

An aerial photograph of a city at dusk or dawn, with a network of glowing location pins and connecting lines overlaid on the image. The pins are connected by thin, glowing lines, creating a web-like pattern across the city. The background shows a cityscape with buildings and roads, with a warm, orange glow from the sky. The word "Geopositioning" is written in a large, bold, white font across the center of the image.

Geopositioning



Geopositioning

- Geopositioning is the process of determining or estimating the geographic position of an object or a person



Global Navigation Satellite Systems

- Global Navigation Satellite Systems (GNSS) work by utilising a constellation of satellites to provide accurate positioning and timing information to users on Earth.

Global Navigation Satellite Systems

- A GNSS system typically consists of a network of satellites orbiting the Earth at various altitudes.
- These satellites are arranged to ensure that at least four satellites are visible from any location on Earth at any given time, providing comprehensive coverage.



Global Navigation Satellite Systems

- Global Navigation Satellite Systems (GNSS) include various satellite systems developed by different countries and regions.





GPS

GPS is the United States' global navigation satellite system, managed by the U.S. Department of Defense



GPS

The GPS project began in the 1970s, and the system became fully operational in the 1990s. It consists of a constellation of satellites that transmit signals to receivers on Earth.



GPS

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- **Wide Adoption:** GPS technology is embedded in countless consumer devices, including smartphones, vehicles, and drones.



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The system aims to provide an independent, high-precision GNSS service to EU citizens, businesses, and government users.



Galileo

The project began in the early 2000s, and the first two operational satellites were launched in 2011. The full constellation is expected to have 30 satellites.



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- **Open Service:** Provides free access to positioning data for civilian users.
- **Commercial Services:** Offers paid services for higher precision and reliability, including authenticated signals for critical applications.



GLONASS

GLONASS is the Russian counterpart to GPS, operated by the Russian government and managed by the Ministry of Defence.



GLONASS

Development began in the 1970s, and the system became operational in the 1990s. After a period of decline, GLONASS has been fully restored and modernized since 2011.



GLONASS

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- **Global Coverage:** The system is designed to provide global coverage, with particular emphasis on northern latitudes.
- **Interoperability:** GLONASS is compatible with GPS and can be used in conjunction with other GNSS systems to improve accuracy



BeiDou

BeiDou is China's GNSS, developed by the Chinese government and operated by the China Satellite Navigation Office.



BeiDou

The BeiDou system has undergone multiple phases. The first phase (BeiDou-1) was launched in the early 2000s, providing regional coverage. The second phase (BeiDou-2) extended coverage to Asia-Pacific, and the current phase (BeiDou-3) provides global coverage.



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- **Short Message Service (SMS):** Unique to BeiDou, this feature allows users to send short text messages via satellite.
- **Interoperability:** BeiDou is designed to work alongside other GNSS systems, including GPS, GLONASS, and Galileo

QZSS

The Quasi-Zenith Satellite System (QZSS) is a regional satellite-based augmentation system designed and operated by Japan to improve the accuracy and reliability of satellite navigation.

IRNSS

The Indian Regional Navigation Satellite System (IRNSS), is an autonomous satellite-based navigation system developed by India's Space Research Organization (ISRO). It provides accurate position information services to users in India and surrounding regions.

Signals and Transmissions

Signal Generation:

- Each GNSS satellite continuously transmits radio signals that contain two main types of information:



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 - Ephemeris Data: Information about the satellite's orbit, including its position and velocity.
 - Almanac Data: General information about the entire constellation, allowing receivers to determine which satellites to listen for.



Signals and Transmissions

Timing Information:

- The signals also include precise timing information, indicating when the signal was transmitted.





Receivers

GNSS Receivers:

- Users on the ground utilise GNSS receivers, which can be handheld devices, smartphones, or specialized surveying equipment.



Receivers

Signal Reception:

- These receivers capture the signals transmitted by the satellites and decode the information contained within.

Trilateration and Position

Distance Measurement:

- To determine a user's position, the GNSS receiver calculates the distance to each satellite.
- This is done using the time it takes for the signal to travel from the satellite to the receiver:

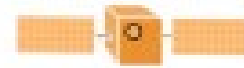
$$\text{Distance} = \text{Speed of Light} \times \text{Time Delay}$$



