EWCE 103

Global Positioning System (GPS)

GPS

Introduction:

- Stands for "**Global Positioning System**."

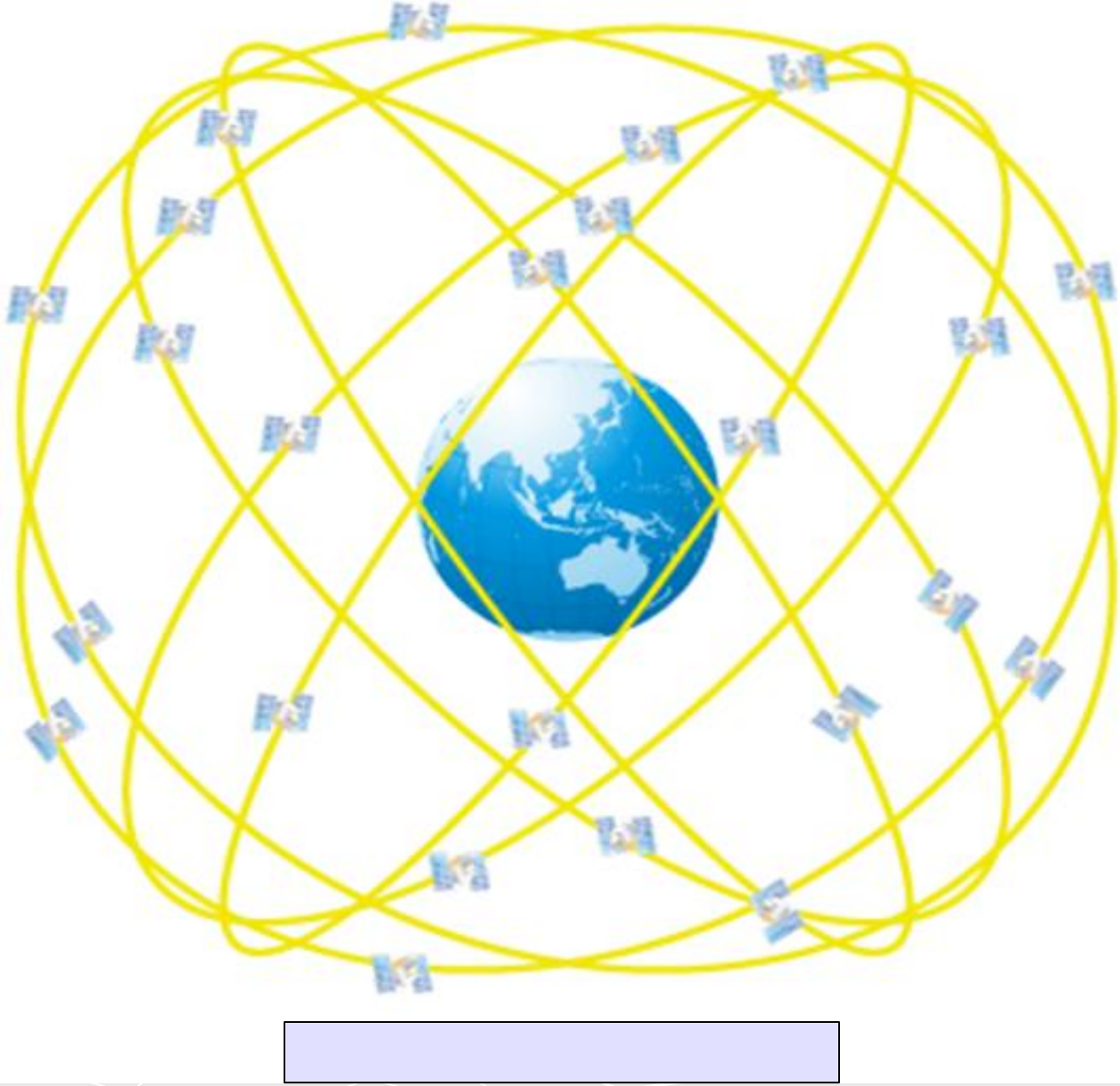
- GPS is a **satellite navigation system** used to **determine the ground position of an object.**

GPS technology was first used by the **United States military** in the **1960s** but since the **1990s** has been open for civilian use and is now used in **common applications** as mobile phones, car navigation etc.

Definition:

GPS is a **highly accurate navigation system** using **signals from satellites** to **determine locations and directions of objects** **on the Earth's surface**, irrespective of weather conditions.

Orbit of GPS Satellites

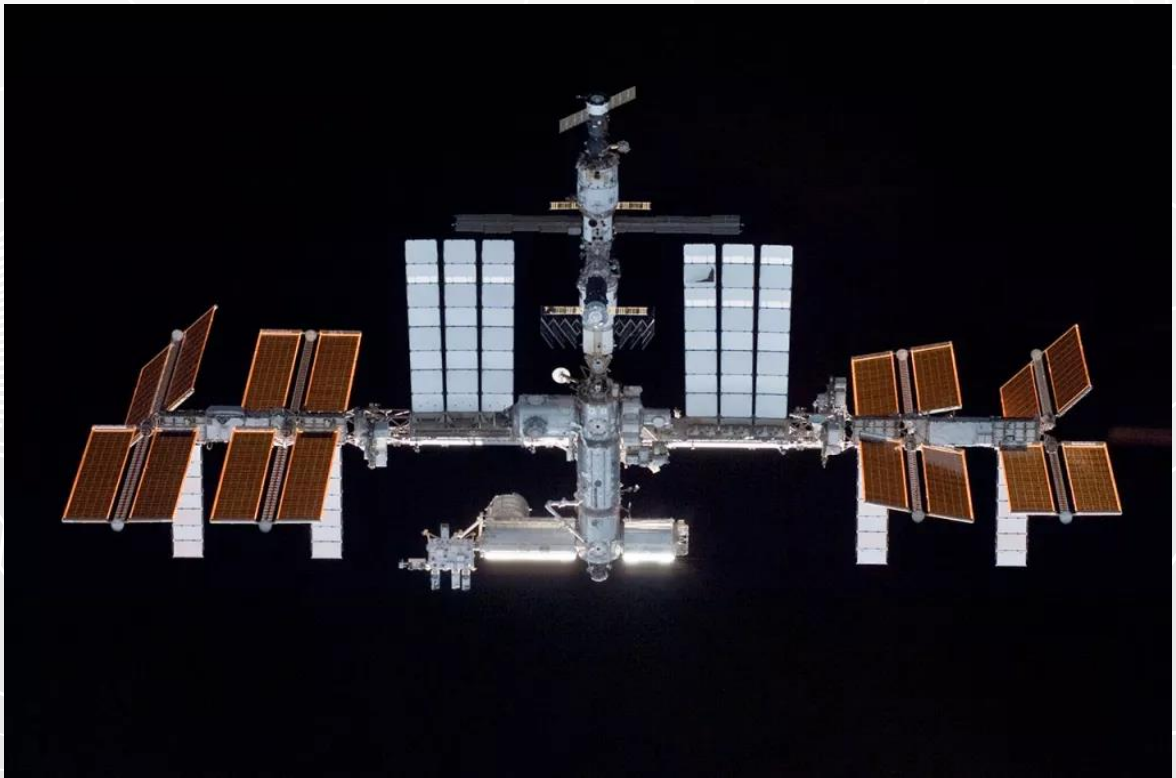


Satellite:

- A satellite is an **object in space that orbits or circles around a bigger object.**

Two kinds of satellites:

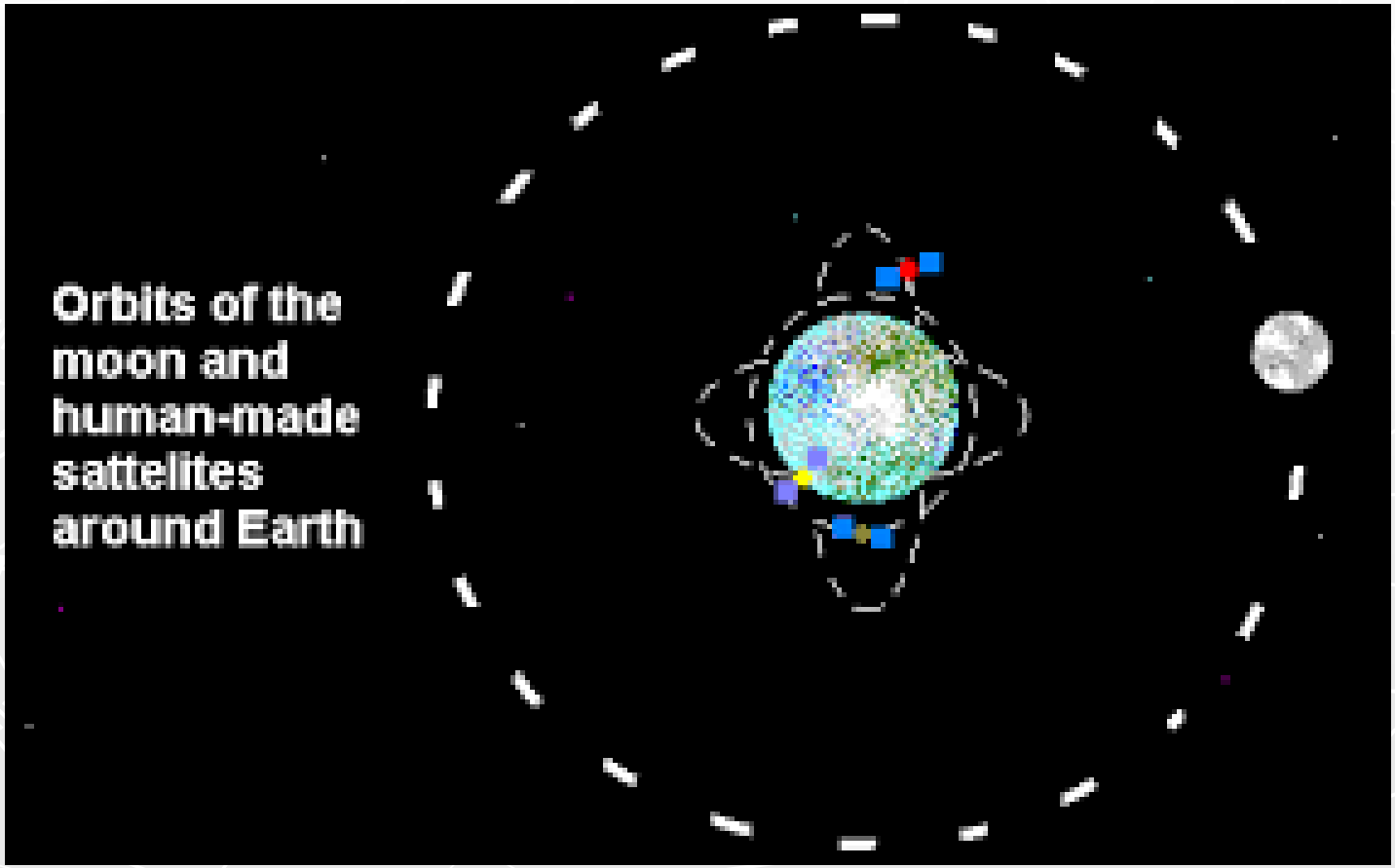
- **natural** (such as the moon orbiting the Earth) or
- **artificial** (such as the International Space Station orbiting the Earth).



What is an Orbit?

- An **orbit** is a **regular, repeating path** that one object in space takes around.

- An **object in an orbit** is called a satellite.



GPS

- GPS system includes **24 satellites** deployed in space about 19,300 kilometers above the earth's surface.

- **Orbit the earth once every 12 hours** at an extremely fast pace of roughly 11,200 kilometers per hour.

- **Satellites are evenly spread out** so that **four satellites are accessible via direct line-of-sight from** anywhere on the globe.



How many satellites are orbiting the Earth in 2023?

- According to the **Index of Objects Launched into Outer Space**, maintained by the United Nations Office for Outer Space Affairs (UNOOSA), there were **11,330** individual satellites orbiting the Earth at the end of June 2023; a whopping **37.94%** increase since January 2022 when we did the last of these updates.

- Since 1957, over the last 66 years, **15,946 objects have been launched** into space.
- According to UNOOSA, **11330 satellites are currently orbiting** the Earth is because (**additional 4616**):

  -some of the launched objects have **burnt up** the atmosphere.

  -some have **fallen back** to Earth;

  -some have been **destroyed in space**; and

  -some are **orbiting other bodies** such as the Moon, Mars, comets, etc.

All of the orbiting satellites are working, aren't they?

- Union of Concerned Scientists (UCS) keep a record of the operational satellites.
- According to UNOOSA, **1,346** objects orbiting the planet were launched in 2023.
- Taking these away from the **11,330** gives a figure of **9,984 orbiting objects at the start of 2023.**

- According to the UCS, at the start of the year there were **6,718 operational satellites** at the start of 2023.
- There are still **3,266 useless hunks of metals** travelling around the planet.

What are all these active satellites doing?

Using the UCS update, as at the end of December, the main purposes for the operational satellites were:

- **Communications:** 4 823 satellites
- **Earth observation:** 1 167 satellites
- **Technology development/demonstration:** 414 satellites
- **Navigation/positioning:** 155 satellites
- **Space science/observation: 109 satellites**
- **Earth science: 25** satellites
- **Other purposes:** 25 satellites.

It should be noted that some of the **satellites have multiple purposes**, and they have been categorized by their main purpose.

What countries operate active satellites?

According to the UCS data:

- There are **75 individual countries** from across the globe that operate active satellites, on top of this there are **multinational operators** such as the European Space Agency which may increase this number.
- The top ten individual countries controlling the greatest number of satellites are:

- United States with **4 511 satellites**.
- China with 586 satellites.
- United Kingdom with 561 satellites.
- Russia with **177 satellites.**
- India with **62 satellites**.
- Canada with 56 satellites.
- Germany with 48 satellites.
- Luxembourg with 45 satellites.
- Argentina with 38 satellites.

Who are the users of the satellites?

Looking at the primary users of satellites gives:

- **5,280 satellites are listed as having commercial users** – again driven by the space-based broadband companies.
- 688 with government users
- **588 with military users**; and
- 162 with civil users.

It should be noted this list is the primary user of the satellite. Of these, there are **305 satellites (4.5%) listed as having multiple users.**

How many satellites are orbiting the Earth in 2023?

According to the **Index of Objects Launched into Outer Space**, maintained by the UNOOSA, there were **11,330 (4616 useless)** individual satellites orbiting the Earth at the end of **June 2023**; a whopping **37.94%** increase since January 2022 when we did the last of these updates.

