Advances in GNSS Technology and how they relate to Quarries

QuarryNZ 2024 Conference
The Future is Digital:
Navigating Shifts in Technology
July 2024

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B.E. (Mining) First Class Honours
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Associate Member Survey & Spatial NZ
Director
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Advances in GNSS Technology and how they relate to Quarries

- Surveying Impact
- Historical Development
- Operational Insights
- Future Quarry Operations

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GNSS technology evolution

GNSS technology evolution

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GNSS technology evolution

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GNSS technology evolution

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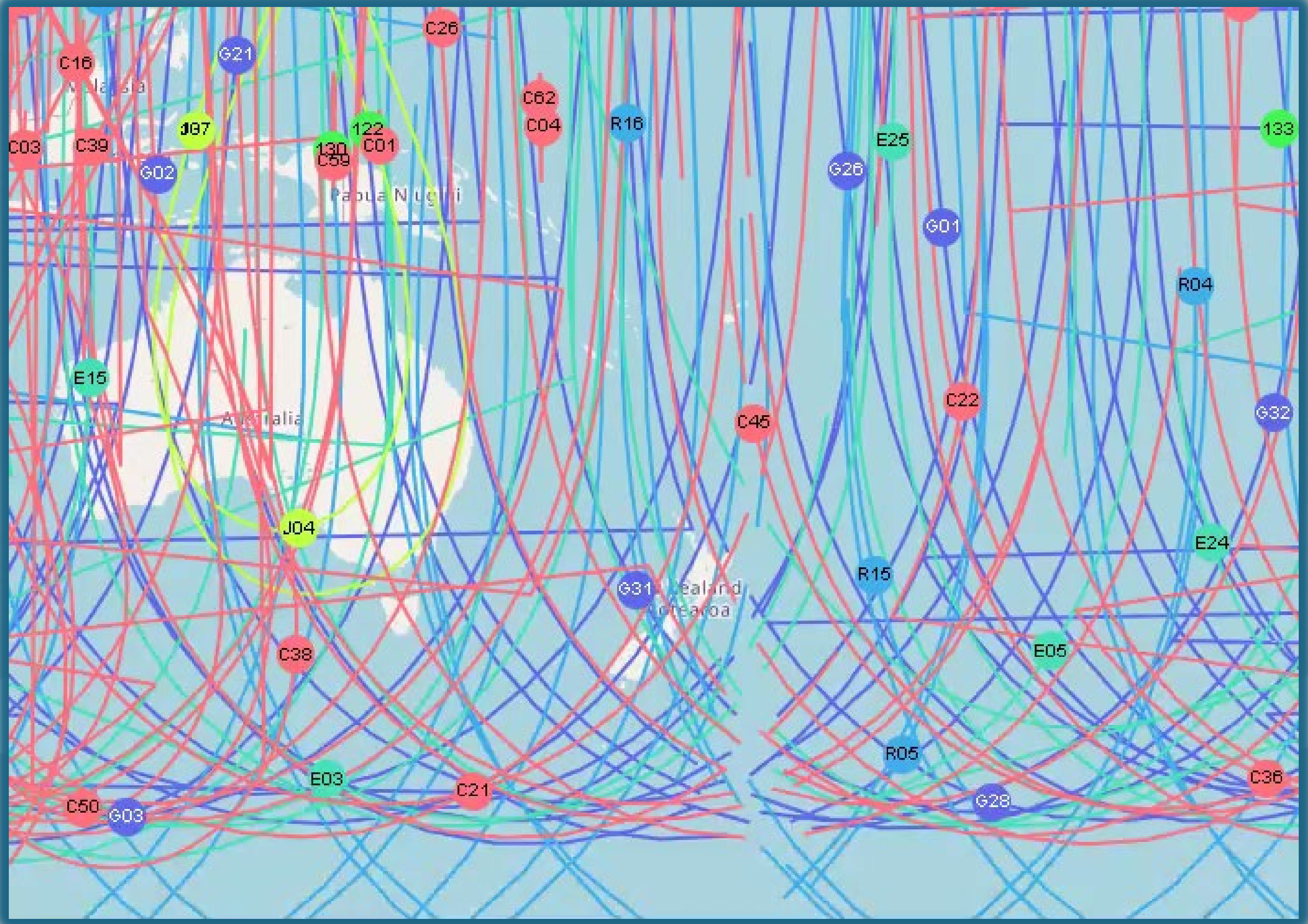
Global Navigation Satellite Systems (GNSS)