Satellite 1



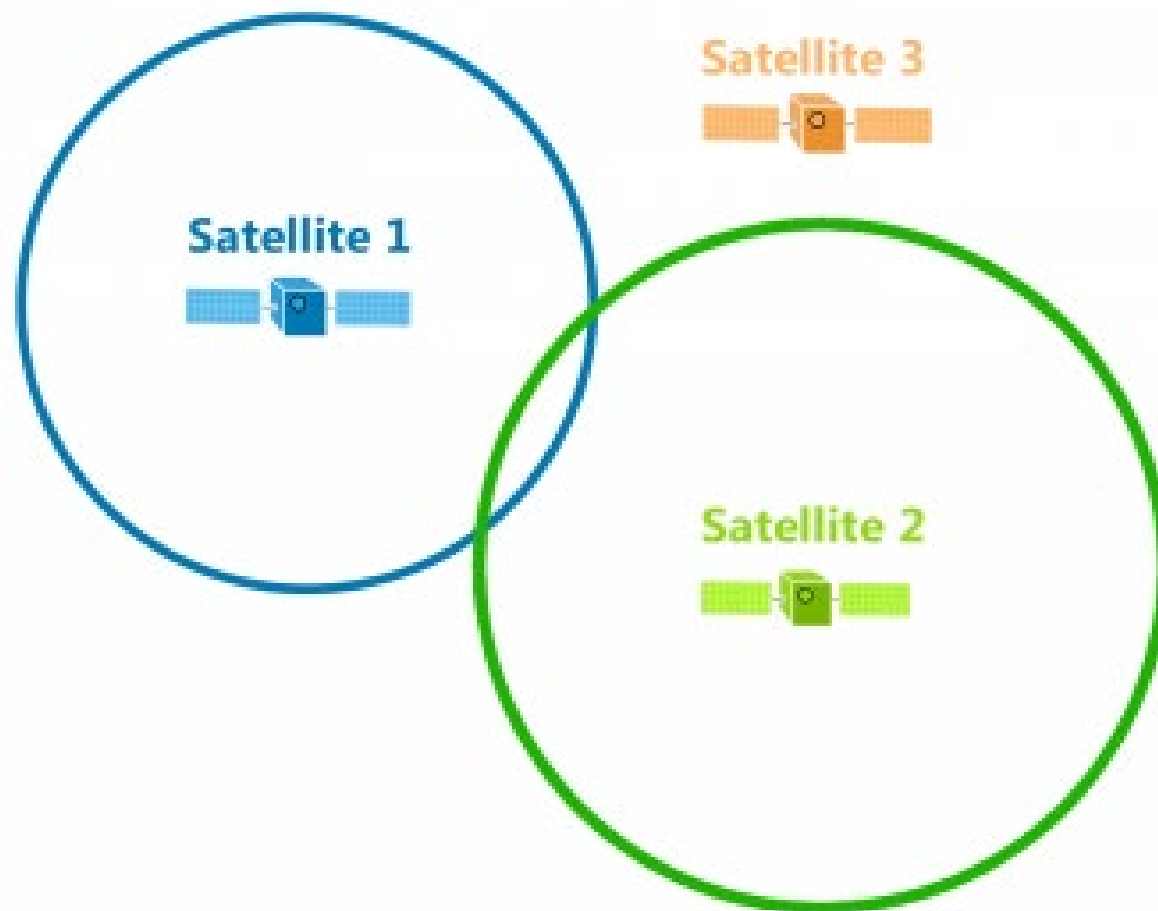
Satellite 3

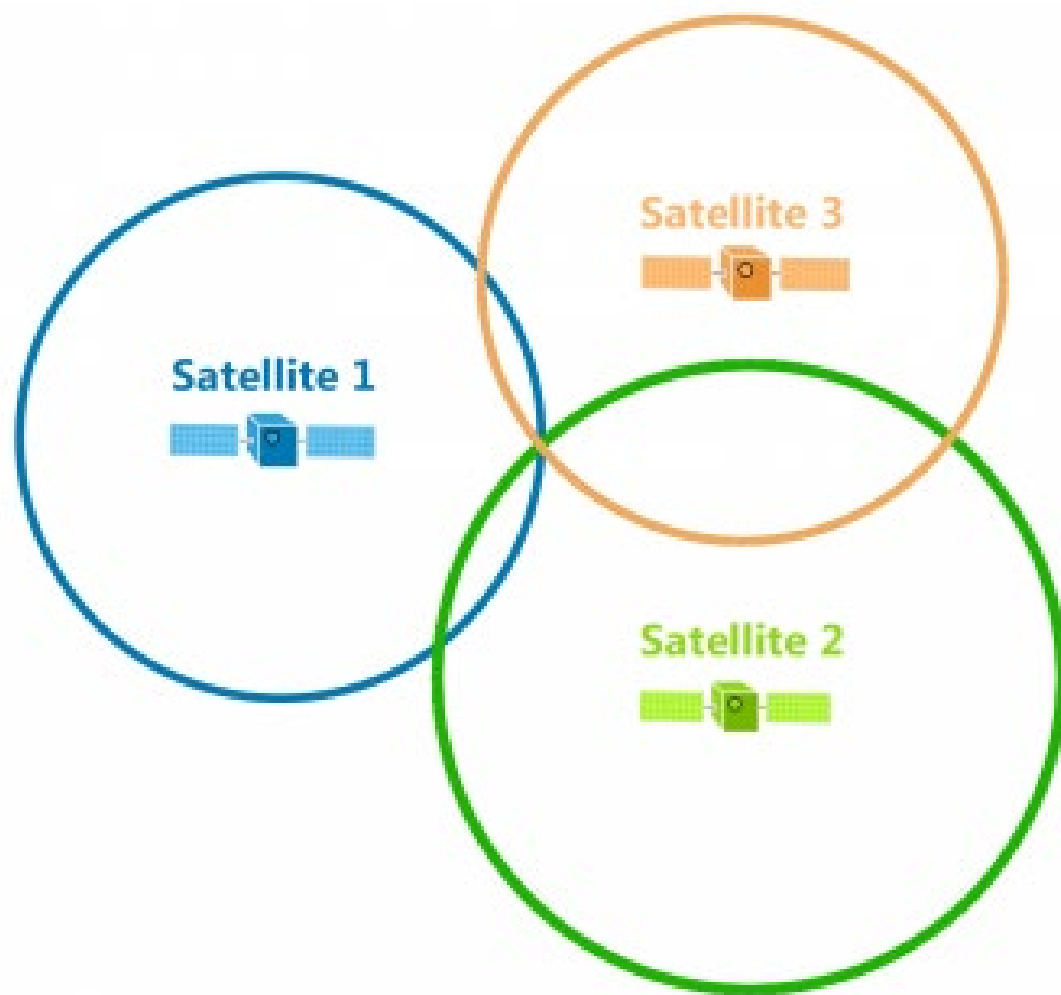


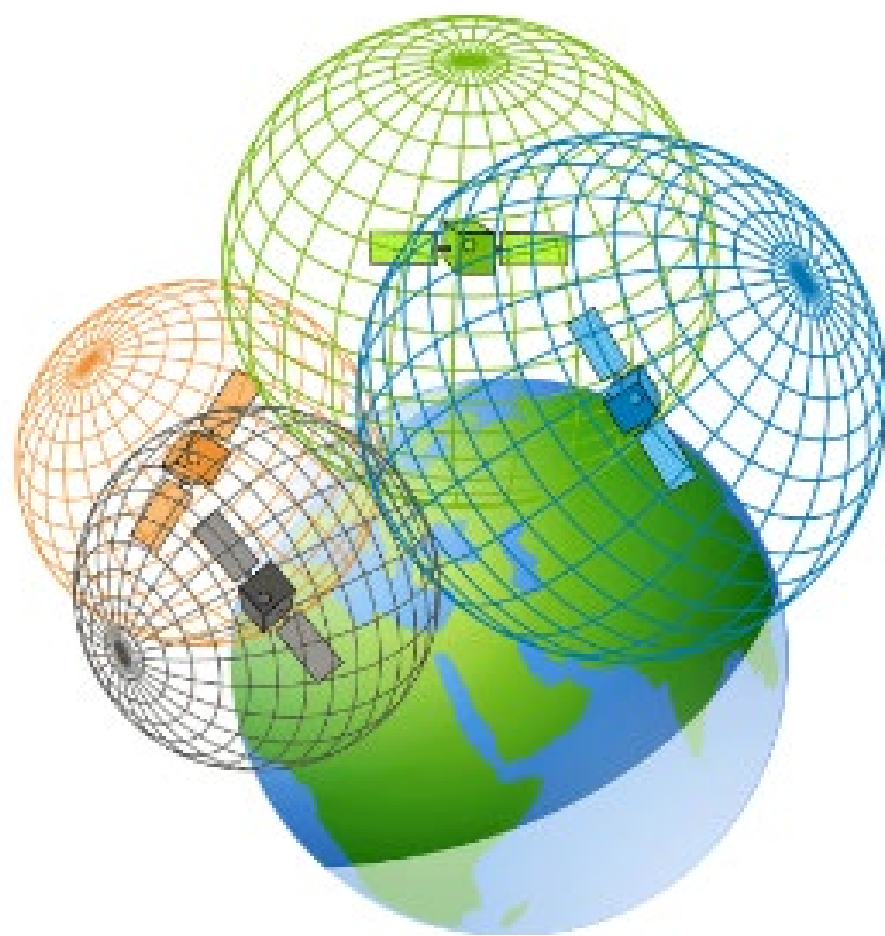
Satellite 2











Triangulation and Position

3D Positioning:

- To compute the user's position (latitude, longitude, and altitude), the receiver needs signals from at least four satellites.
- With three satellites, it can determine a 2D position (latitude and longitude), while the fourth satellite is needed for altitude and to correct for any timing errors in the receiver's clock.





Error Correction and Precision

- Several factors can cause errors in positional computation, affecting measurement accuracy.
- These include clock errors, ephemeris errors, satellite configuration, atmospheric interference, and multipath.
- Each of these factors contributes to inaccuracies in the system.