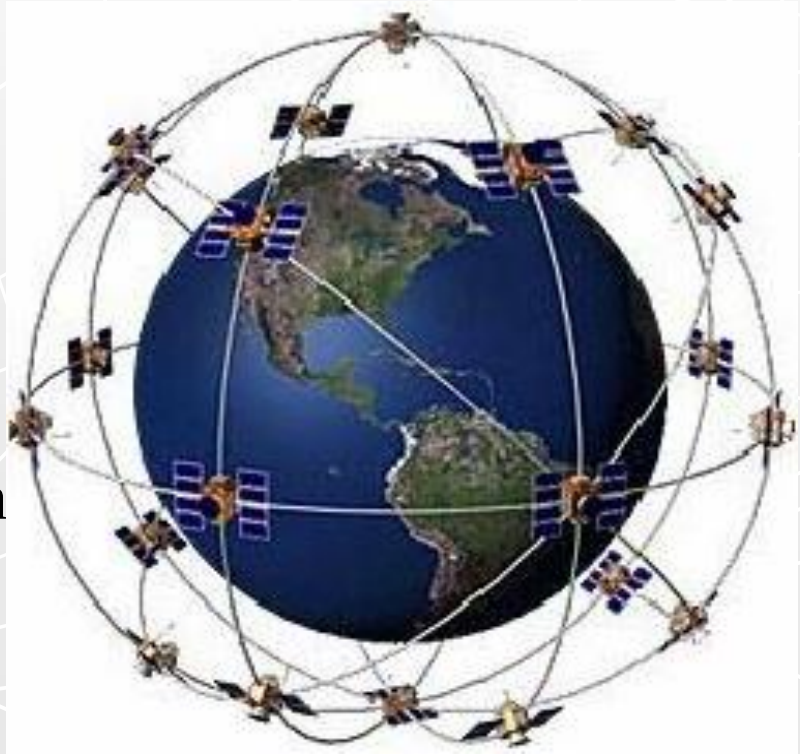


Basic Structures of GPS

GPS consists of the following **three segments.**

Space segment (GPS satellites):

- A number of GPS satellites are deployed **on six orbits** around the earth at the **altitude of approximately 19**,400 km (**four GPS satellites per one orbit**), and move around the **earth at 12-hour-intervals at 11200 km/hr.**
- **Emitting continuous navigation signals.**
- Receivers on the ground snag these signals out of the air, using them to calculate time, location and velocity with high accuracy.



Basic Structures of GPS

Control segment (Ground control stations)

- **Ground control stations** play roles of **monitoring, controlling and maintaining satellite in orbit** to make sure that the **deviation** of the satellites from the orbit as well as **GPS timing are within the tolerance level.**

- Mainly responsible for the **proper operation of the GPS system**.



Sajeeb Wazed Ground Station, the **primary ground station** for the Bangabandhu-1 satellite located near the Telecommunications Staff College in Telipara, Gazipur.



Sajeeb Wazed Satellite Ground Station, the secondary Ground Station at Betbunia, Rangamati.

- **Secondary ground station** is at Betbunia, Rangamati. The first test signal after launch was received by the operators on May 12, 2018.

- The country's first satellite earth station at Betbunia under Kawkhali upazila of Rangamati district, which was **inaugurated by Father of the Nation** Bangabandhu Sheikh Mujibur Rahman on June 14, 1975.



User segment (GPS receivers):

-mobile phones,

-car navigation systems, and

-watches, and GPS devices.

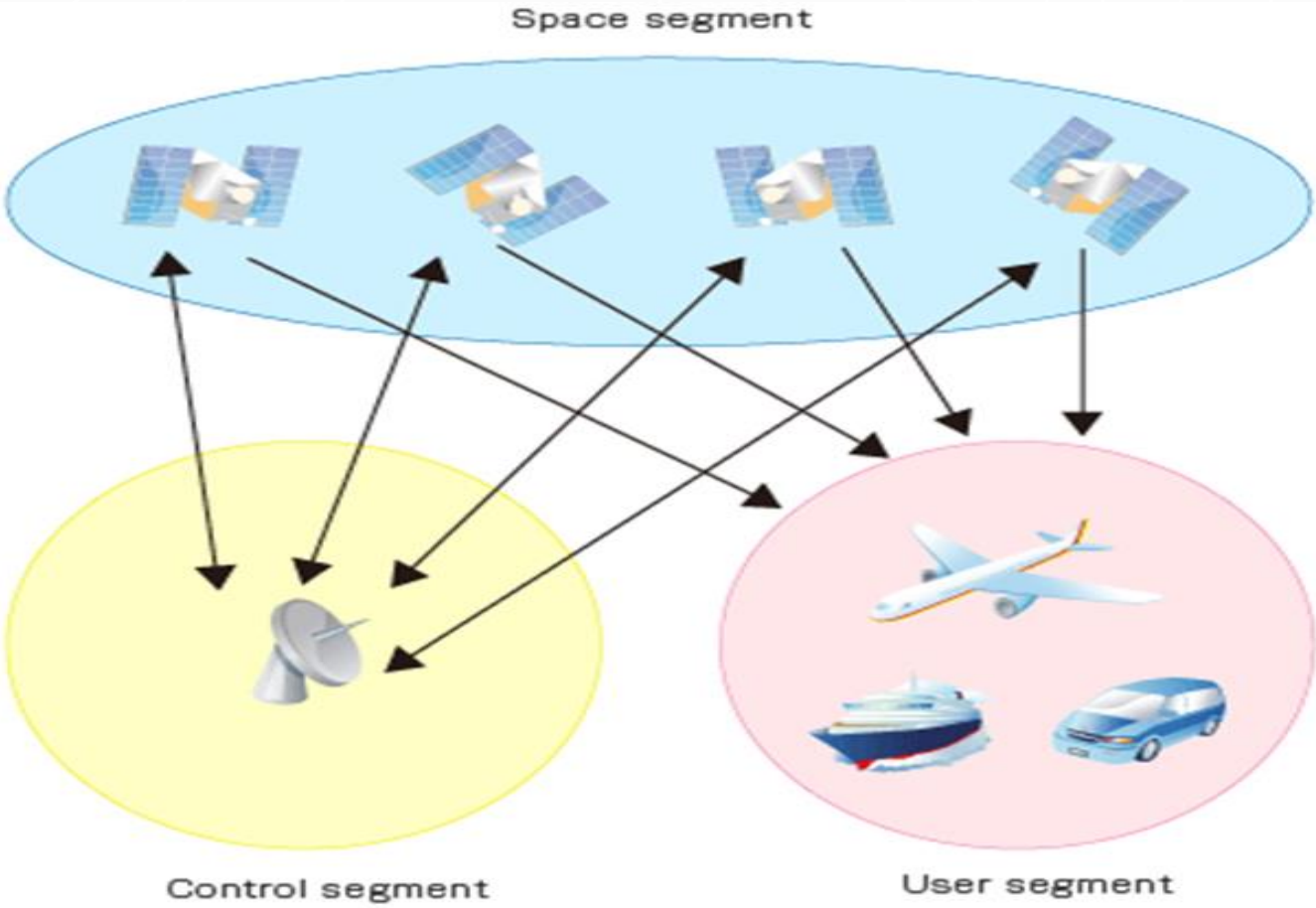


Fig. 1-2 Three elements of GPS

Bangabandhu Satellite-1

- Bangabandhu Satellite-1 is the **first terrestrial communication and broadcasting satellite** of Bangladesh.

- It is **named** after the father of the nation, Bangabandhu Sheikh Mujibur Rahman.

- Manufactured by **Thales Alenia Space of France** and launched from the Kennedy Space Center, privately owned spacecraft **Space X**, on May 11, 2018.

