since **2006**)

Norway (since **2009**)

Galileo Galilei (1564-1642)

Galileo

System Description

- 30 satellites
- orbital altitude: 23,222 km
- 3 orbits, 56° inclination, ascending nodes separated by 120° longitude (9 operational satellites and one active spare per orbit)
- satellite lifetime: >12 years
- satellite mass: 675 kg
- power of solar arrays: 1,500 W (end of life)

Galileo launch on a Soyuz rocket, 21 October 2011

Services

- Galileo satellite-only services
  - Galileo Open Service (OS)
  - Safety of Life (SoL) not before 2020 if at all
  - Commercial service (CS)
  - Public regulated Service (PRS)
  - Support to Search and Rescue service (SAR)
- Galileo locally assisted services
- EGNOS service
- Galileo combined service

Galileo - Mid term review

- Limiting to 18 satellites would lead to Significantly reduced performance and increased problems in case of satellite loss
- Each year's delay of full operation will decrease the value of the benefits by 10-15 % owing to both the loss of revenue generated and the development of alternative solutions and competing systems.

Next steps

- Need to launch first services in 2014-15
- Services will cover Open Service, Search and Rescue and Public Regulated Service but without accuracy and availability at their optimum level
- The EU budget Galileo and EGNOS was €3.4 billion until 2013.
- It is estimated that €1.9 billion will be necessary for the 2014–2020 period to complete the Galileo infrastructure.
- The operational costs of Galileo and EGNOS estimated at € 800 mill/a

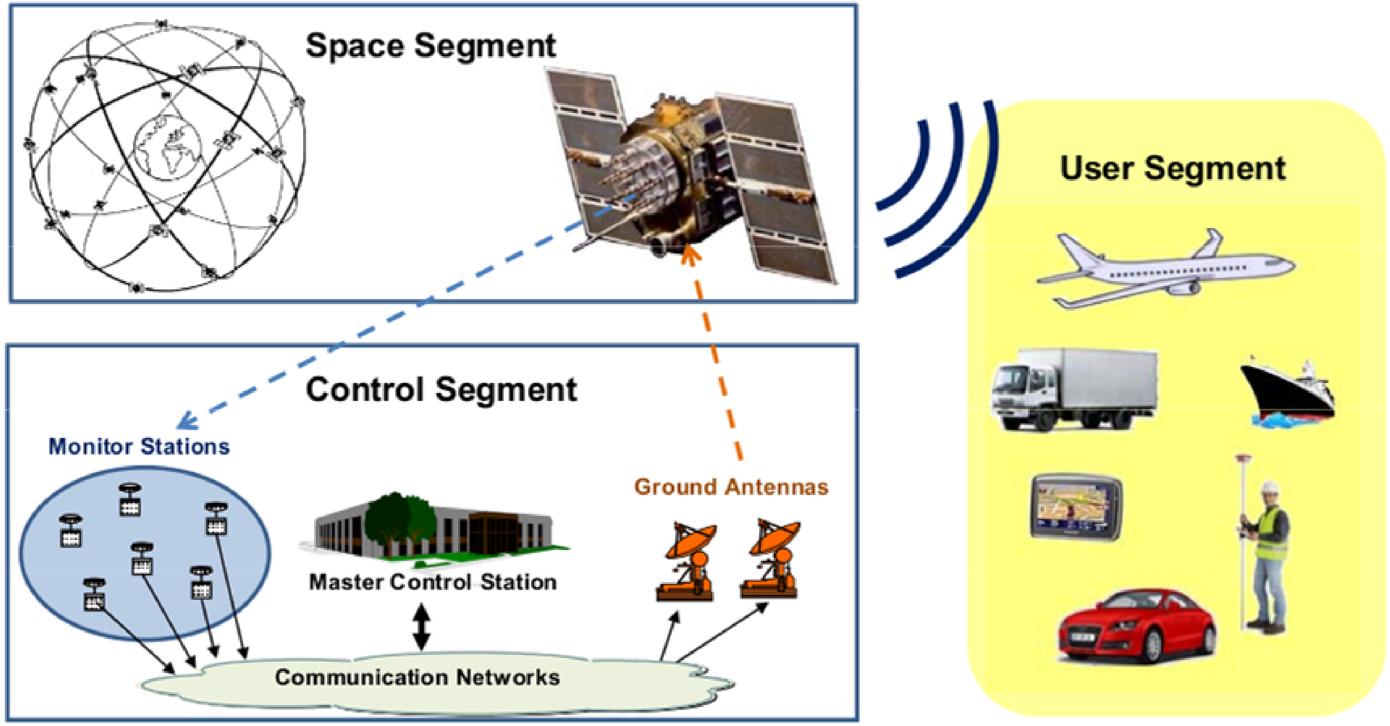
What aspects of GNSS are important?

- **Availability**: Percentage of time the minimum number of satellites are in view, so the position, navigation or timing solution can be computed by the user.
- **Accuracy**: difference between true and computed position (absolute positioning).
- **Continuity**: Ability to provide the required performances during an operation without interruption, once the operation has started.
- **Integrity**: Additional user information on the reliability of the signal within the operational requirements.
- **Robustness to spoofing and jamming**: Authentication information provided to users ensuring the signal comes from a satellite in space (enabling sensitive applications).
- **Indoor penetration**: Ability of signal to penetrate inside buildings, e.g. through windows.

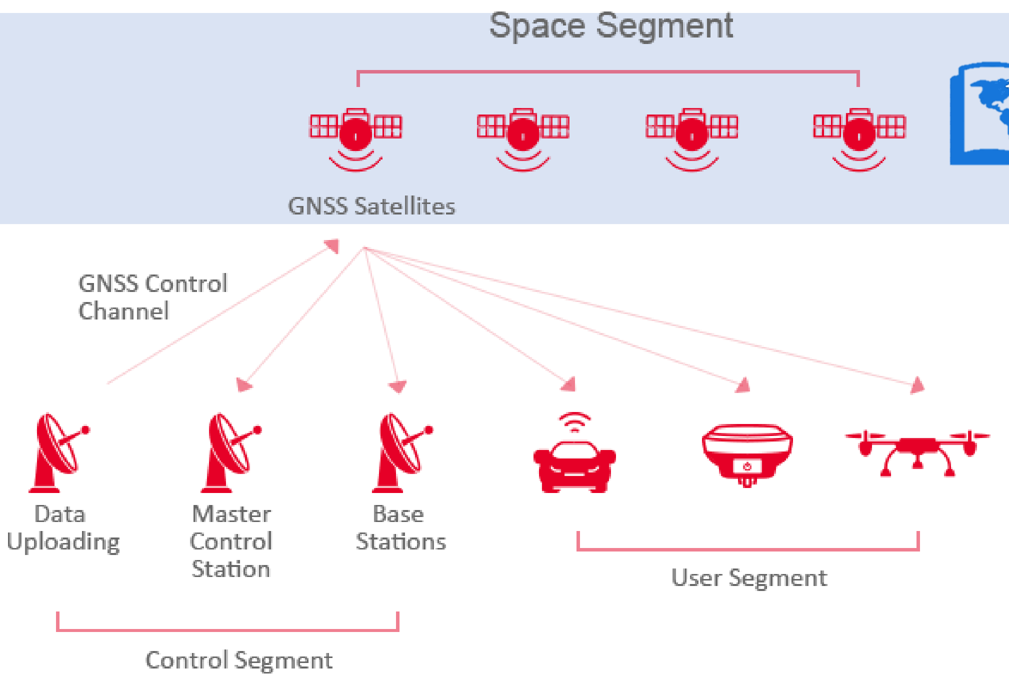
GPS/GNSS Segments

Control Segment

- The control segment consists of 5 monitoring stations and 1 out of which serve as the master control station.
- It is solely responsible for the construction, launching, maintenance, and virtually constant performance monitoring of all GPS satellites along with the Meteorological data.
- The data received by monitoring station is sent to the master control segment for preprocessing which involves the computation of satellite position, clock and orbital corrections.



GPS/GNSS Segments



Space Segment

- It consists of the Constellation of NAVSTAR earth orbiting satellites.
- They orbit at altitudes of about 20000 Km each with orbital periods of 12 hours.
- GPS satellites send radio signals.

	GPS	Global Positioning System	United States	27 satellites
	GLONASS	Globalnaya navigatsionnaya sputhikovaya sistema	Russia	24 satellites
	Galileo	Europe's own global navigation satellite system	European Union	27 satellites
	BeiDou	BeiDou Navigation Satellite System	China	35 satellites
	QZSS	Quasi-Zenith Satellite System	Japan	3 satellites
	IRNSS	Indian Regional Navigation Satellite System	India	7 satellites

GPS/GNSS Segments

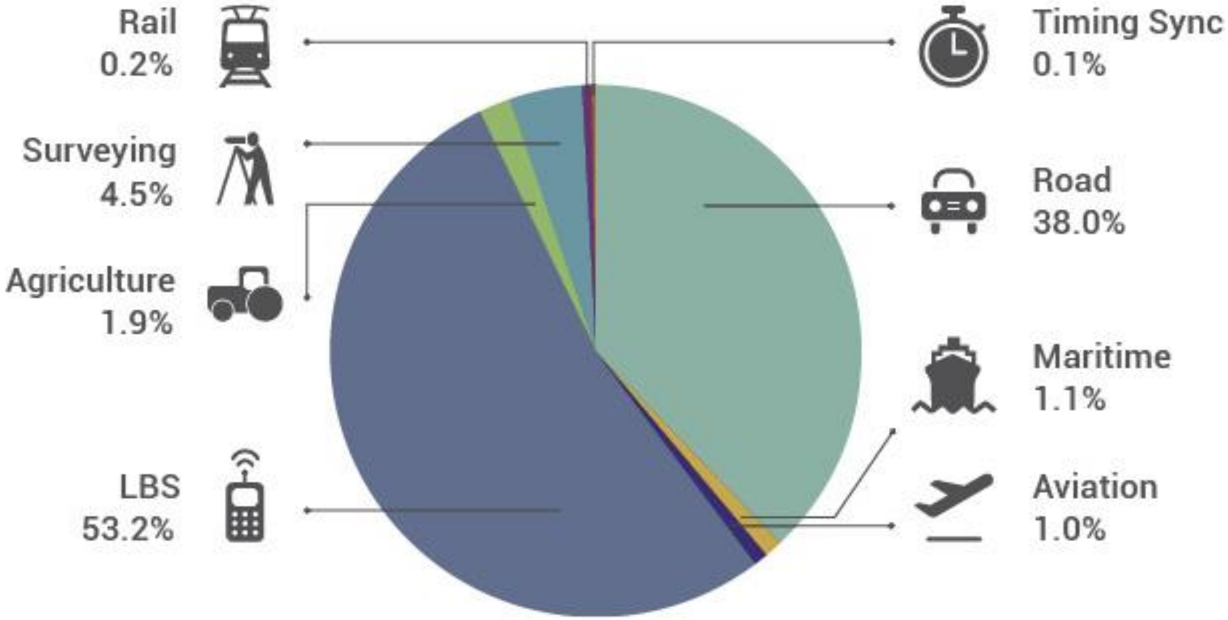
User Segment

- Consists of GPS receivers.
- GPS receiver convert the radio signals into Position, Velocity and Time estimates.
- 3 satellites are required to compute Position (X,Y,Z)
- 4^{th} satellite is used to recalibrate receiver clock (Time).

GNSS Receiver Functions

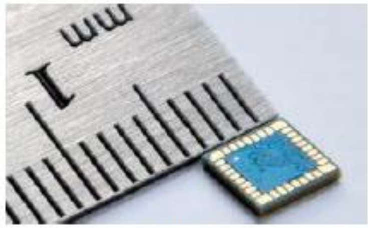
- Acquire GNSS signals
- Measure and track signals
- Recover navigational data

Application Domains of GNSS



GNSS Technology Trends

- **Improving batteries and power consumption**
  - Enabling 'always on' GNSS positioning.
- **Smaller size**
  - The advent of flexible electronics will allow GNSS receivers to be included in clothing and other personal items that could assist in locating lost and stolen items.
- **Receivers are becoming "connected"**
  - Using assistance data provided over mobile networks, giving the receiver orbital information about the satellites and allowing for a faster location fix to be found.