Clock Errors

Satellite Clock Errors:

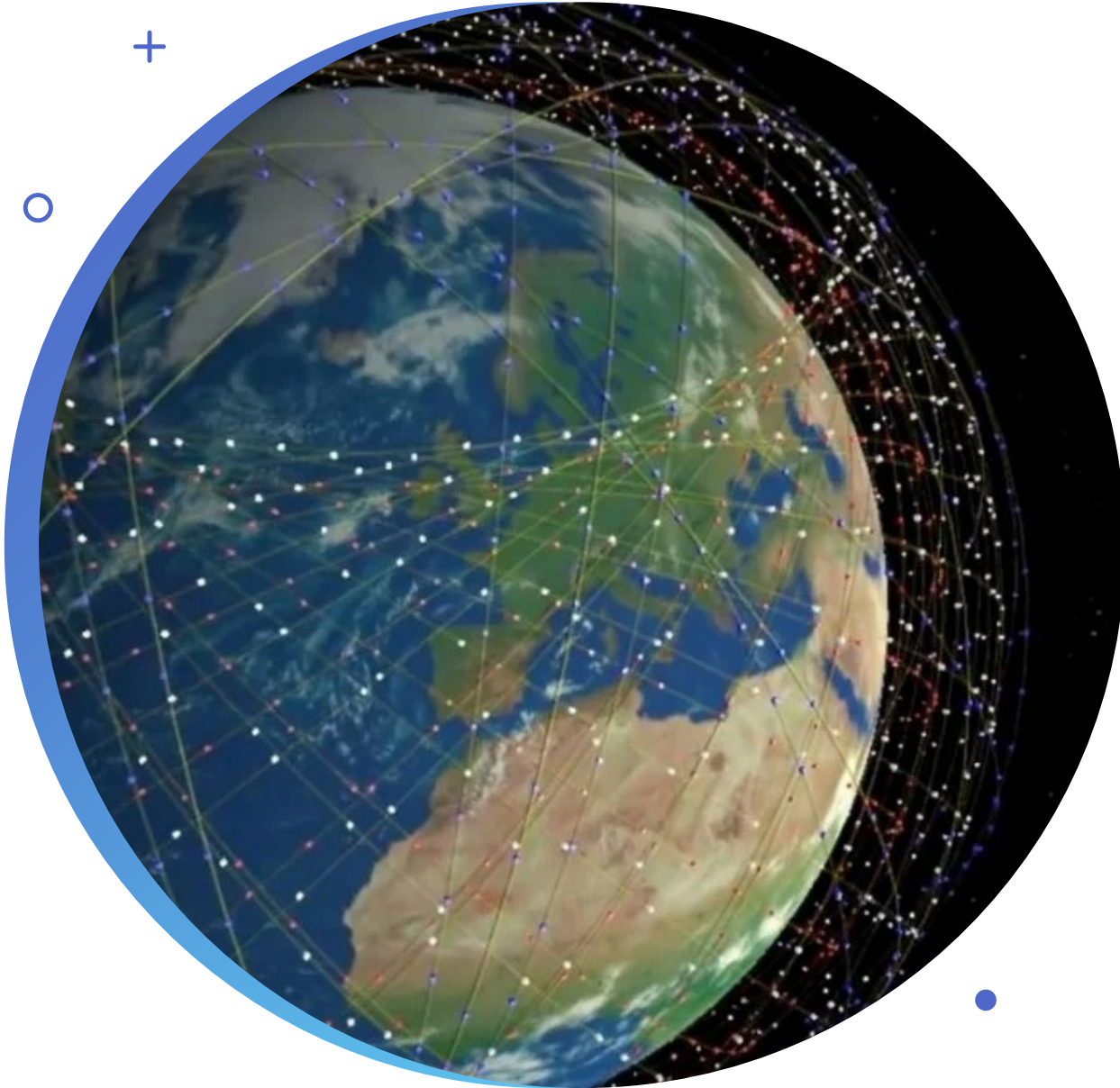
- GPS satellites carry very precise atomic clocks, but slight timing inaccuracies can occur.



Clock Errors

Receiver Clock Errors:

- GPS receivers, especially low-cost or non-professional ones, typically use less accurate clocks.