- Satellite was the **first payload launched by a Space X** on-board **Falcon 9** version 1.2 rocket**.**

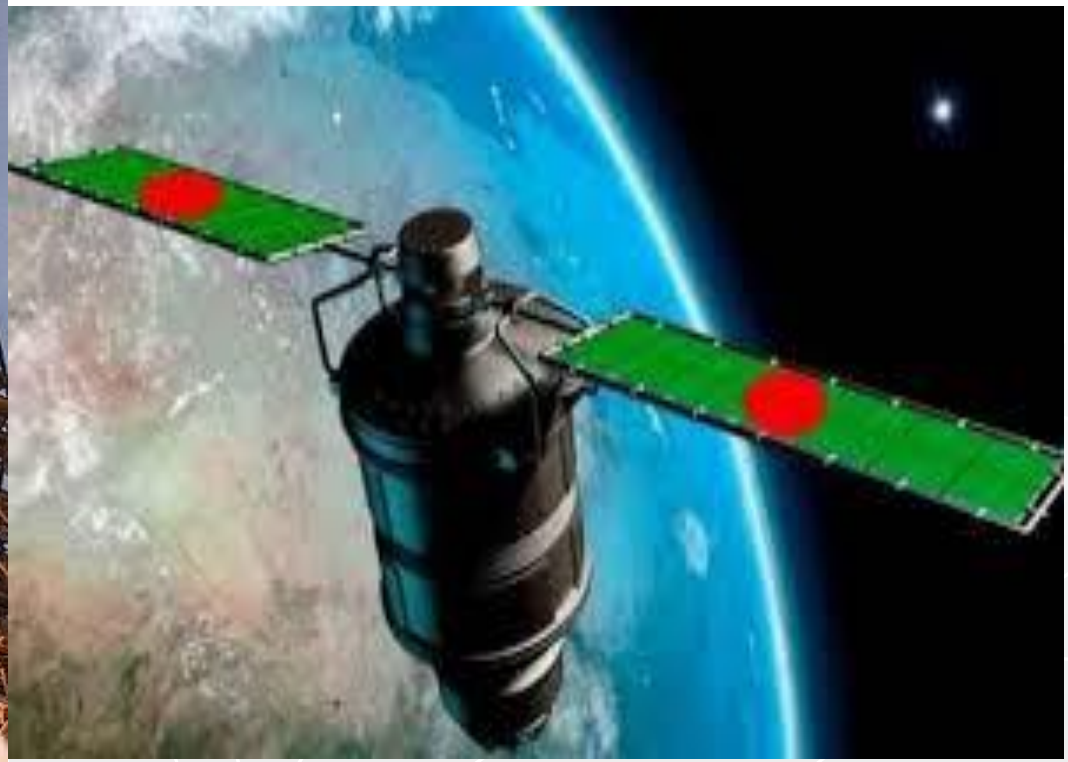
- Two ground stations have been set up at Joydevpur in Gazipur district and Betbunia in Rangamati district.



ThalesAlenia Space, the joint venture between Thales (67%) and Leonardo (33%), a Italian Space Agency (ASI) to **design, develop and qualify a spacecraft** for a dedicated In-Orbit Servicing (IOS) demonstration mission.

Thales Alenia Space is leading a Temporary Grouping of Companies regrouping Leonardo, Telespazio, Avio and D-Orbit.





Falcon 9 rocket launching with Bangabandhu-1

- **Mission type:** Communications and Broadcasting Satellite.
- **Operator**: Bangladesh Communication Satellite Company Limited, BCSCL, Bangabandhu Satellite Project.
- **Mission duration**: 15 years.
- **Launch site**: Kennedy Space Center Launch Complex 39A.
- **Contractor:** SpaceX



Bangabandhu Satellite-1

- For this purpose, ground stations have been set up at **Joydevpur** in Gazipur district and **Betbunia** in Rangamati district.

- Joydebpur ground station is **the main station**. And Betbunia station has been **backed up as a secondary station**.

- In addition, two ground satellite stations have been set up in **Indonesia** and the **Philippines**.

The primary service area (PSA) of the satellite is **Bangladesh** and **neighboring countries**, while secondary service areas (SSA) include **South East Asia**, **Europe**, **Middle East** and **North Africa** (MENA), as well as **East Africa**.

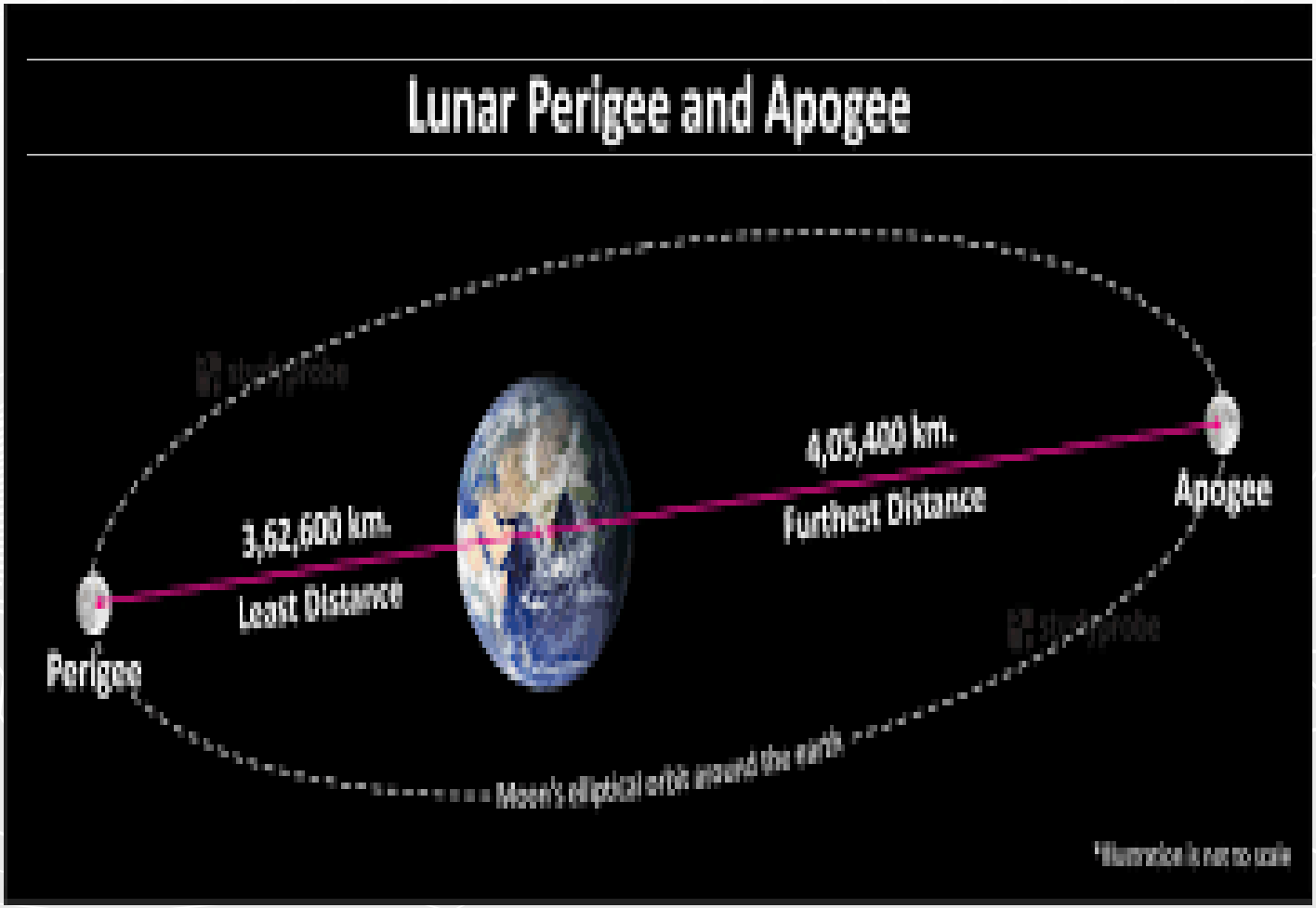
Bangabandhu Satellite is **not only in Bangladesh**, but also in **other countries of the world, various media organizations** are currently using Bangabandhu-1 satellite rental transponders.