The Jupiter SE880

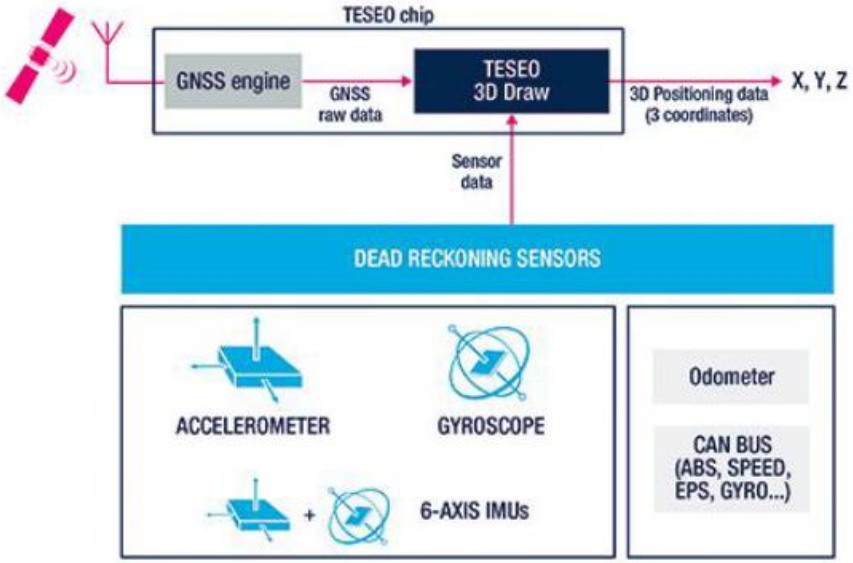
RTKite GNSS Receiver

- **Multi-purpose devices with new software applications are replacing dedicated hardware devices**
  - The ability to deliver applications through software instead of dedicated hardware (e.g. smartphone navigation apps in cars replacing PNDs) may counter-balance the proliferation of micro-receivers.

Personal Navigation Devices

GNSS Technology Trends

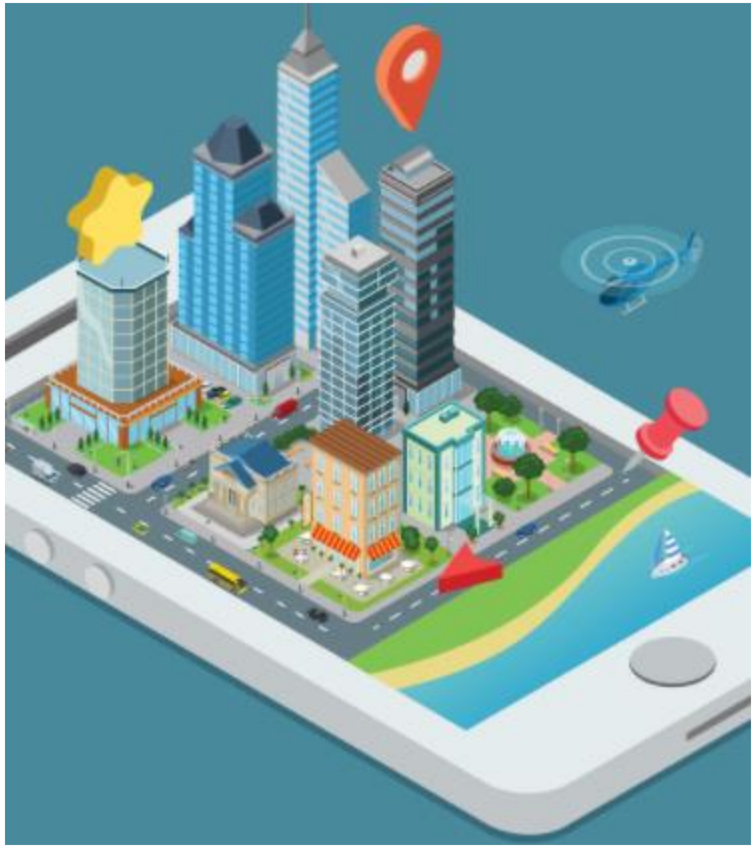
- **Combining sensors improves performance**
  - Complementary positioning techniques – such as cellular network based positioning, Bluetooth beacon , localization using Wi-Fi base stations and inertial sensors – can be combined with GNSS to improve performance.
  - This typically supplements coverage in such challenging environments as urban canyons, reduces time to first position fix (by providing a starting point, although less accurate than GNSS), increases accuracy, or simply provides redundancy.



GNSS Applications

- **Smart cities**

  - In 2014, 54% of the world's population lived in urban areas and it is predicted that by 2050 this will increase to 66%.
  - The smart cities concept tackles this challenge. An intelligent urban management approach covering various utilities (e.g. transport, energy, water, waste…) can contribute to making cities more sustainable and allow for more effective and efficient management of them.
  - With easy implementation for various smart mobility and LBS applications, GNSS is supporting the smart cities concept. Especially when implemented in a hybrid positioning solution, GNSS delivers location information regardless of the environment.
  - GNSS can be part of autonomous driving solutions, travel optimization and such automatic transactions as entering a tolled road section or a car park.



GNSS Applications

- **Multimodal logistics**

  - GNSS-based solutions are particularly well-suited for on-the-route positioning, enabling operators to monitor goods and assets during their transfer between different transport nodes and hubs.
  - GNSS-based data such as positioning and timing can be combined with information on the status of the container and the cargo, as well as with RFID positioning for asset and goods identification at hubs.
  - This information is transmitted to logistic operators and their clients to improve efficiency and effectiveness of transport activities, as well as to manage emergencies by knowing where to act if anything goes wrong.
  - Containers are the optimal target for GNSS in a multimodal perspective. For example, they are widely adopted and their capacity is high enough to invest in a GNSS-based device. Containers are also already equipped with an ISO 6346 BIC code, which identifies the owner and the principal operator.

Location-Based Services (LBS)

Location-Based Services (LBS)

- **Navigation**
  - Route planning and turn-by-turn instructions based on GNSS positioning support both pedestrian and road navigation. Sensor fusion is enabling the uptake of indoor navigation.
- **Mapping & GIS**
  - Smartphones enable users to become map creators.
- **Geo marketing and advertising**
  - Consumer preferences are combined with positioning data to provide personalized offers to potential customers and create market opportunities for retailers.
- **Safety and emergency**
  - GNSS, in combination with network based methods, provides accurate emergency caller location.
- **Enterprise applications**
  - Mobile workforce management and tracking solutions are implemented by companies to improve productivity.

- **Sports**
  - GNSS enables monitoring of users' performance through a variety of fitness applications, such as step counters and personal trainers.
- **Games and augmented reality**
  - Positioning and virtual information are combined to entertain the user and improve everyday life.
- **Social networking**
  - Friend locators provided by dedicated apps or embedded in social networks use GNSS to help keep in touch and share travel information.

Road

- **Smart Mobility**
  - **Navigation**: the most widespread application, providing turn-by-turn indications to drivers through Portable Navigation Devices (PNDs) and In-Vehicle Systems (IVS).
  - **Fleet management**: on-board units (OBUs) transmit GNSS positioning information through telematics to support transport operators in monitoring the performance of logistics activities.
  - **Satellite road traffic monitoring**: collect car location data from vehicles through Personal Navigation Devices (PNDs), In-Vehicle Systems (IVS) and mobile devices, processing this traffic information to be distributed to users and other interested parties.

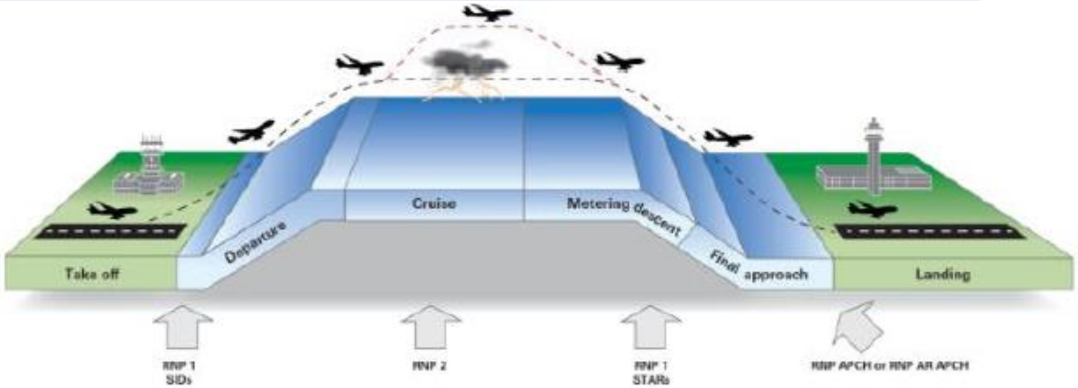
- **Safety-critical applications**

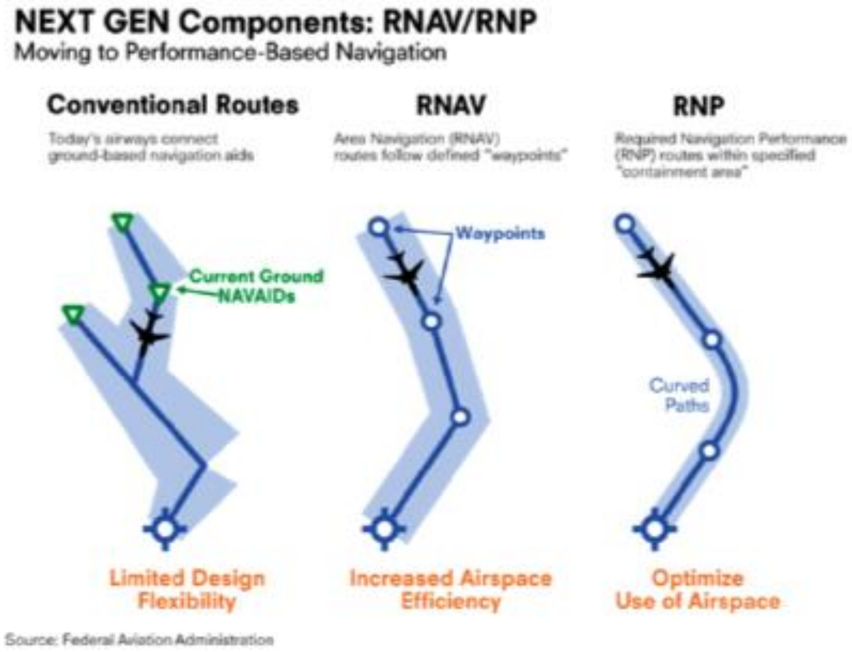
  leverage precise and secure positioning in situations with potential harm to humans or damage to a system/environment

  - In **connected vehicles** GNSS positioning will be integrated with the information coming from other sensors and communication technologies in in-vehicle systems (IVS), enhancing the safety and comfort of the driver.
  - **Dangerous goods tracking** can be done by transmitting GNSS-based positioning data on the vehicles, carrying them along with other information about the status of the cargo.

Aviation

- **Regulated applications in Aviation**
  - Performance Based Navigation (PBN), whereby an aircraft follows a specific procedure or route within a prescribed error margin. These procedures are available in en-route flight and when approaching airports.
  - Aircraft should be equipped with Emergency Locator Transmitters (ELTs) that help Search and Rescue operations in the event of an incident. Many ELTs utilize GNSS to report their position when triggered.
  - In Surveillance, aircraft can automatically report their position to air traffic controllers on the ground using Automatic Depended Surveillance – Broadcast (ADS-B).