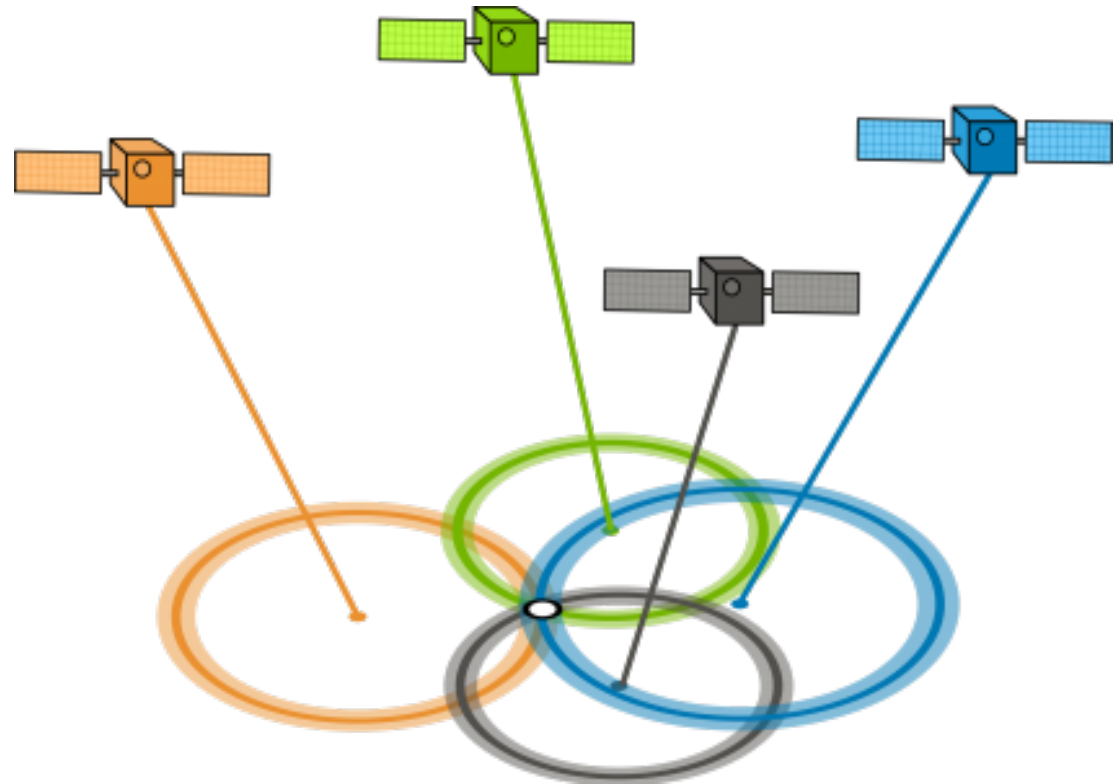
Ephemeris Errors

Orbital Information Errors:

- The ephemeris refers to the data that describes the satellites' orbits and is broadcast to GPS receivers.
- Any small inaccuracies in the satellites' reported positions can introduce errors in the calculation of the user's position.

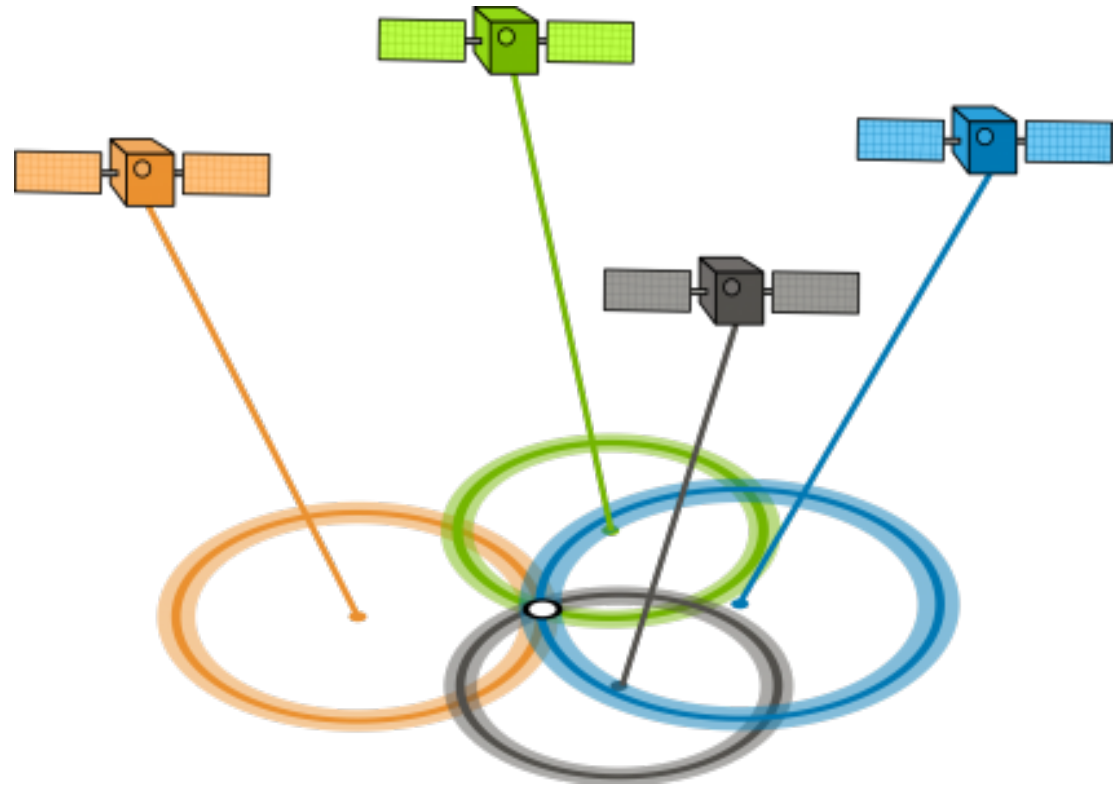
GDOP and PDOP

GDOP measures the overall effect of satellite geometry on the precision of the GNSS positioning solution.



GDOP and PDOP

PDOP is a specific type of GDOP that focuses solely on how satellite geometry impacts the accuracy of the 3D position (latitude, longitude, and altitude).



Interpreting GDOP and PDOP Values

Lower values for both GDOP and PDOP indicate a better satellite configuration, leading to higher positioning accuracy.

< 3: Excellent satellite geometry. Highly accurate positioning.