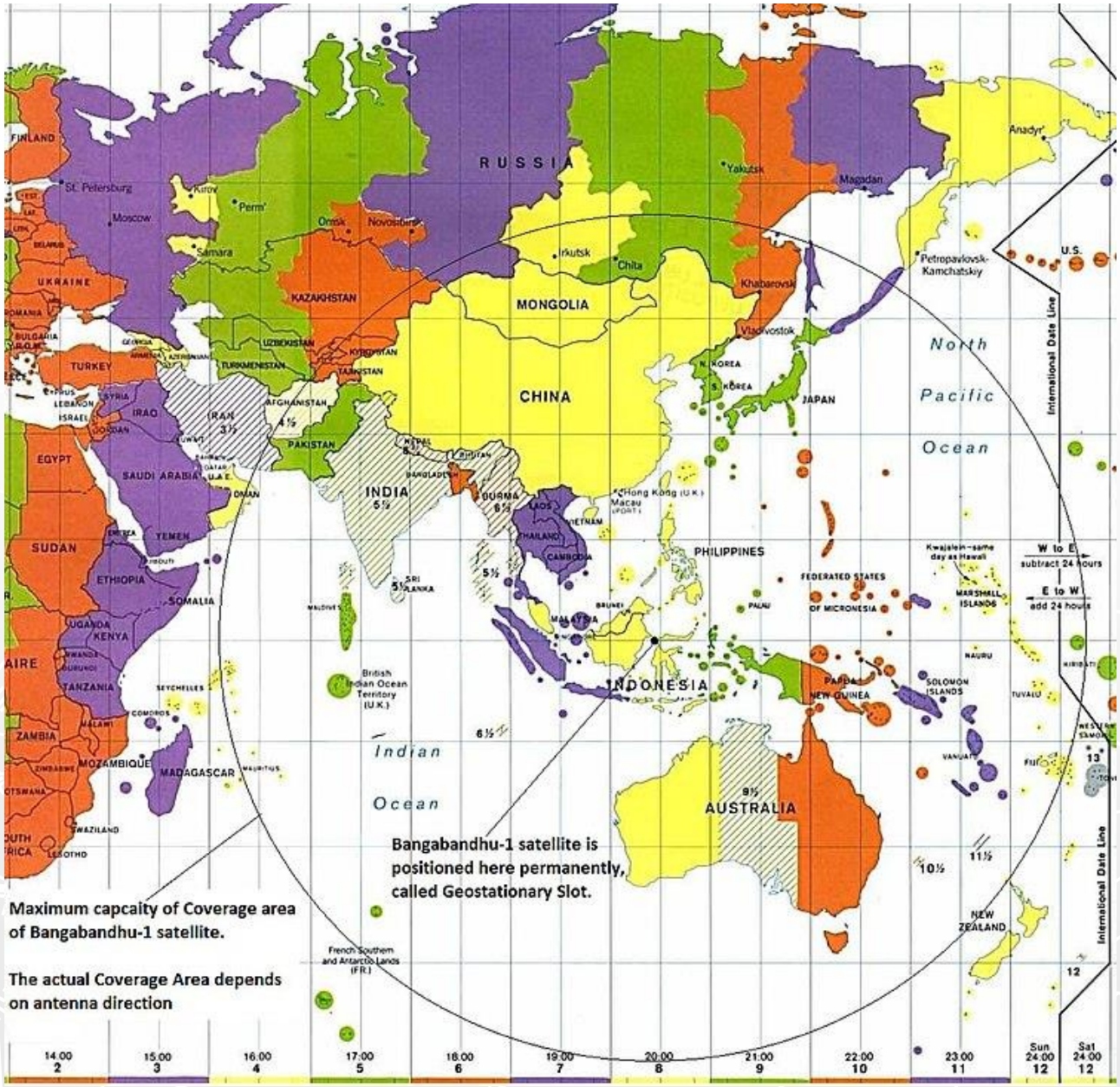
Notable among them are:

- 2 private TV channels **of Honduras,**
- 1 private TV channel of **Turkey**,
- 1 private TV channel of **Philippines** (some more contracted),
- 2 TV channels of **Ghana** (a few more are waiting),
- 1 private TV Channel of **Cameroon**.
- **South Africa** 2 online based TV Channels.

Bangabandhu Satellite-1

Spacecraft properties	
Perigee **altitude**	35789.3 km
Apogee **altitude**	35798.5 km





Bangabandhu Satellite-1 position and its coverage area 119.09°E

GPS

How GPS works?

- GPS satellites **transmit signals** containing the **time and location of the satellite.**

- **Ground-based receiver** **receives signals** from **four or more GPS satellites** to **calculate its location on the Earth's surface**.

- **Constant signaling** can then **update speed and direction of information for moving receivers**.

GPS

Requirement of GPS device to work correctly,

- Must **first establish a connection** to the required number of satellites.
- Process can take anywhere from a **few seconds to a few minutes**, depending on the strength of the receiver.

-**For example**, a **car's GPS** unit will typically establish a GPS connection faster than the receiver in a **watch or smartphone**.

- **Smartphones, tablets, and other mobile** devices often **use other means to determine location**, such as nearby **cell towers** and **public Wi Fi signals**

- Technology, sometimes referred to as the **Local Positioning System (LPS),** is often used **to supplement GPS** when a consistent satellite connection is unavailable.

Limitations

Since GPS receivers require a relatively unobstructed path to space, **GPS technology is not ideal for indoor use.**

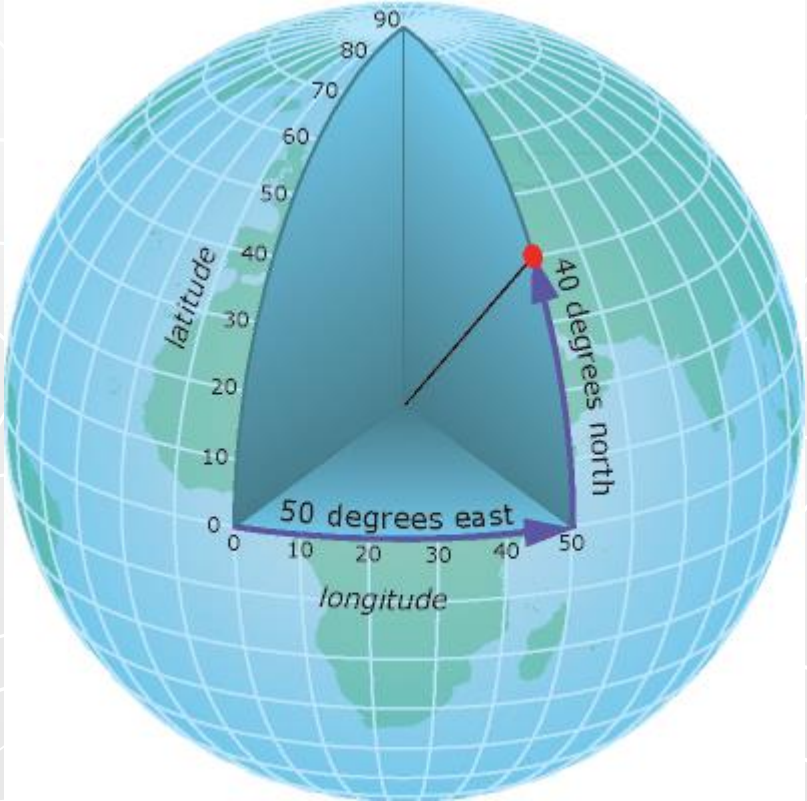
GPS Developed by different Countries:

- GPS- Global Positioning System: **USA**
- GLONASS- Global Navigation Satellite System: **Russia**
- BNASS- BeiDou Navigation Satellite System: **China**
- EUGPS- European Union Galileo Positioning System: **EU**
- NavIC- Navigation with Indian Constellation: **India**
- QZSS- Quasi-Zenith Satellite System: **Japan**

GPS

How GPS is Used in Surveying?

- Surveying and mapping was one of the **first commercial adaptations of GPS**, as it **provides a latitude and longitude position directly** without the need to measure **angles** and **distances** between points.



GPS

- GPS **hasn't entirely replaced** surveying field instruments such as the Theodolite, Electronic Distance Meter, or the more modern Total Station, **due to the**
  - Need for GPS to be able to **'see' the satellites**
  - **Restricting its use** near trees and tall buildings.