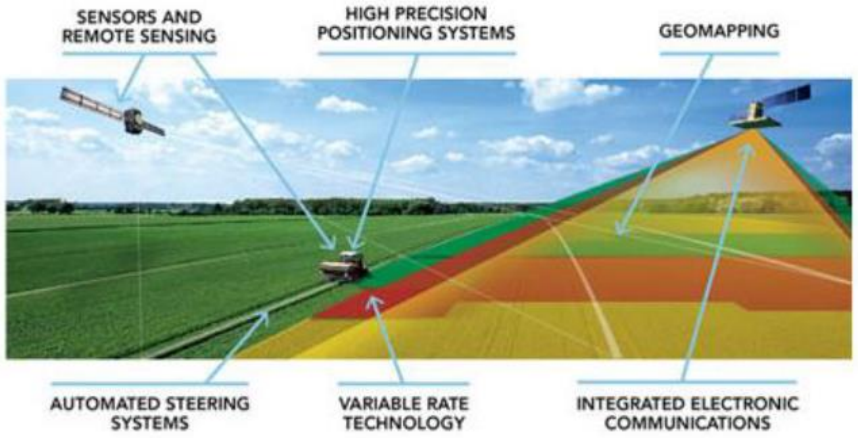
Agriculture

- **Precision agriculture**
  - Application of different technologies and solutions to manage the variability of agricultural production, improving crop yield and reducing the sector's environmental impact.
  - Technologies: GNSS, Earth Observation, Aerial photography.
  - Needs in Precision agriculture:
    - Positioning accuracy
    - Reliability
    - Cost-effectiveness
    - Ease of use
    - Interoperability

  - Farm management, Sustainability of agriculture, reduction of environmental footprint and food safety for society.

Agriculture

- **Precision agriculture**
  - Precision agriculture systems increase productivity in all phases of the agricultural activity, from soil preparation to harvesting:
    - Less time is needed per operation
    - Downtime due to fog or nightfall is reduced
    - Soil compaction is minimized by driving over precisely the same tracks
    - Fuel consumption is reduced
    - Savings on input costs (seeds, fertilizers, pesticides) are achieved
    - Soil and plant physicochemical parameters are monitored to ensure the optimal conditions for plant growth.

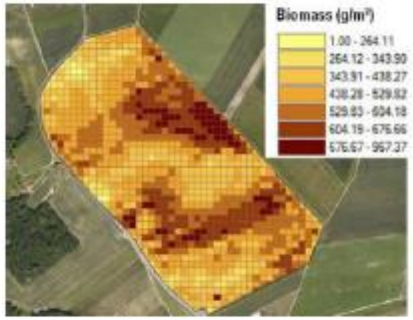


- **Farm machinery guidance**
  - uses GNSS positioning to assist drivers in following the optimal path, thus minimizing risks of overlaps.
- **Automatic steering**
  - completely takes over the steering of farm equipment.

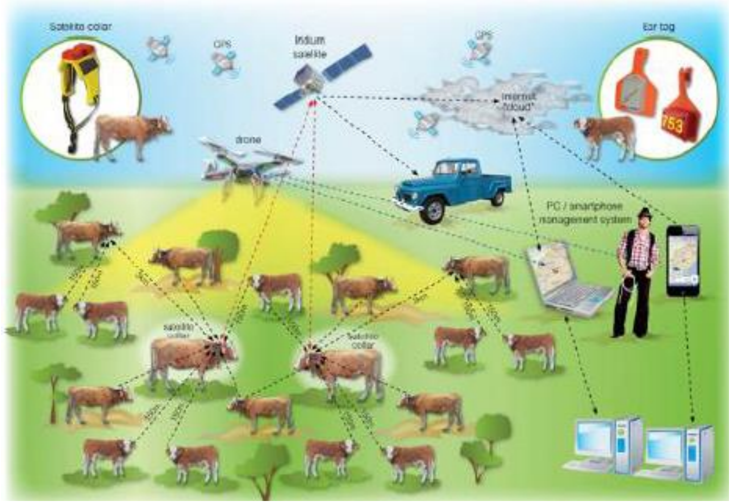
Agriculture

- **Variable rate application**
  - combines GNSS positioning with information from other sensors and digital maps to distribute the right amount of agrichemicals.

- **Yield monitoring**
  - enables site-specific monitoring of harvest, combining the output of a yield sensor with the GNSS positioning of the harvester.



- **Livestock tracking**
  - uses GNSS to track animals.



- **Biomass monitoring**
  - enables site-specific monitoring of biomass in an agricultural field, providing up-to-date information on crop development.
- **Soil condition monitoring**
  - enables updates on soil moisture levels, fertility or diseases to optimize their management. GNSS positioning and software applications identify the exact position of the soil samples sent to laboratories. Data from soil sampling is then used in VRT application maps.

Surveying

- **Construction Surveying**
  - covers the different construction stages of a building or civil engineering project, whereas machine control applications automate construction activities thanks to GNSS.
    - Machine control applications use GNSS positioning, for example, to automatically control the blades and buckets of construction equipment using information provided by 3D digital design.
    - Person-based applications enable many positioning tasks, including making surveys, checking levels, performing built checks and staking out reference points and markers.

- **Mapping**
  - GNSS is used to define specific location points of interest for cartographic, environmental and urban planning purposes.
- **Mining**
  - mine surveying involves measurements and calculations at each stage of mine exploitation, including a safety check.

Timing & Synchronization

- **Telecommunications**
  - Uses the GNSS timing function for handover between base stations in wireless communications, time slot management purposes and event logging. Digital cellular network and Public Switched Telephone Network (PSTN).

- **Banks and Stock Exchanges**
  - The Finance sub-segment uses GNSS to timestamp financial transactions, allowing one to trace causal relationships and synchronize financial computer systems.

GNSS Fundamentals Cont….

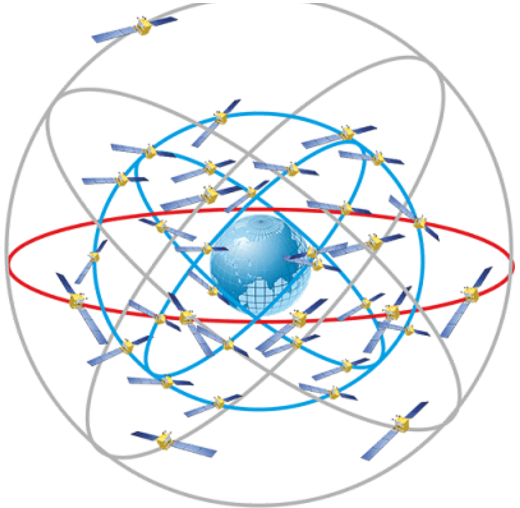
Part-II

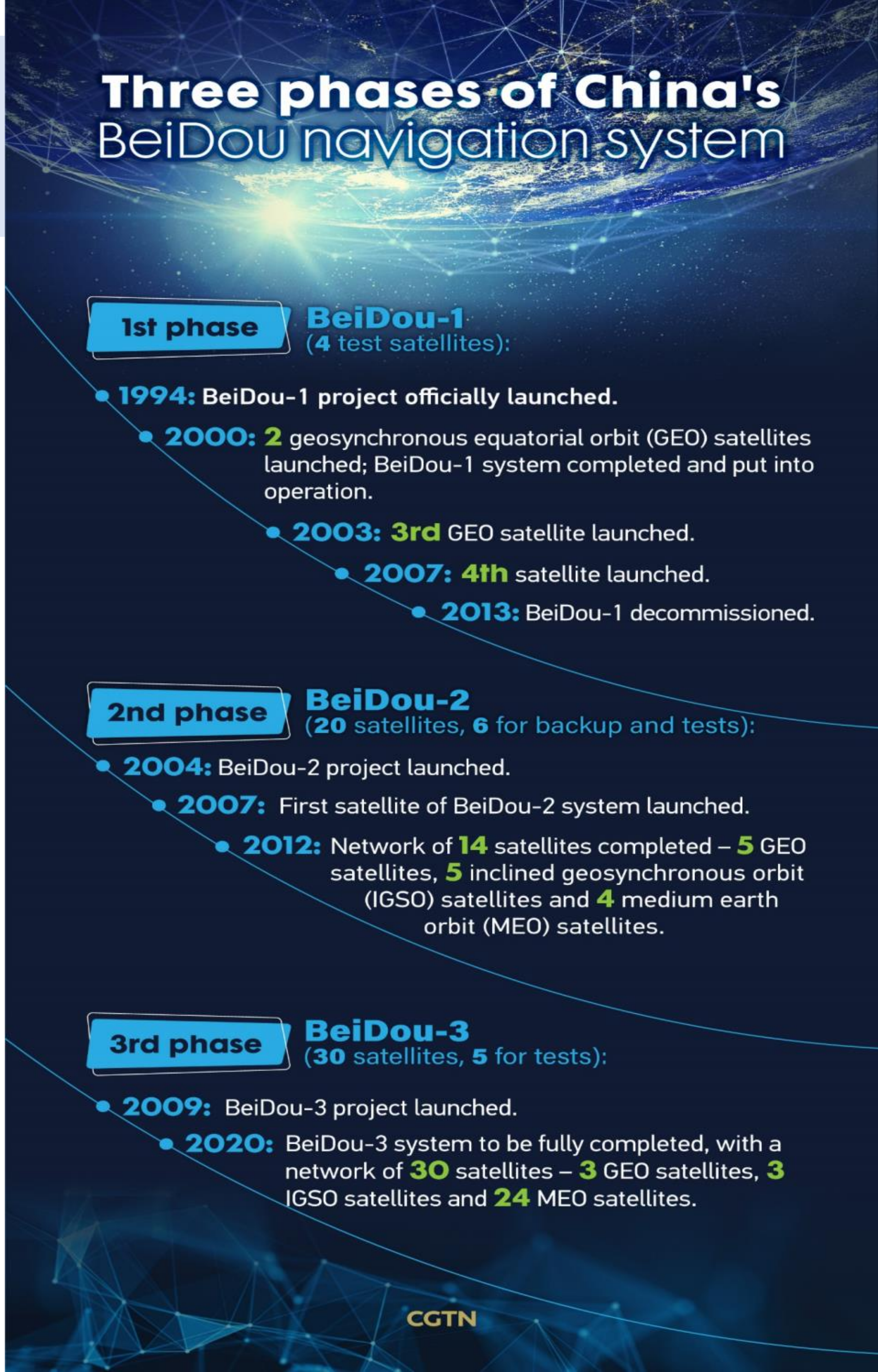
BeiDou

BeiDou Navigation Satellite System (BDS)

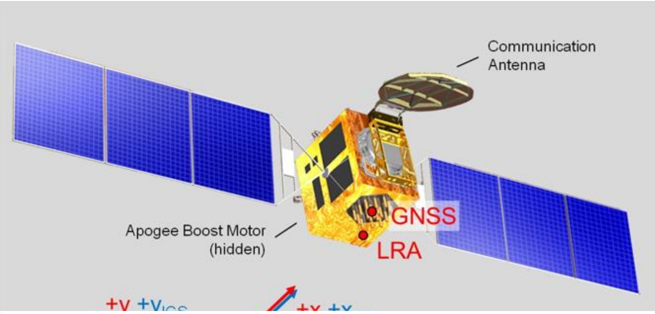
- BDS provides all-time, all-weather and high-accuracy positioning, navigation and timing services to global users.