3-6: Good satellite geometry. Decent accuracy.

6-10: Moderate satellite geometry. Positioning accuracy decreases.

>10: Poor satellite geometry. High uncertainty in position estimation.

Atmospheric Interference

Ionospheric Delays:

- The ionosphere is a layer of Earth's atmosphere that contains charged particles. As GPS signals pass through the ionosphere, they are slowed down, which can introduce errors in distance calculations



Atmospheric Interference

Tropospheric Delays:

- The troposphere is the lowest part of the Earth's atmosphere, containing weather systems. Variations in temperature, pressure, and humidity can also delay GPS signals.



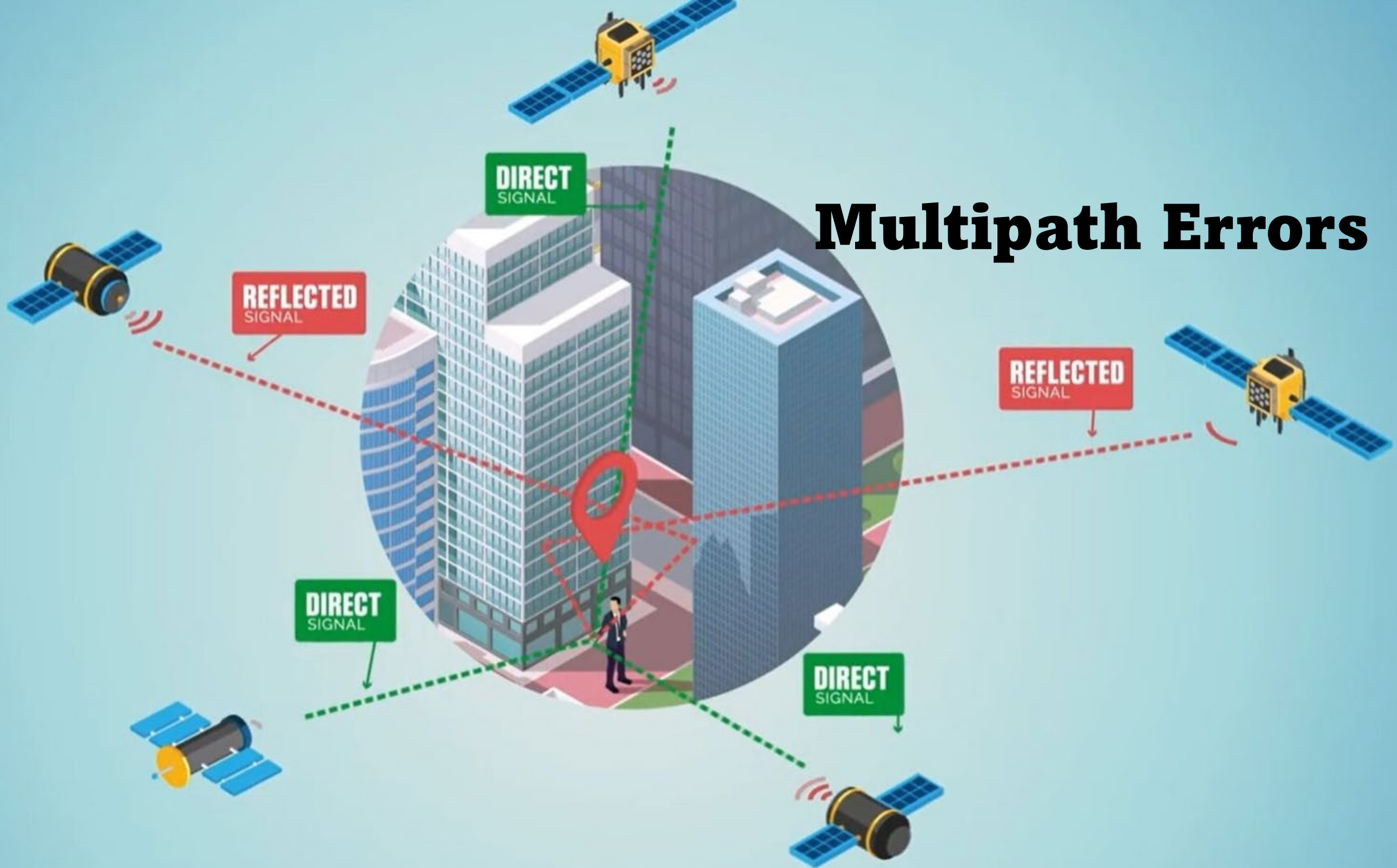


Multipath Errors

Signal Reflection:

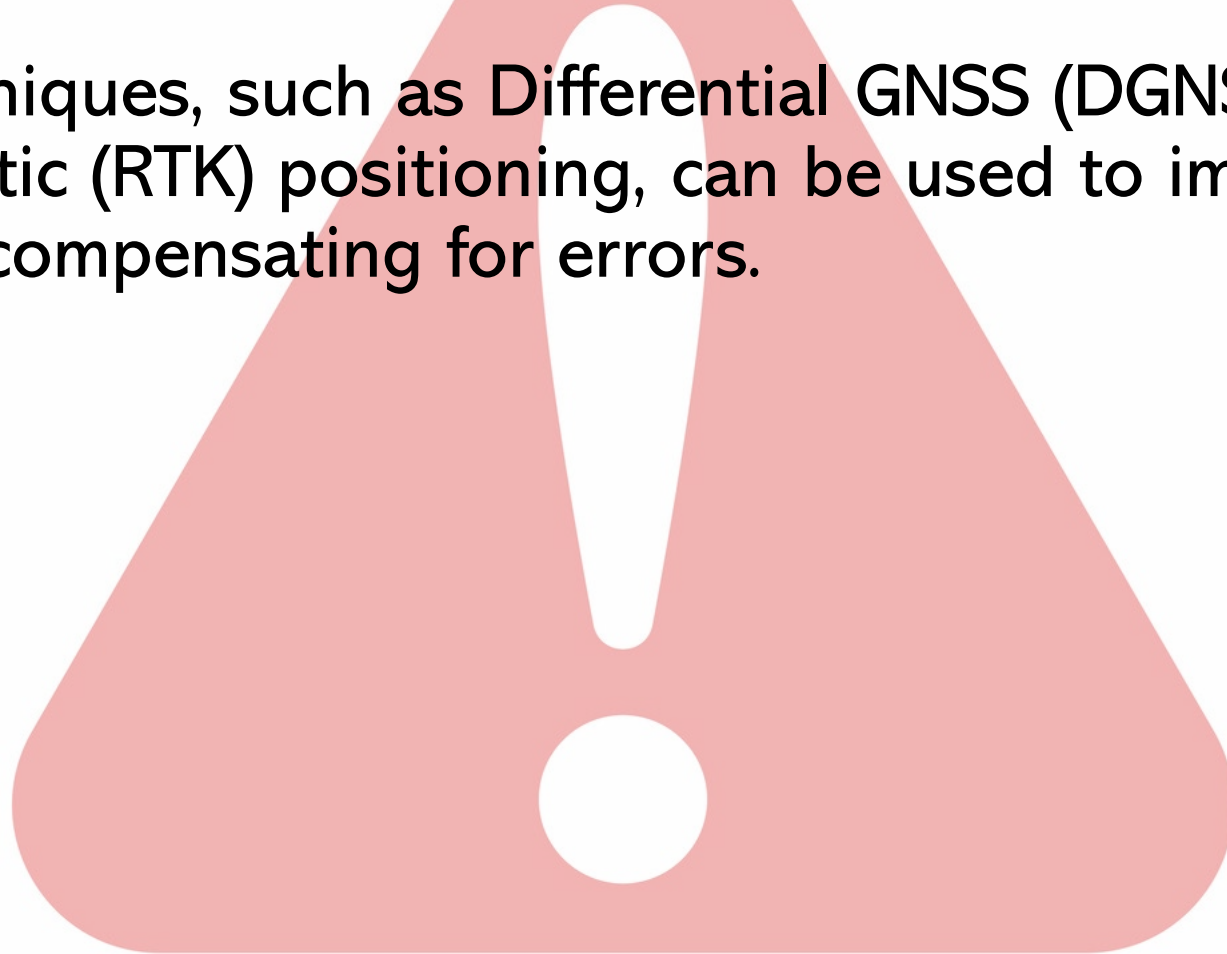
- Multipath errors occur when GPS signals reflect off nearby surfaces, such as buildings, water, or the ground, before reaching the receiver.

Multipath Errors



Correction Methods

- Various techniques, such as Differential GNSS (DGNSS) and Real-Time Kinematic (RTK) positioning, can be used to improve accuracy by compensating for errors.



DGNSS

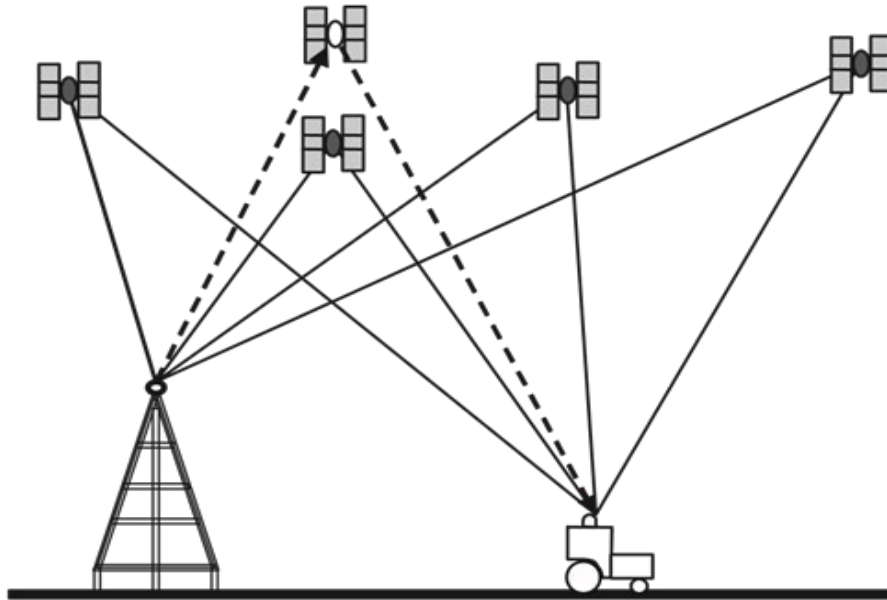
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- It achieves this by comparing the GNSS data from a **base station** with the data from a **rover** (the surveyor's GNSS receiver in the field).