GPS utilized by surveyors

Methods of GPS measurement utilized by surveyors:

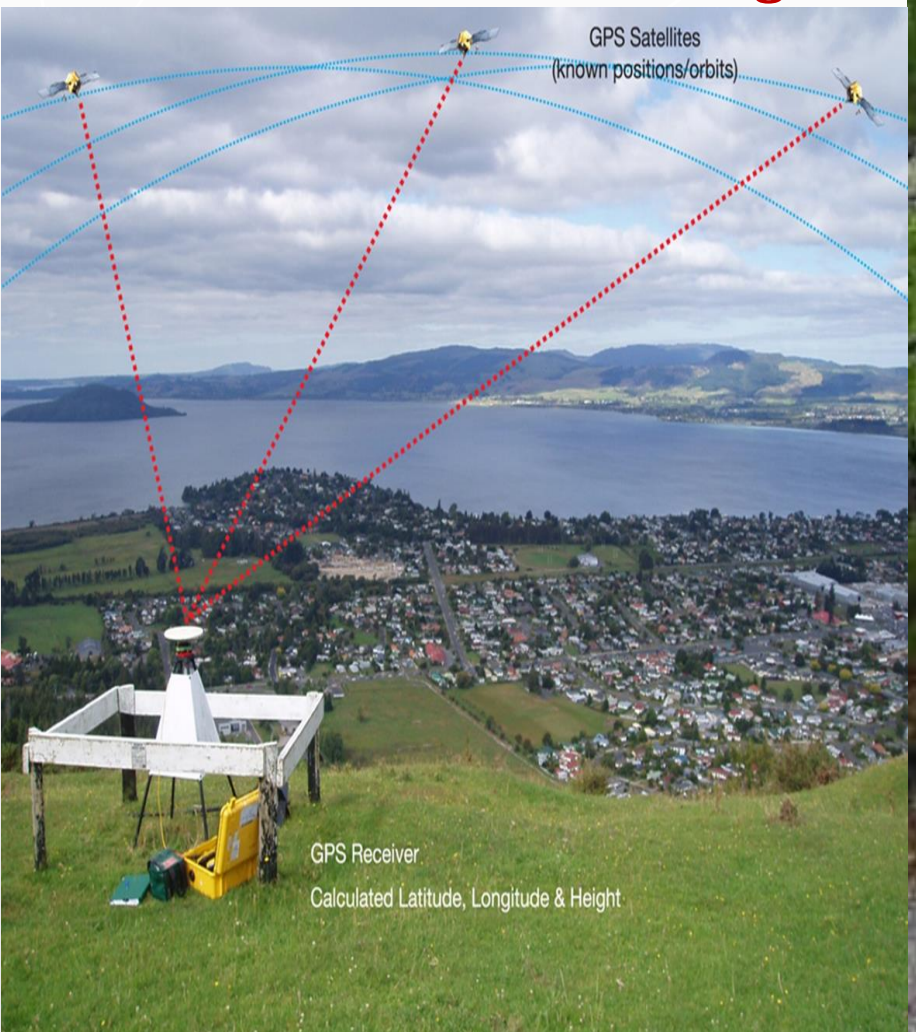
Static GPS for establishing Baseline

- **Static GPS is used for determining accurate coordinates for survey points,** by simultaneously recording GPS observations over a known and unknown survey point for at least 20 minutes.
- **Data is then processed to provide coordinates with an accuracy of better than 5mm** depending on the duration of the observations and satellite availability at the time of the measurements.

GPS utilized by surveyors

Methods of GPS measurement utilized by surveyors:

Static GPS for establishing Baseline

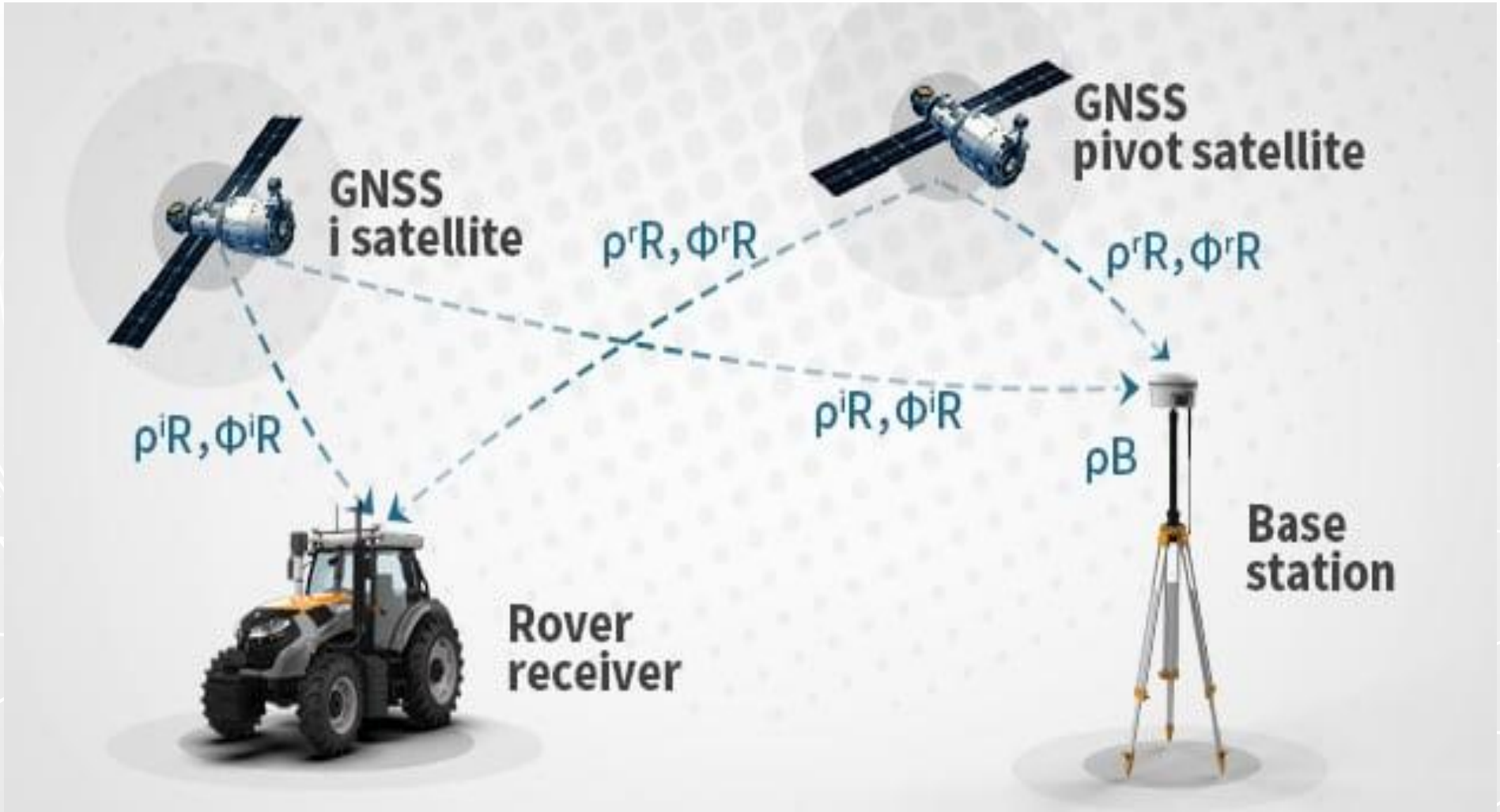




What is RTK?