- 5 **BeiDou-G** satellites in the geostationary orbit (GEO)
- 27 **BeiDou-M** satellites in medium Earth orbit (MEO)
- 3 **BeiDou-I** satellites in inclined geosynchronous orbits (IGSO)

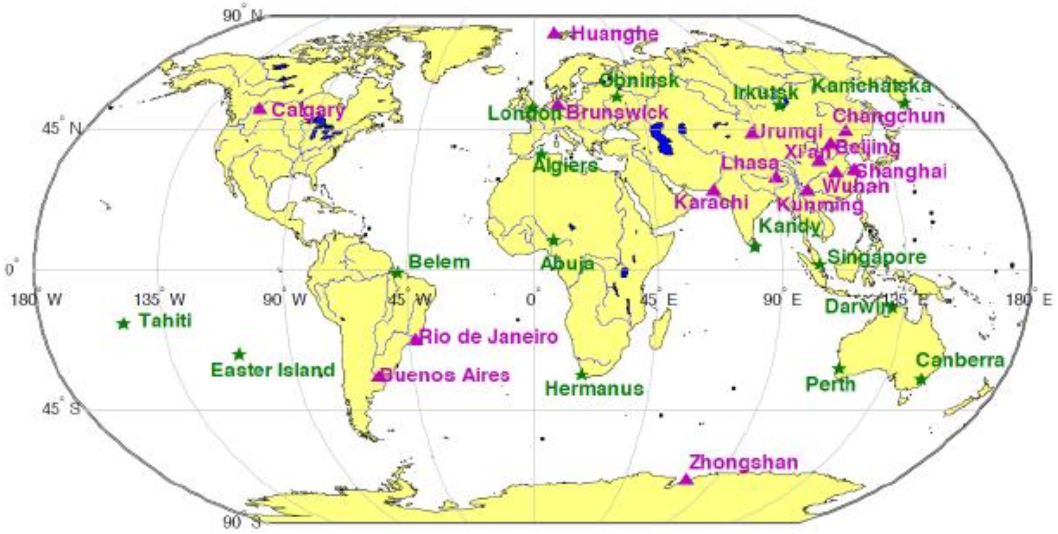




BeiDou: Segments



- **Space Segment**: The space segment is a hybrid navigation constellation consisting of GEO, IGSO and MEO satellites.
- **Ground Segment**: The ground segment consists of various ground stations, including master control stations, time synchronization and uplink stations, as well as several monitoring stations.
- **User segment**: The user segment consists of chips, modules and antennas, as well as terminals, application systems and application services, which may be compatible with other GNSS systems.



QZSS

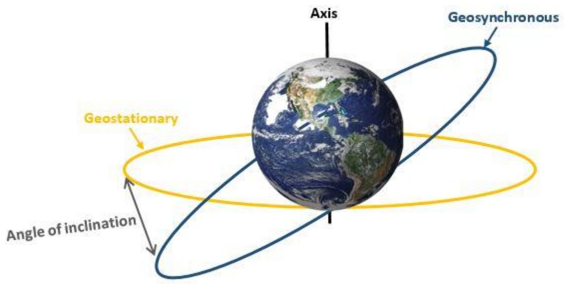
Quasi-Zenith Satellite System (QZSS)

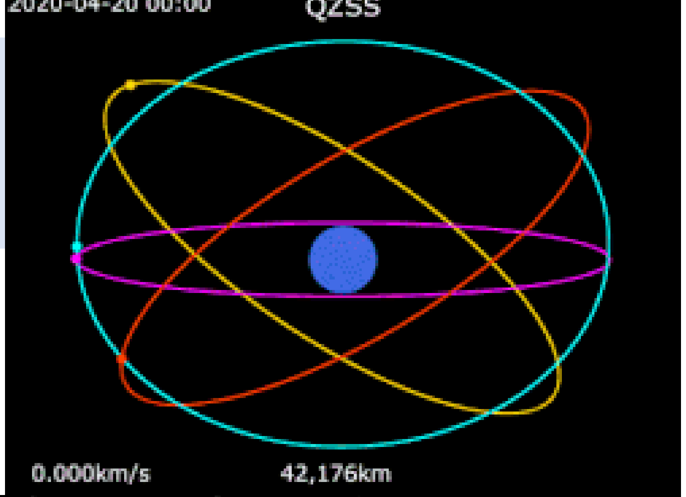
- QZSS or Michibiki (to guide, to show the way) is regional navigation satellite system commissioned by the Japanese Government in 2002 as a National Space Development Program.

- At the beginning the system was developed by the Advanced Space Business Corporation team.

- In 2007, the work was taken over by JAXA together with satellite Positioning Research and Application Center.

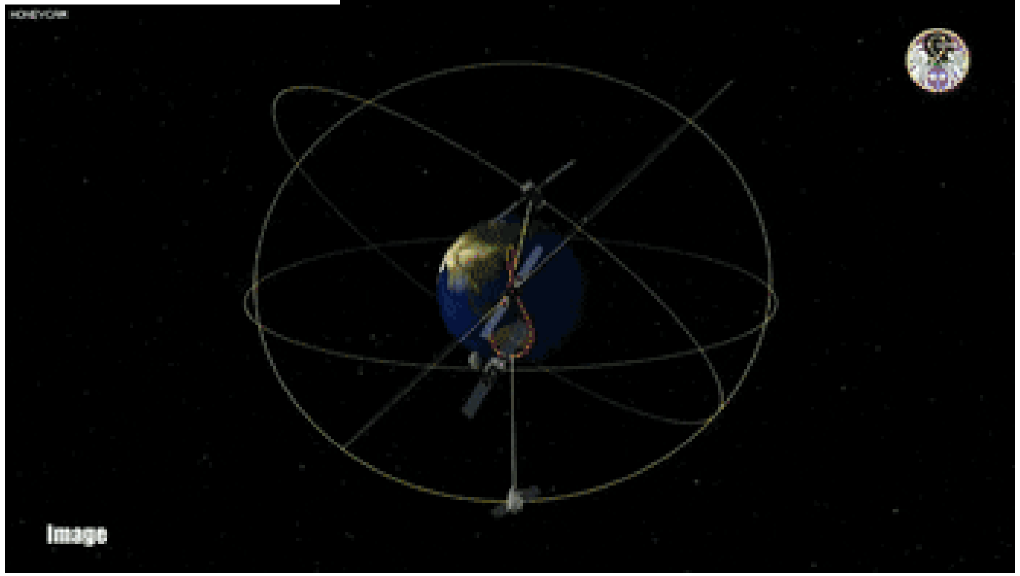
QZSS





- The goal of QZSS is to provide highly precise and stable positioning services in the Asia-Oceania region, compatible with GPS.
- QZSS uses one geostationary satellite and three satellites in Tundra-type highly inclined, slightly elliptical, geosynchronous orbits.
- Altitude 32,000 km to 40,000 Km

Geostationary satellites are made to stand still in the sky above the equator at a fixed longitude so they can be seen at any time from the earth's surface.

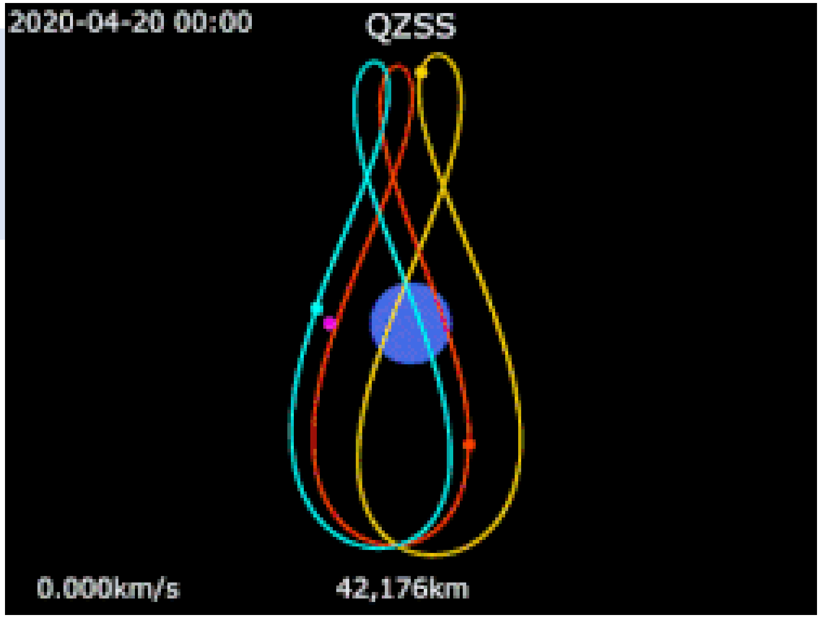


Each orbit is 120° apart from the other two. Because of this inclination, they are not geostationary; they do not remain in the same place in the sky. Instead, their ground traces are asymmetrical figure-8 patterns, designed to ensure that one is always almost directly overhead (elevation 60° or more) over Japan.

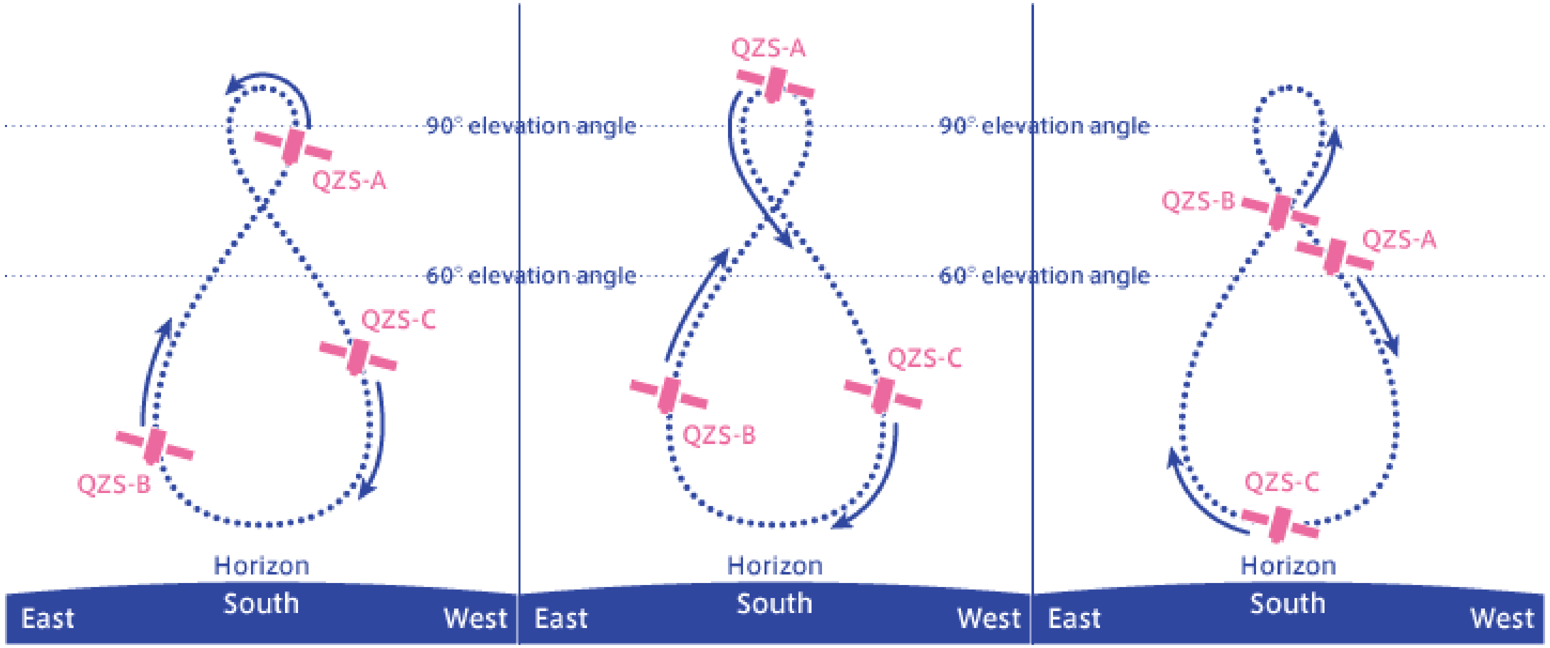
QZSS

- Satellites on quasi-zenith orbits (QZO) have a slower speed in the northern hemisphere by moving away from the earth, and a faster speed in the southern hemisphere by coming closer to the earth.

- Satellites spend approximately 13 hours in the northern hemisphere and roughly 11 hours in the southern hemisphere, allowing them to remain near Japan for a long period of time.