DGNSS



Differential GNSS (DGNSS)

- Base Station Setup: A base station is set up at a known, precisely surveyed location. Since the exact position of the base station is known, it can calculate the difference (error) between its known position and the position calculated by GNSS satellites.

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- **Real-Time Corrections:** The rover applies these corrections to its own GNSS measurements to calculate a more accurate position.

RTK

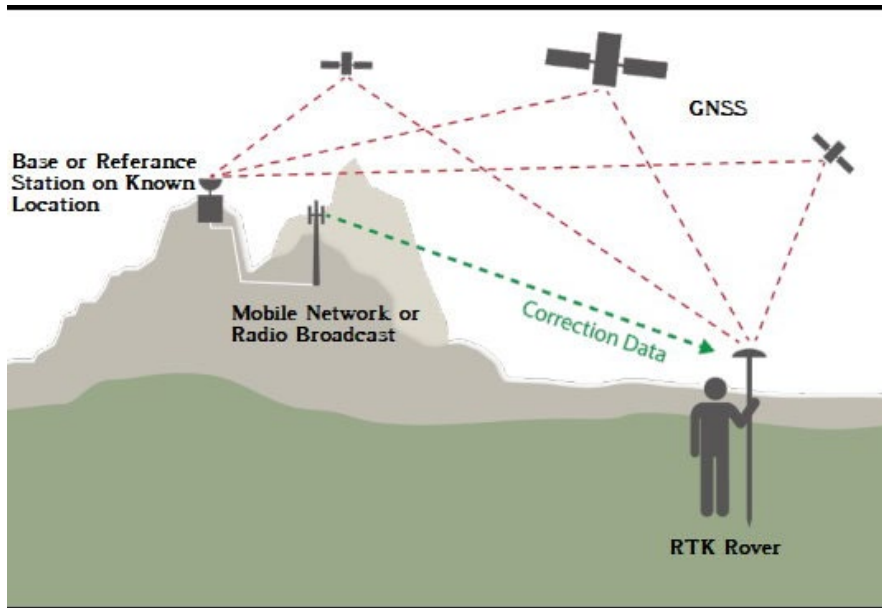
Real Time Kinematic (RTK)

- An advanced GNSS correction method that delivers centimetre-level accuracy in real time, making it one of the most precise techniques available for surveying.

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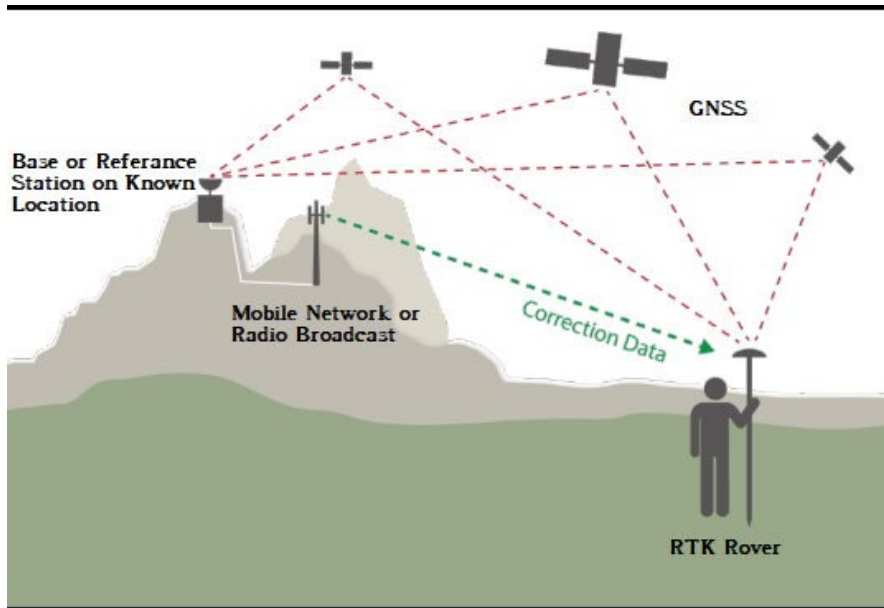
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- RTK corrects not only for position errors but also for carrier-phase measurements, which improves the precision.



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- **Corrections Sent to Rover:** The base station continuously compares its calculated position from the satellite signals to its known location and transmits error corrections to the rover.
- **Rover Positioning:** The rover receives the correction data and uses it to adjust its own carrier-phase measurements in real time, achieving centimetre-level positioning accuracy.