- RTK (Real-time kinematic positioning) is a **technology used** to **improve the accuracy** of GNSS positioning.
- GNSS receivers **measure the time** it takes for a **signal to travel** from the satellite to the receiver.
- **Transmitted signal** travels through the ionosphere and atmosphere, **slowing down** and **perturbing** along the way.
- Because of that, the **GNSS receiver can only calculate** and determined the position with low accuracy of 2-4 meters.
- **RTK solves this problem.** It can provide users with centimeter accuracy of up to 2cm for applications that require greater precision.

RTK Observations for Positions:



GPS

Real Time Kinematic (RTK) Observations for Positions:

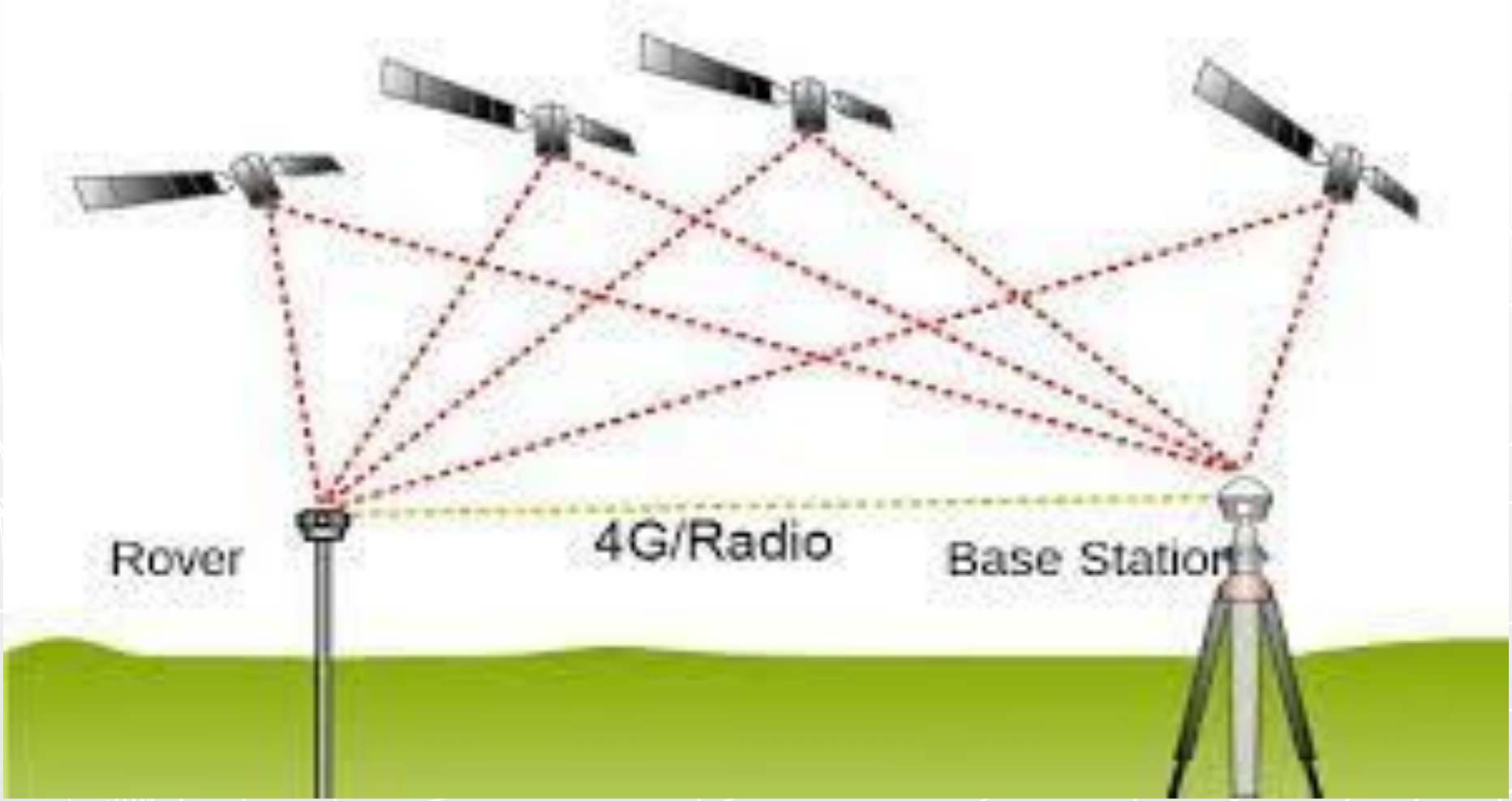
- **Base Station**: one **receiver remains** in one position **over a known point.**

- **Rover Station: A**nother **receiver moves** between positions.

- **Position of the Rover: Position can be computed and stored within a few seconds**, using a **radio link to provide a coordinate correction**.

- **Baseline**: Method gives **similar accuracy to baseline** measurements **within 10km of the base station**.

GPS Satellite & Receiver



Continuously Operating Reference Stations (CORS).

CORS

- Continuously Operating Reference Stations is a network of stations that provide GNSS data consisting of carrier phase and code range measurements in support of 3D positioning, meteorology, space geophysical applications.

- CORS Network: CORS infrastructure is basically a Network of permanently installed reference stations (or GNSS receivers), continuously streaming raw satellite observations to a central server.

Continuously Operating Reference Stations (CORS).

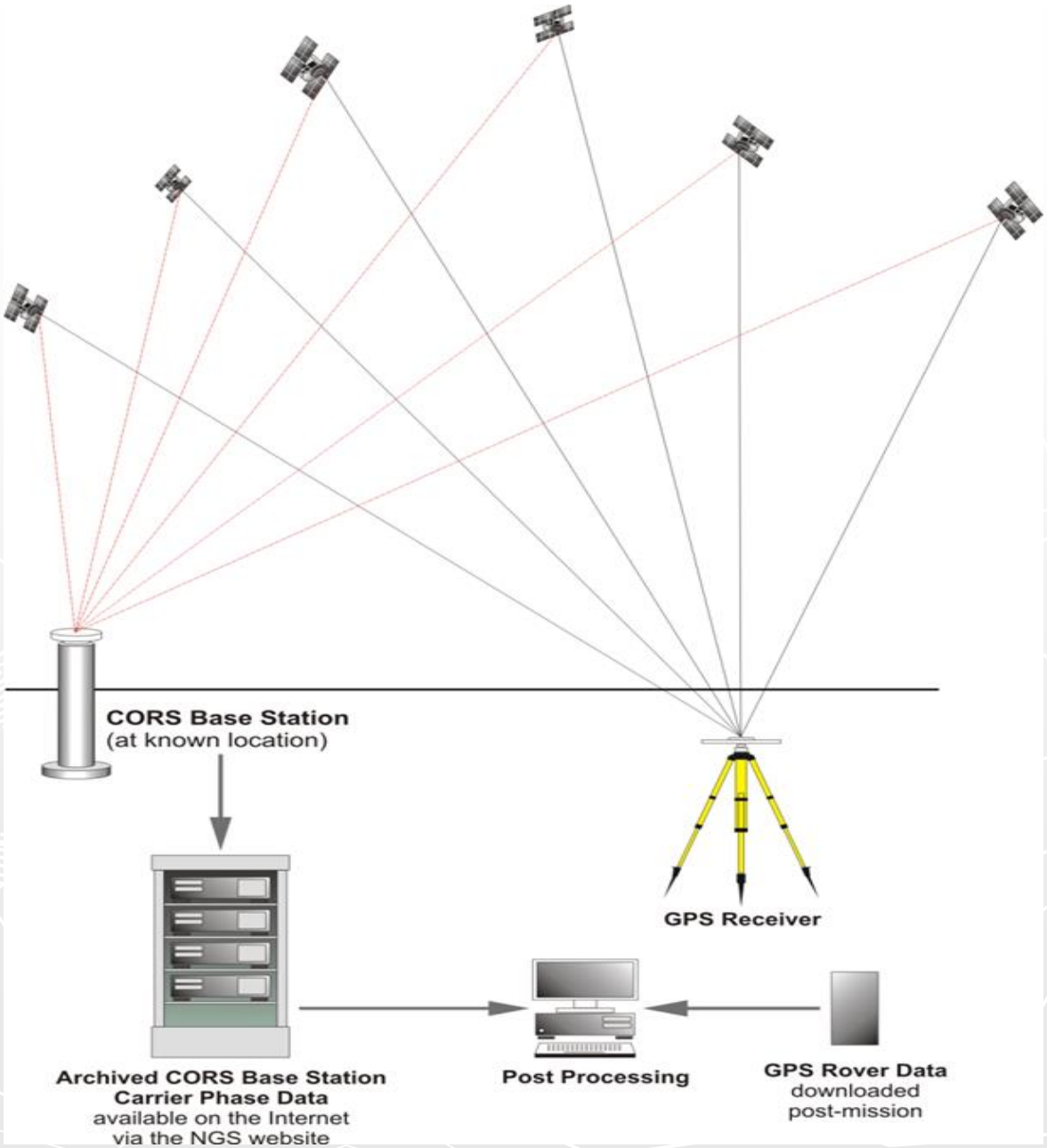
- A Continuously Operating Reference Station (CORS) network is a network of RTK base stations that broadcast corrections, usually over an Internet connection.
- Real-time kinematic positioning (RTK) is the application of surveying to correct for common errors in current satellite navigation (GNSS) systems.
- In addition to analyses and processing, Central sever archive and catalogue these reference station data, and host it over web for further consumption by users.
- The CORS network is available 24 hours per day, 7 days a week and 365 days a year. Its data and corrections are hosted on web for easy consumption.