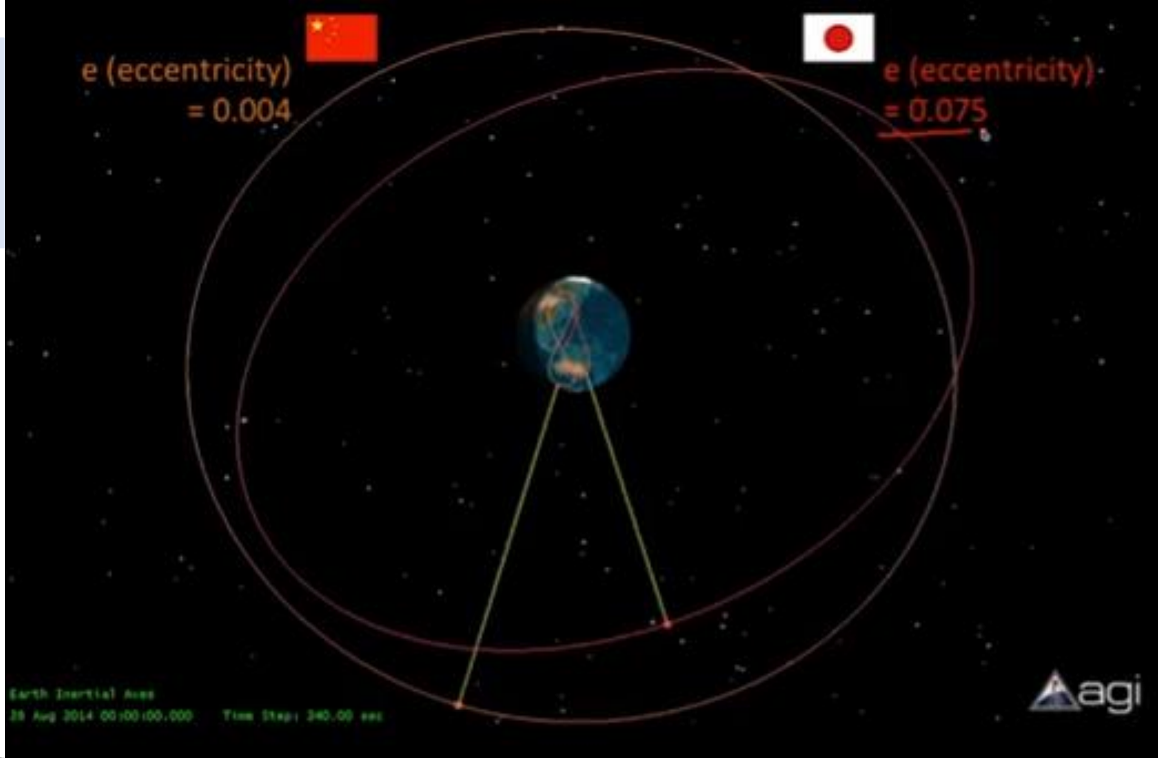


Quasi-Zenith Satellite (QZS) movements as seen from near Tokyo



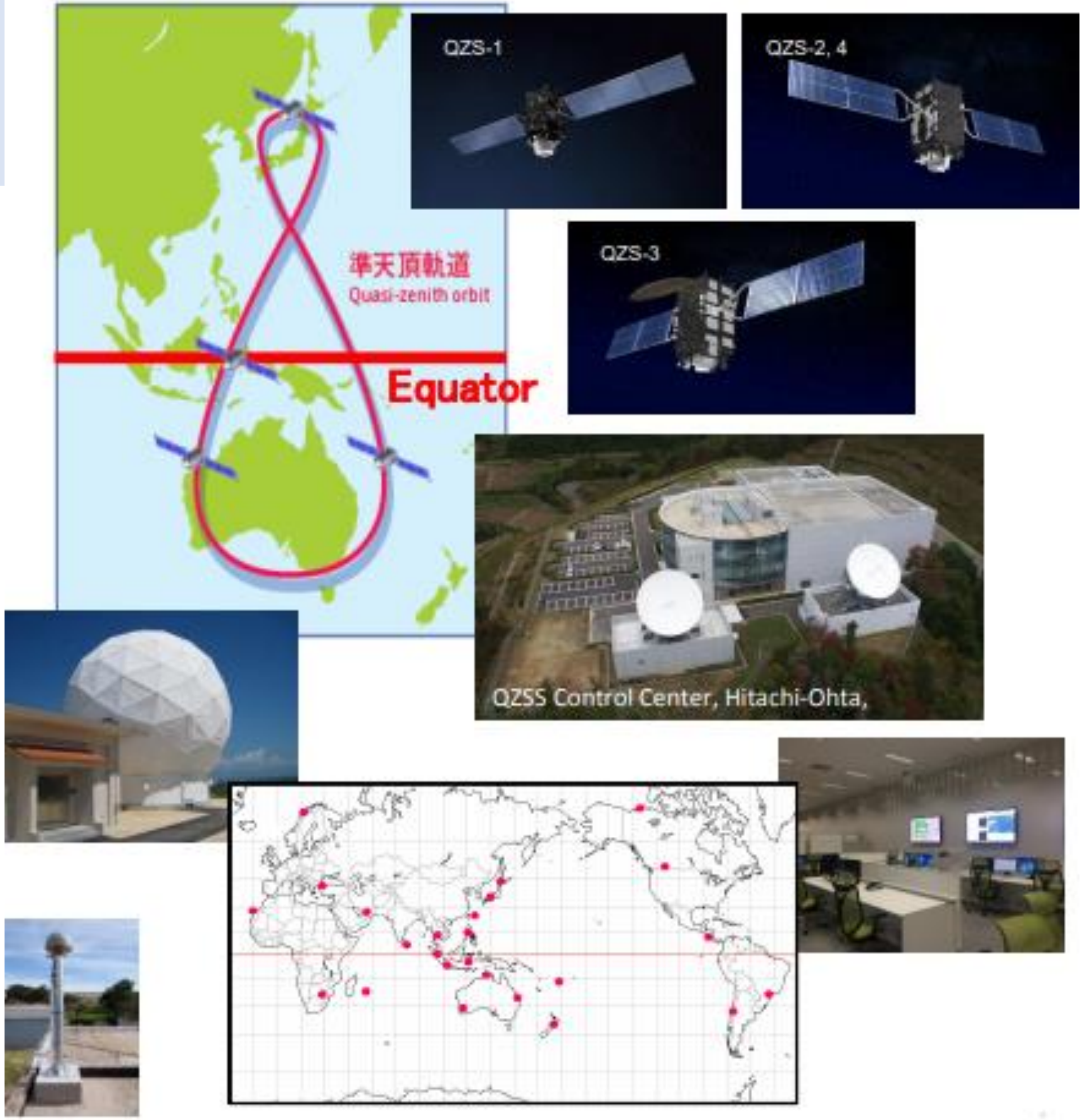
Difference of eccentricity

- Eccentricity: how much a conic section (a circle, ellipse, parabola or hyperbola) varies from being circular.
- A circle has an eccentricity of zero, so the eccentricity shows you how "un-circular" the curve is.



QZSS: Segments

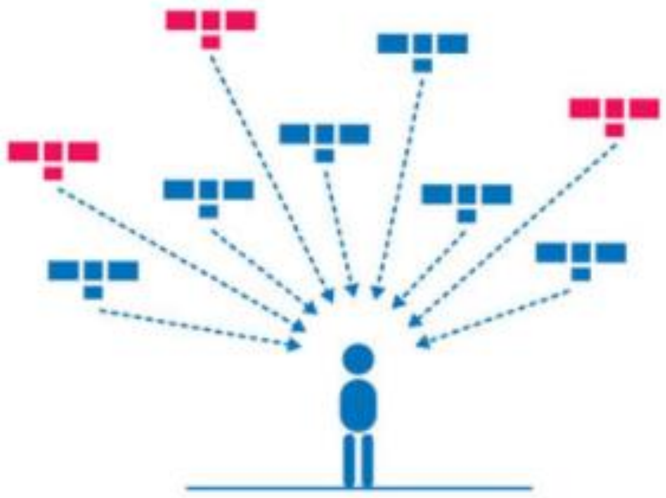
- Space Segment:
  - □ 1 GEO Satellite, 127E
  - □ 3 QZO Satellite (IGSO)
- Ground Segment:
  - □ 2 Master Control Stations
    - ▪ Hitachi-Ota and Kobe
  - □ 7 Satellite TTC Stations
    - ▪ Located south-western islands
  - □ Over 30 Monitor Stations around the world
- User Segment:
  - □ GPS Complementary (Ranging signals)
  - □ GNSS Augmentation (Error corrections)
  - □ Messaging Service (Disaster relief, management)



https://www.unoosa.org/documents/pdf/icg/2019/icg14/06.pdf

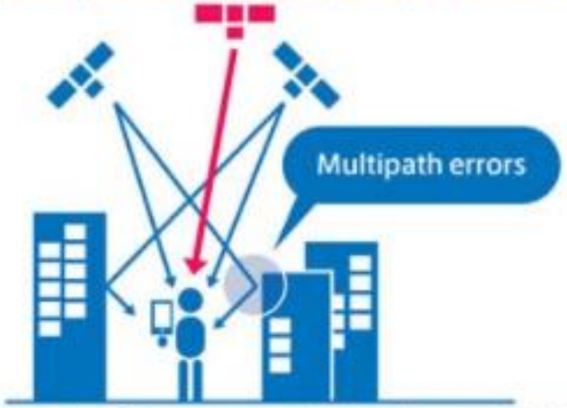
Advantages of QZSS

- QZSS signal is designed in such a way that it is interoperable with GPS
- QZSS is visible near zenith; improves visibility & DOP in dense urban area
- Provides Orbit Data of other GNSS signals
- Provides Augmentation Data for Sub-meter and Centimeter level position accuracy
- Provides Messaging System during Disasters