GPS

Continuously Operating Reference Stations (CORS).

- GPS receiver is **permanently installed in a location** as **a starting point** for any GPS measurements in a area.
- **Common users** of CORS are mining sites, major engineering projects and local governments.
- **Surveyors' GPS receivers** can then **collect field data** and **combine it with the CORS data** to calculate positions.

Continuously Operating Reference Stations (CORS)



GPS

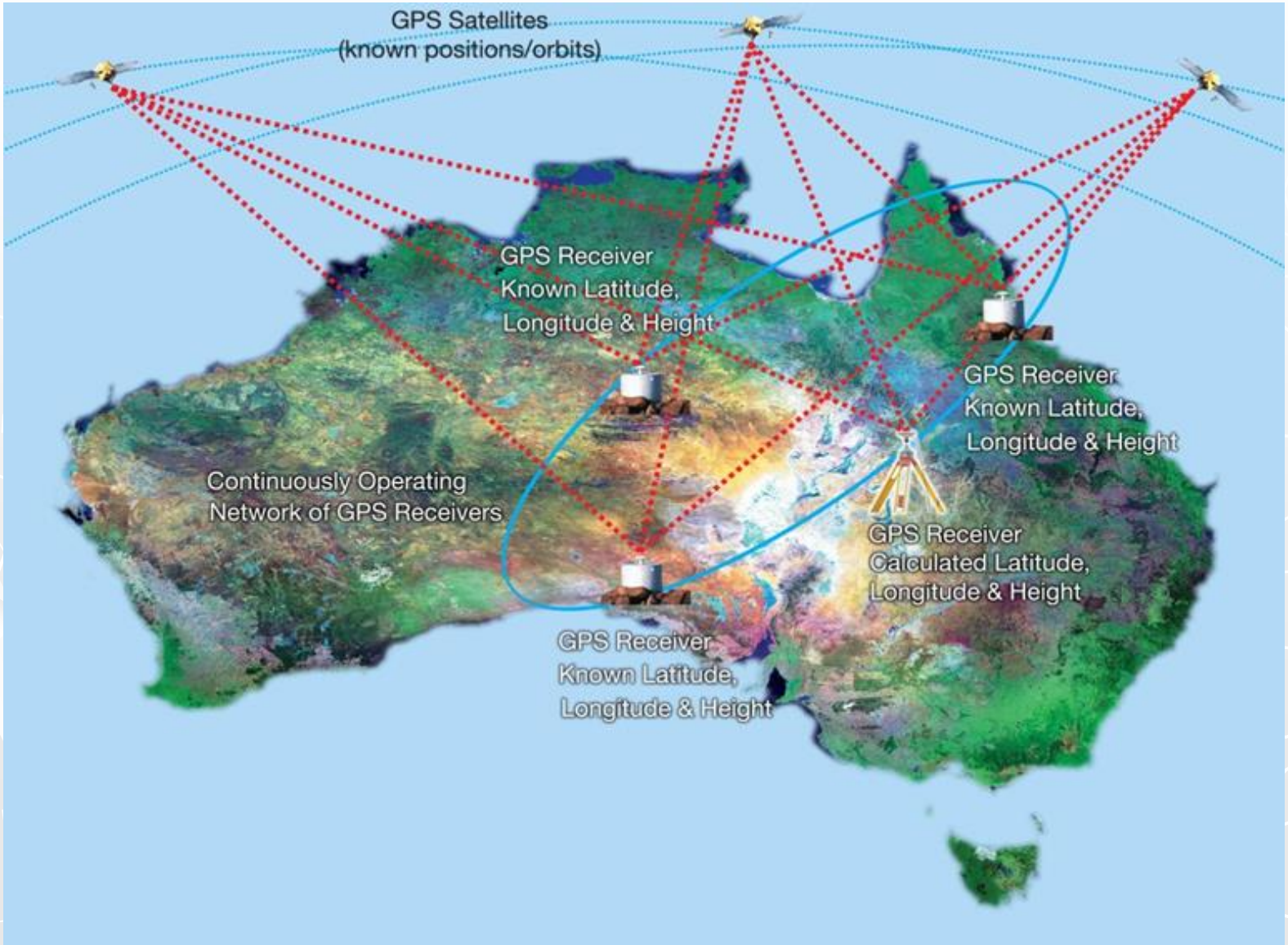
CORS Network

- Many **countries have a CORS network** that are used by many industries.

Example

- **Australia's CORS network** is the **Australian Regional GPS Network (ARGN),** and uses an **online processing system** to deliver data over the internet within 24 hours, and **give positions within an accuracy of a few centimeters.**

A GPS CORS network



Applications

Applications of GPS

- **Used as receivers for directions and as navigations app** that tells us where we are and how to move between points.
- Used to **make digital maps**.
- GPS apps are **not only used by individual** but also by **different organizations** for **different purposes**. For example, it is useful to **pilots, surveyors, farmers**, boat captains, military and scientists among others

Industrial Use GPS:

Aviation:

- Provide **real-time aircraft position**.
- **Provide a map** of various destinations depending on where the **aircraft operates**.
- **Decide which route** is the **fastest**, **safest,** and **most fuel-efficient** among the destinations.
- **Track the aircraft and direct the pilot** in the case of c**hange in the weather conditions** or any other issue that may arise.

Farming

- **Map their plantations and ensure** that they return to precisely the same time when **planting or weeding in the next season**.
- **Effective especially in seasons when it's foggy** with less visibility since the machine will still operate since its GPS and not visual reference guides it.
- **Suitable for use in mapping soil sample locations**, and the farmers can locate the areas that have **soils suitable for farming**.

GPS in Farming



Benefits and Advantages:

Highly Accurate and Fast Process:

- GPS technology supports the surveying process **by providing data with highest accuracy**.
- Data collection **process is faster**, the time for getting final results and making decisions is shorter.

Time, Cost and Labor Saving Technique

- Traditional and conventional surveying can be very costly and time consuming process.
- A single surveyor can now complete all the tasks in one day.

Not Affected By Weather Conditions

- GPS surveying is **not affected by weather conditions** like **snow**, **rain**, high or low temperatures.
- GPS surveying is **not affected by constraints** like the **line of site visibility** between the survey locations.

Thank you