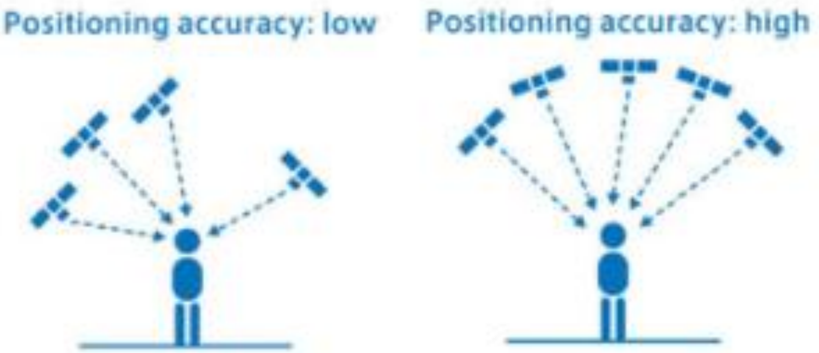


Integrated usage of QZS with GPS satellites

Improved positioning accuracy by multipath reduction



Multipath effects are minimal on satellites with high elevation angles

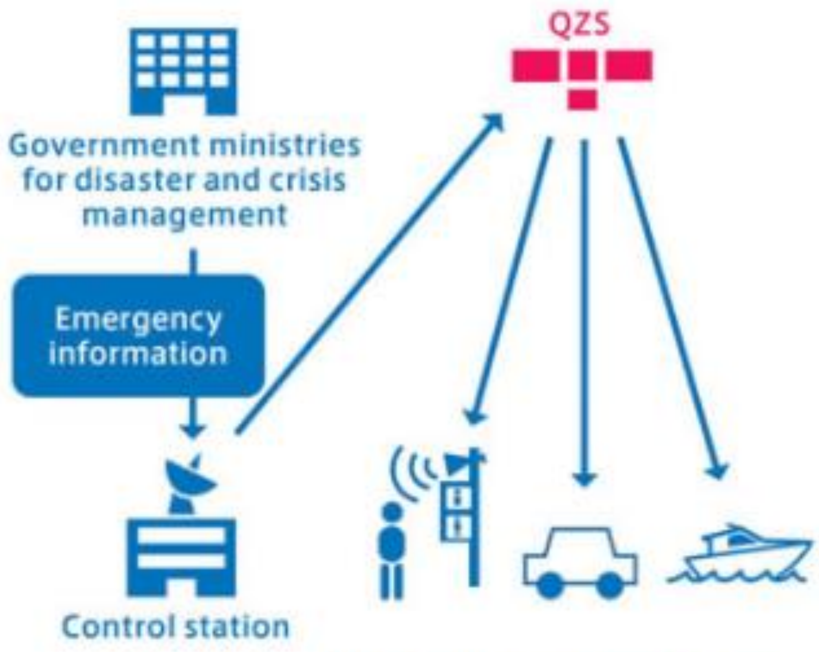


Improvement of positioning accuracy via satellite placement

https://qzss.go.jp/en/overview/services/sv04_pnt.html

Applications of QZSS

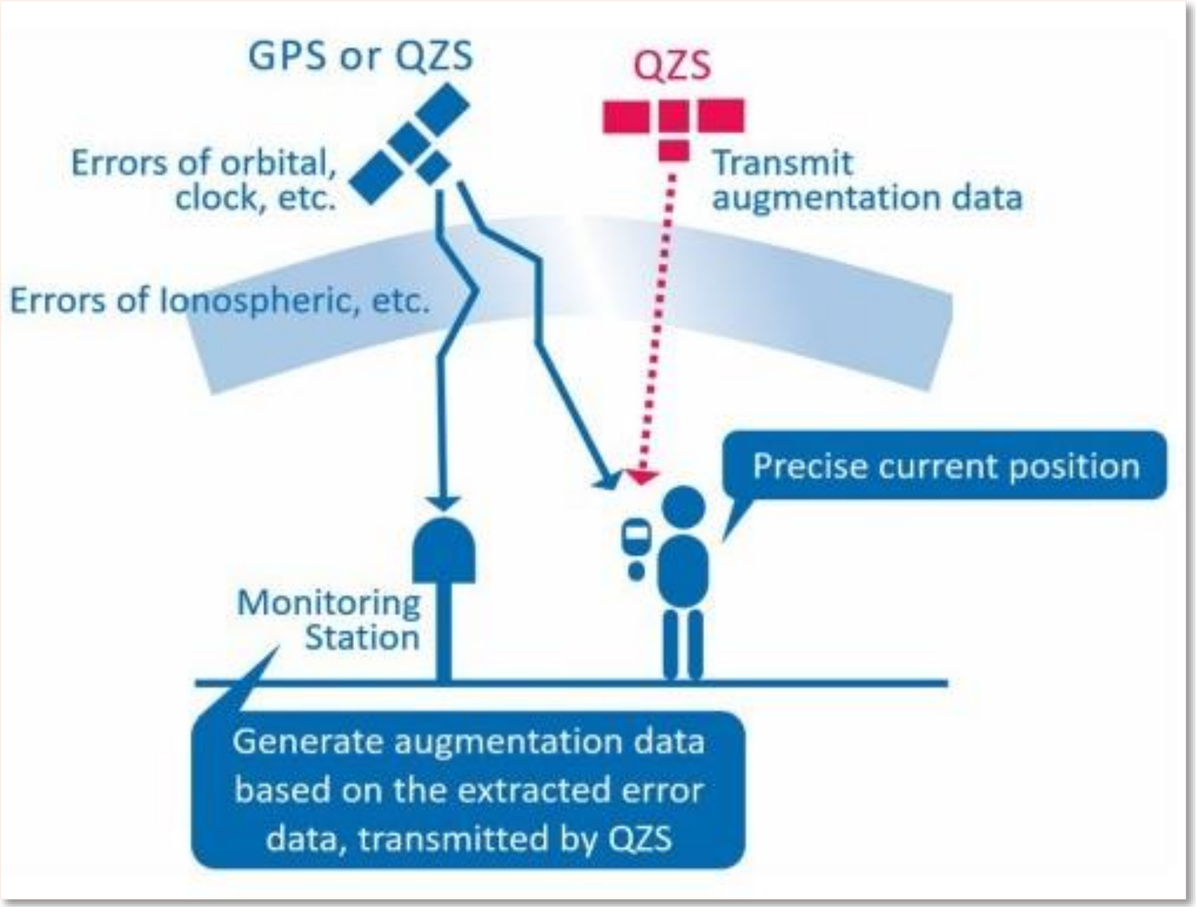
- Short Message Broadcast during Emergencies and Disasters
  - crisis management information released by organizations for disaster prevention—including information when a disaster like an earthquake or tsunami occurs—is transmitted via Quasi-Zenith Satellites (QZS)
  - Disaster-related information is transmitted in intervals of four seconds.



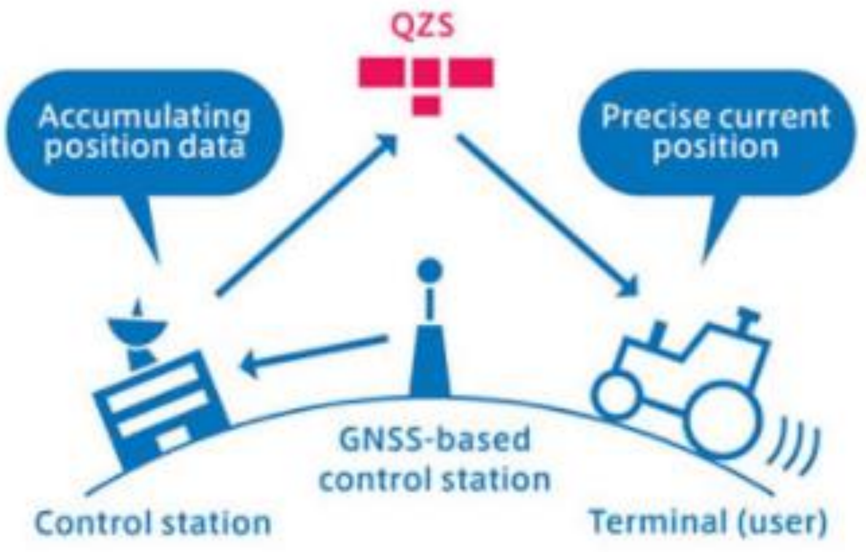
Satellite Report for Disaster and Crisis Management (DC Report)

Applications of QZSS

- Sub-meter Level Augmentation Service (SLAS)
  - To reduce errors in satellite positioning, information that can be utilized to decrease these errors (sub-meter level augmentation information)—such as ionospheric delay, orbit errors and clock errors—is transmitted by Quasi-Zenith Satellites (QZS).



Applications of QZSS



- Centimeter Level Augmentation Service (CLAS)
  - To carry out highly precise satellite positioning, distances from the Geospatial Information Authority of Japan's GNSS-based control stations are calculated using data from these control stations.
  - Information used to accurately search for one's current position (centimeter level augmentation information) is transmitted by QZS.

IRNSS/NavIC

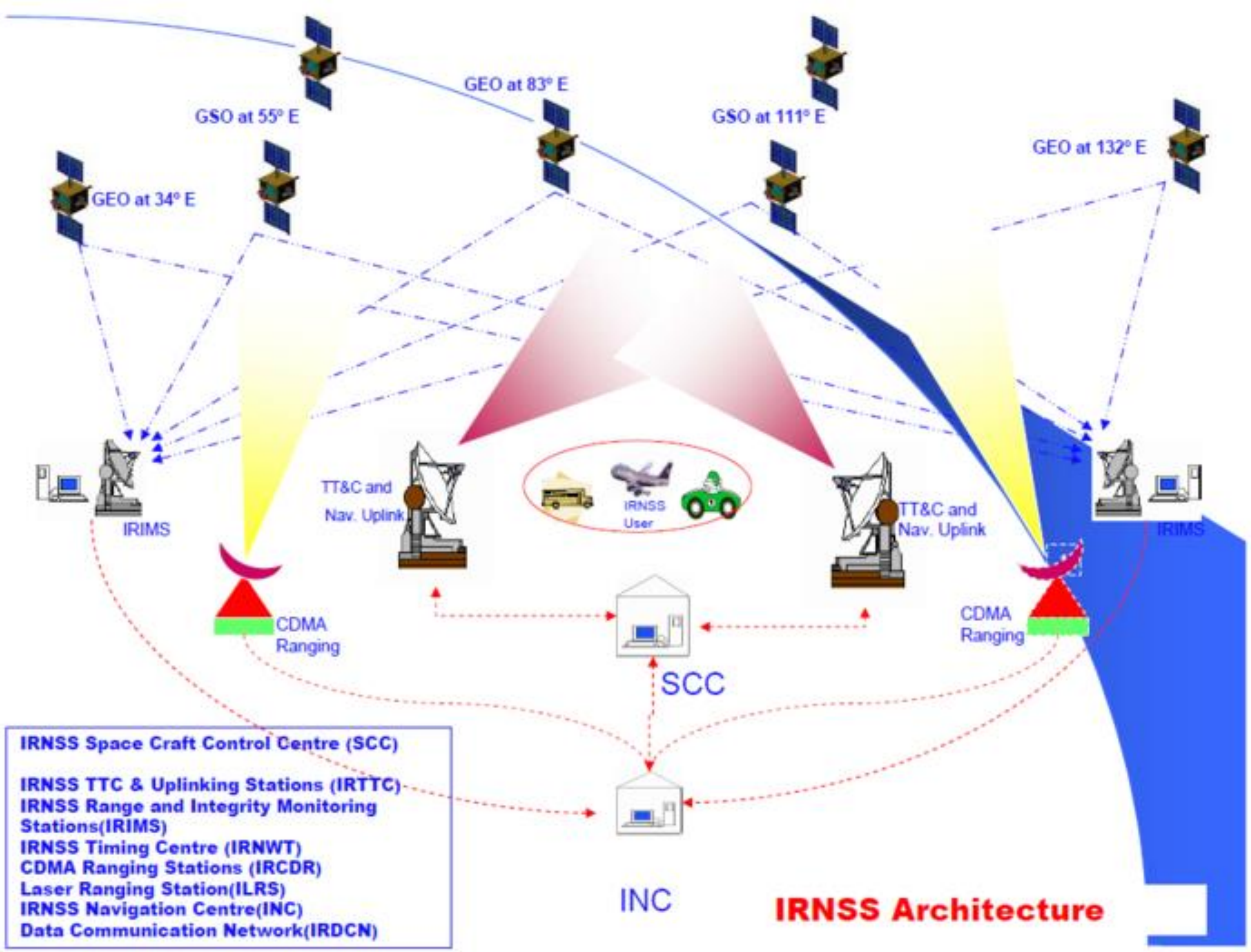
- Indian Regional Navigation Satellite System (IRNSS) with an operation name of NAVIC (i.e., Navigation with Indian Constellation) is an autonomous regional satellite navigation system.

- INRSS is an independent and autonomous regional navigation system aiming a service area about 1500 km around India.

- INRSS is being developed by Indian Space Research Organization (ISRO) under Indian government.

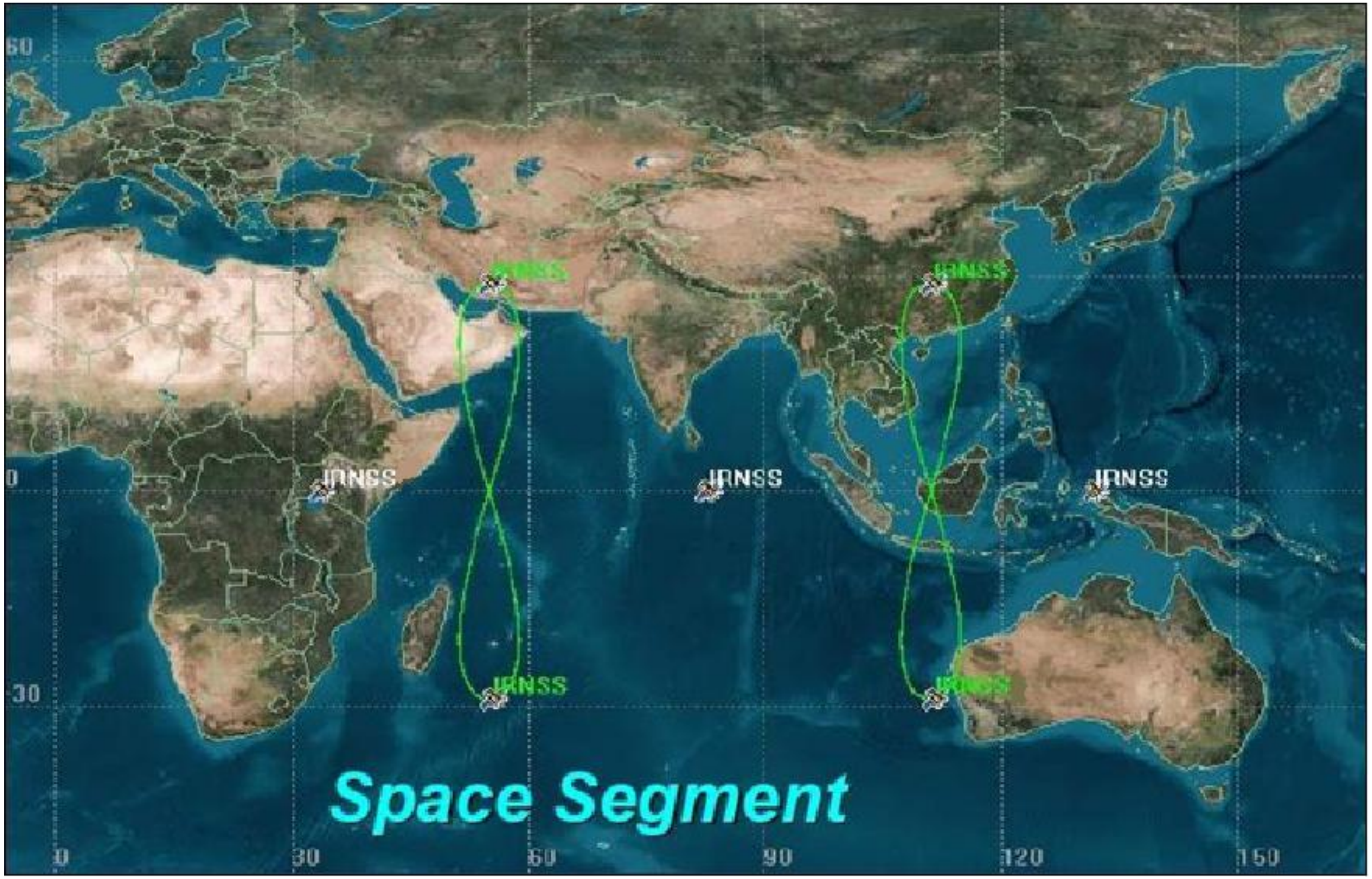
IRNSS/NavIC

- Constellation consists of 7 satellites
- 3 satellites are in the geostationary orbit.
- 4 satellites are in geosynchronous orbits with the required inclination and equatorial crossings in two different planes.
- All the satellites (IRNSS 1A – 1G) of the constellation are configured identically.



IRNSS/NavIC: Segments

Space Segment	
Satellites in Constellation	7
Ground Segment	
ISRO Navigation Centre	2
Reference Stations	17
CDMA Ranging Stations	4
Network Timing Centre	2
Spacecraft Control Centre	2
Frequency band	L5 and S
Service	SPS and RS



IRNSS/NavIC: Segments

- User Segment:
  - The user segment consists of a specially designed dual frequency receiver.
  - Several types of receivers are planned with single and dual frequency reception. Single frequency receivers may be provided with capability to receive ionospheric correction.
  - The user receiver may receive other constellations in addition to INRSS.
  - All the seven INRSS satellite will be continuously tracked by the user receiver.

INRSS provides two types of service:

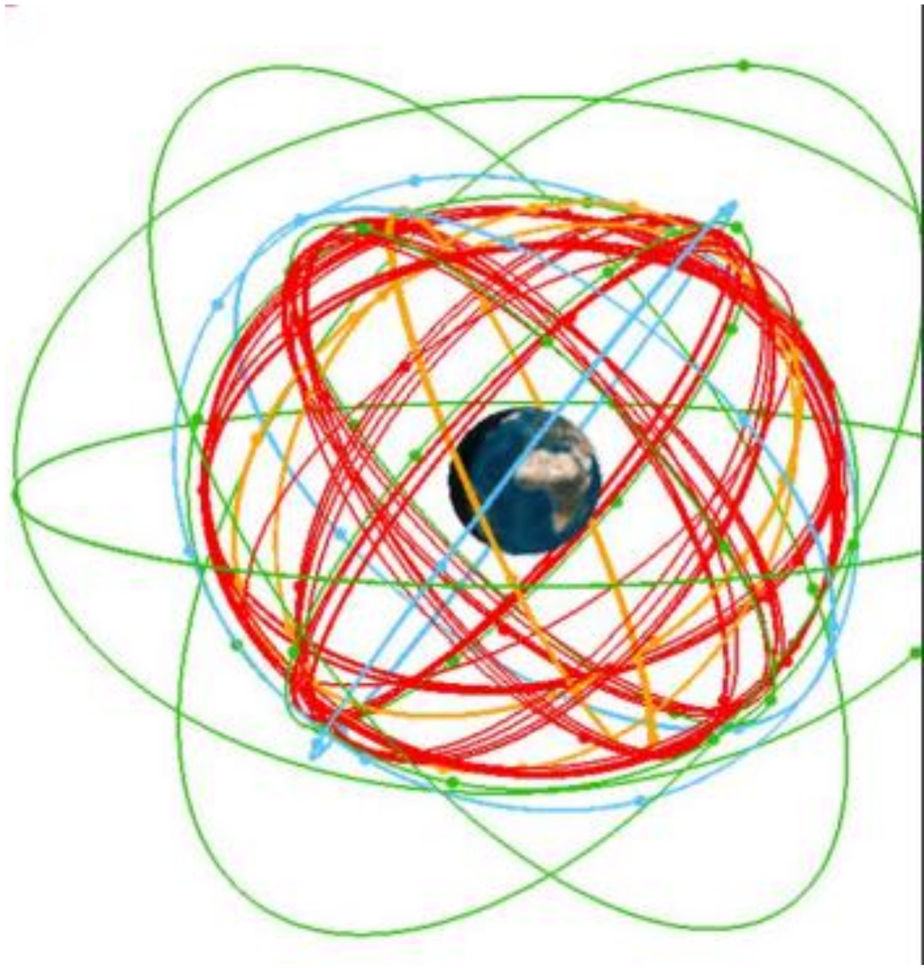
Standard Positioning Service (SPS), which is provided to all the users.

Restricted Service (RS), which is an encrypted service provided only to the authorized users.

GNSS: Summary

GNSS is great opportunity for science and research

- Over **130 GNSS satellites available with unique features for scientific exploitation**
- Providing **Global coverage, multi-constellation, multifrequency** and **long-term data availability** (decades !) which correlates with many scientific applications.
- A dense network of precious GNSS data available worldwide including several hundreds of professional receivers and **billions of smartphones** and **IoT sensors**.
- Systems under **continuous technological improvements** (more stable clocks, new on-board sensors, more signals and of better quality) enhancing scientific possibilities



GNSS Scientific Fields

Earth Science and Space Weather:

E01 Geodesy / Precise positioning
E02 Geodynamics, geophysics and oceanography
E03 Global tectonics
E04 Reference frames
E05 Ionosphere / space weather
E06 Troposphere / climatology
E07 Disaster monitoring
E08 Gravity field
E09 GNSS remote sensing, GNSS reflectometry

Fundamental Physics:

P01 Test of General Relativity and alternative theories
P02 Fundamental constants
P03 Relativistic reference frames
P04 Relativistic positioning
P05 Astrometry, VLBI, pulsar timing
P06 Quantum technologies for positioning and timing
P07 Gamma Ray Burst detection and GNSS
P08 GNSS and dark matter

Space-Time Metrology:

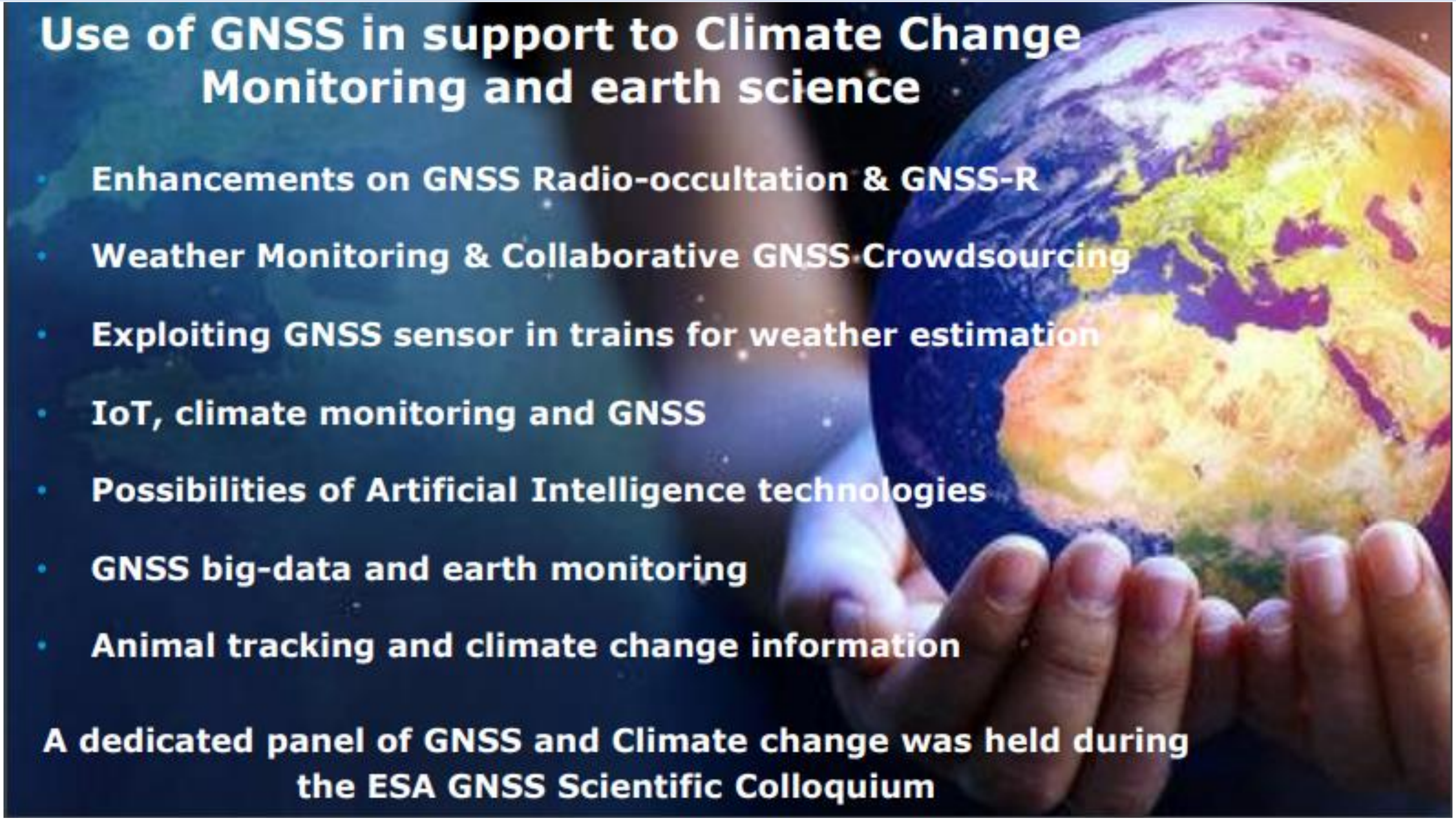
M01 Atomic clocks for space and ground-segment
M02 Galileo timing system
M03 Time scales and time transfer
M04 Inter-satellite links
M05 Precise orbit determination
M06 High-precision clocks in receivers

Space Service Volume and transversal activities

T07 Space service Volume navigation
N01 Signal processing
N04 Sensors, hybridization for science
N06 Animal tracking / Migrations
T01 GNSS Big Data for science / scientific data archives
T04 Cubesats and UAVs for GNSS science
T05 Software receivers / low-cost SDR platforms
T06 GNSS science and education

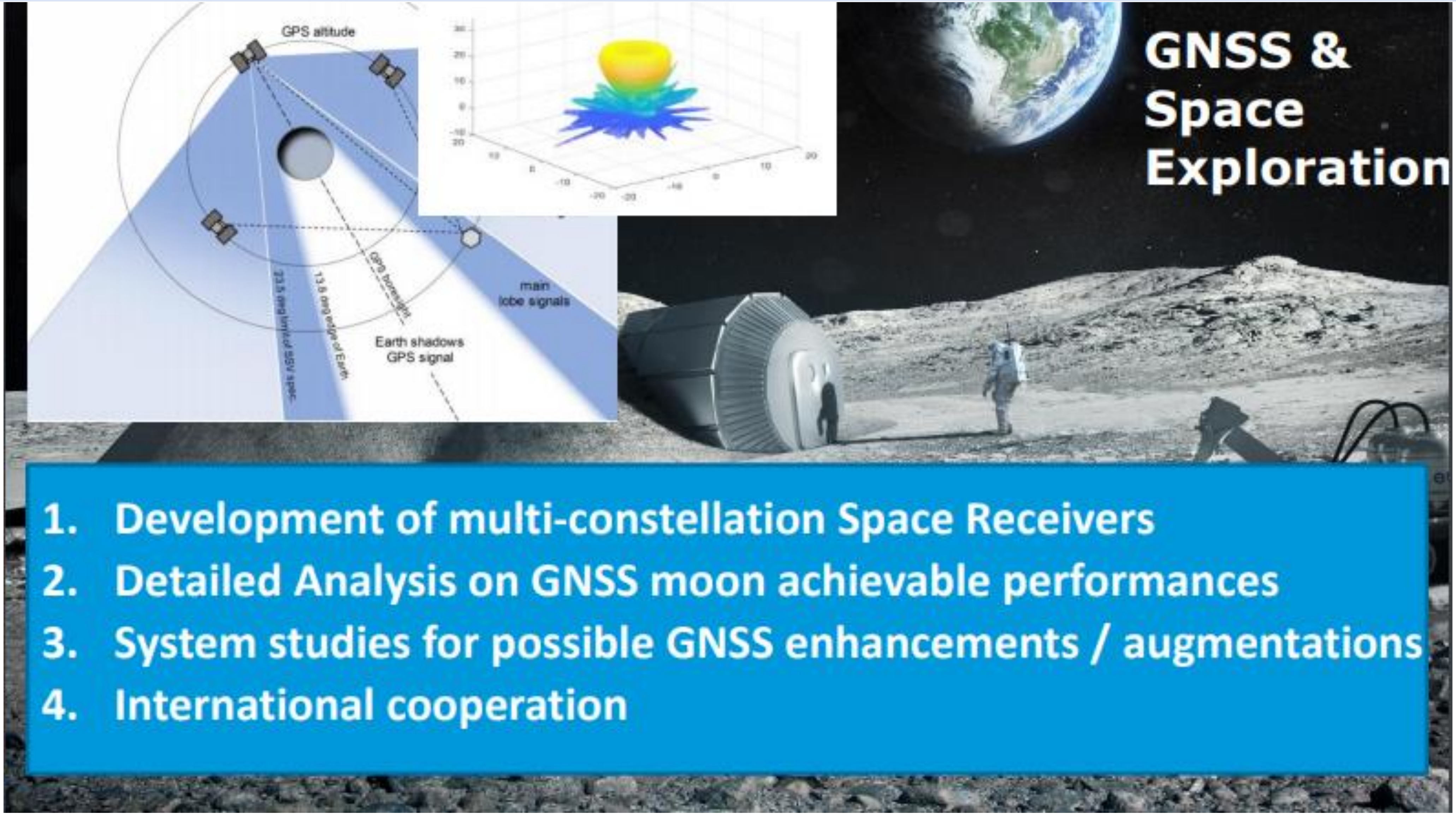
https://www.unoosa.org/documents/pdf/icg/2019/icg14/10.pdf

GNSS Scientific Fields



https://www.unoosa.org/documents/pdf/icg/2019/icg14/10.pdf

GNSS Scientific Fields



GNSS Commercial Fields

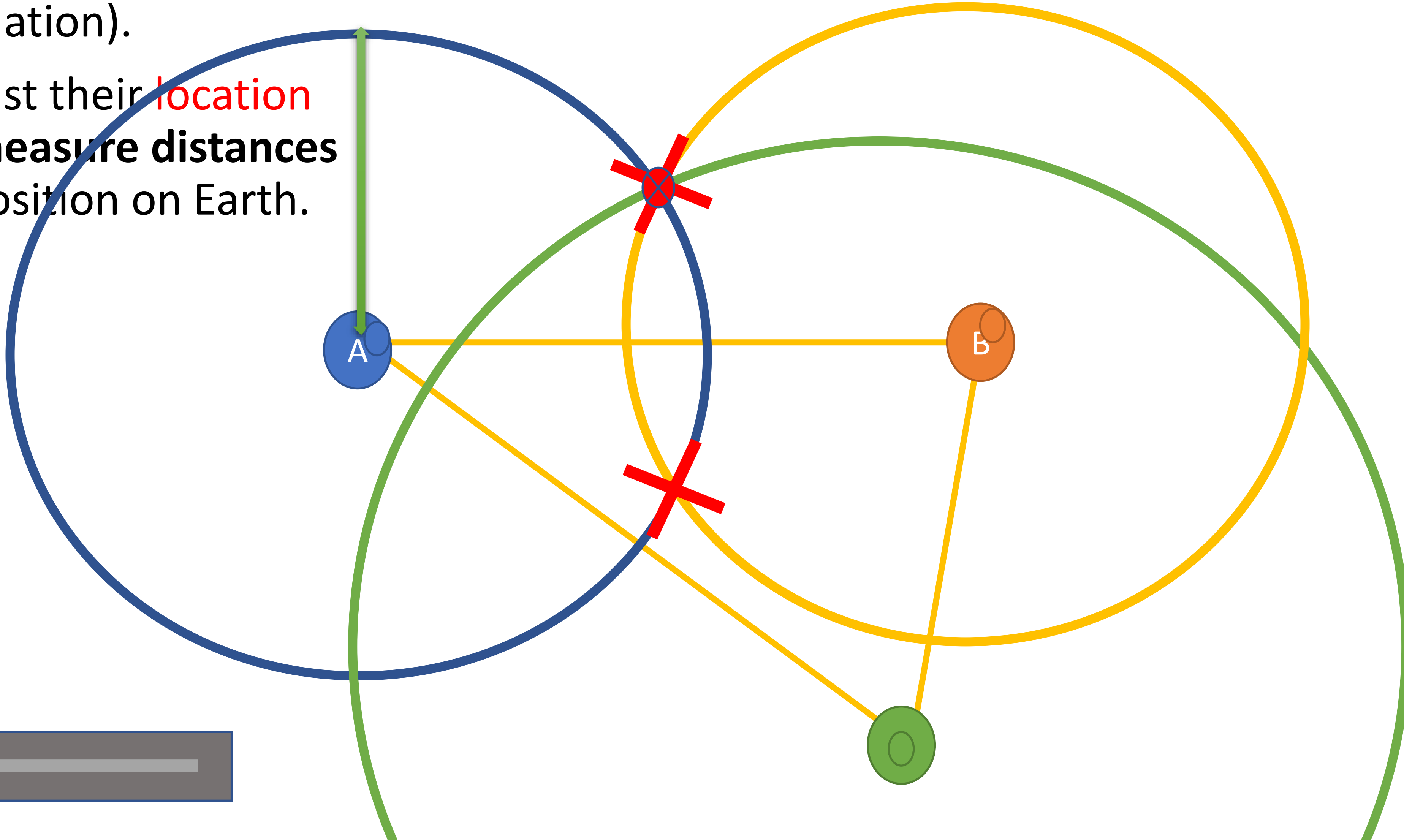
Mutli-GNSS Issues

- Compatibility
  - Interference issues (disrupt radio frequency signal)
- Interoperability
  - Use of the same receiver and antenna to receive different signals
- Interchangeable
  - Any four satellites would provide 3D position [one GPS, one GLONASS, one Galileo and one BeiDou]

- Robust and efficient algorithm for regional data improvement.

GPS/GNSS Positioning

- GPS positioning is based on the concept of trilateration (not triangulation).
- As GPS satellites broadcast their location and time, **trilateration measure distances** to pinpoint their exact position on Earth.



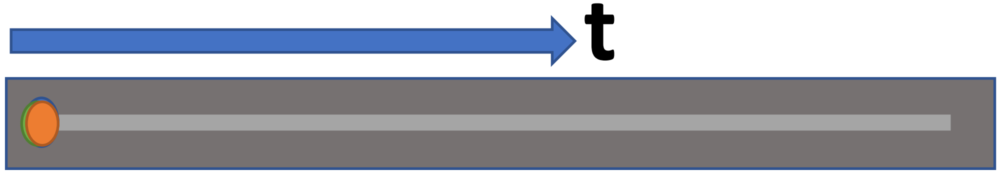
Satellite Location

Clock Time

C = 3000000km/s

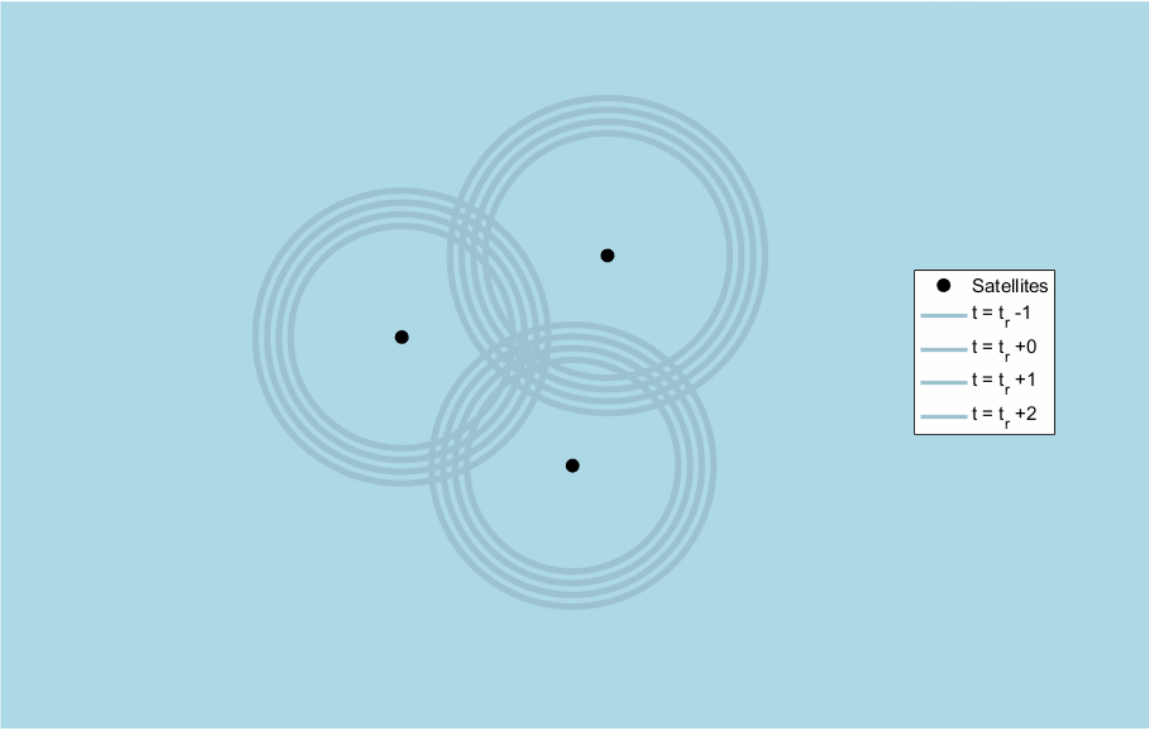
$$t * V = S$$

t



GPS/GNSS Positioning

- In three-dimensional world that GPS satellites broadcast signals as a sphere.
- Each satellite is at the center of a sphere.
- Where all spheres intersect determines the position of the GPS receiver.



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