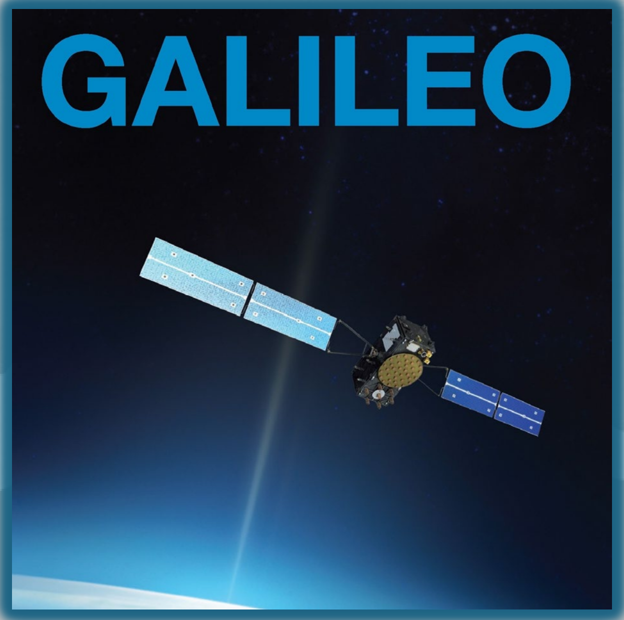
Global Navigation Satellite Systems (GNSS)

Global Positioning System
United States Air Force

Global Navigation Satellite Systems (GNSS)

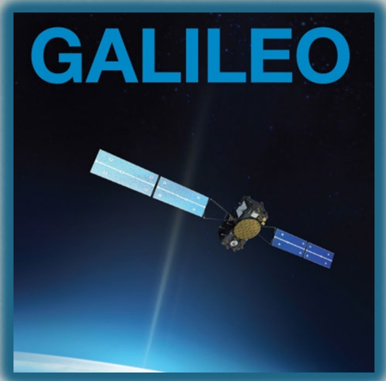
Global'naya Navigatsionnaya
Sputnikovaya Sistema
Russion Federation

Global Navigation Satellite Systems (GNSS)



Galileo
European Union Agency for the Space Programme

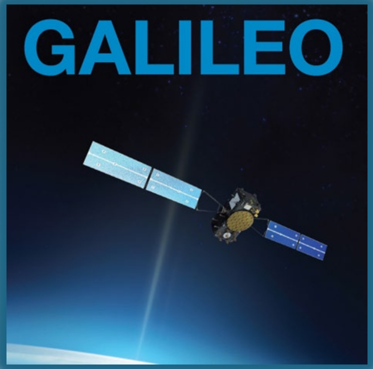
Global Navigation Satellite Systems (GNSS)

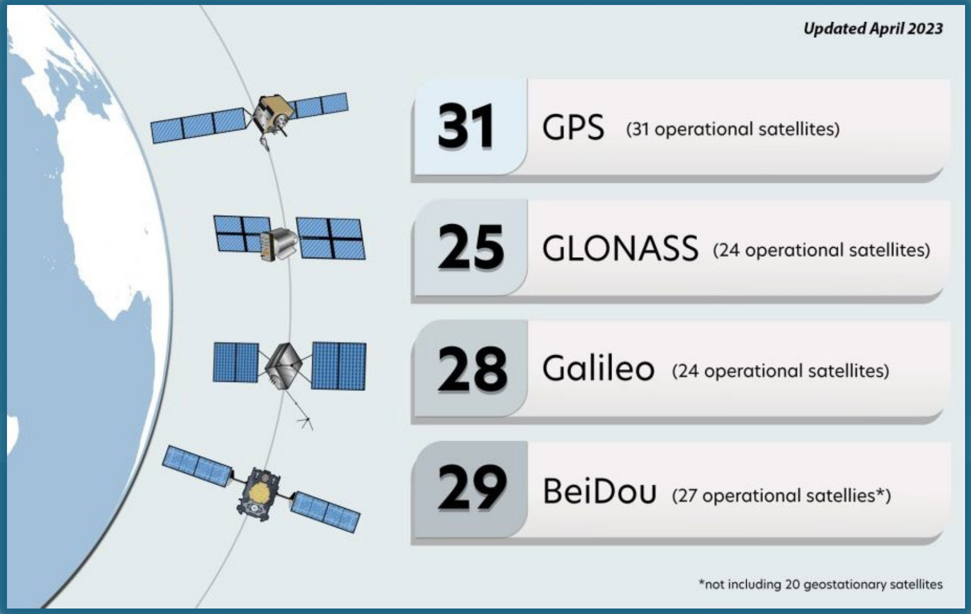


BeiDou Navigation Satellite System

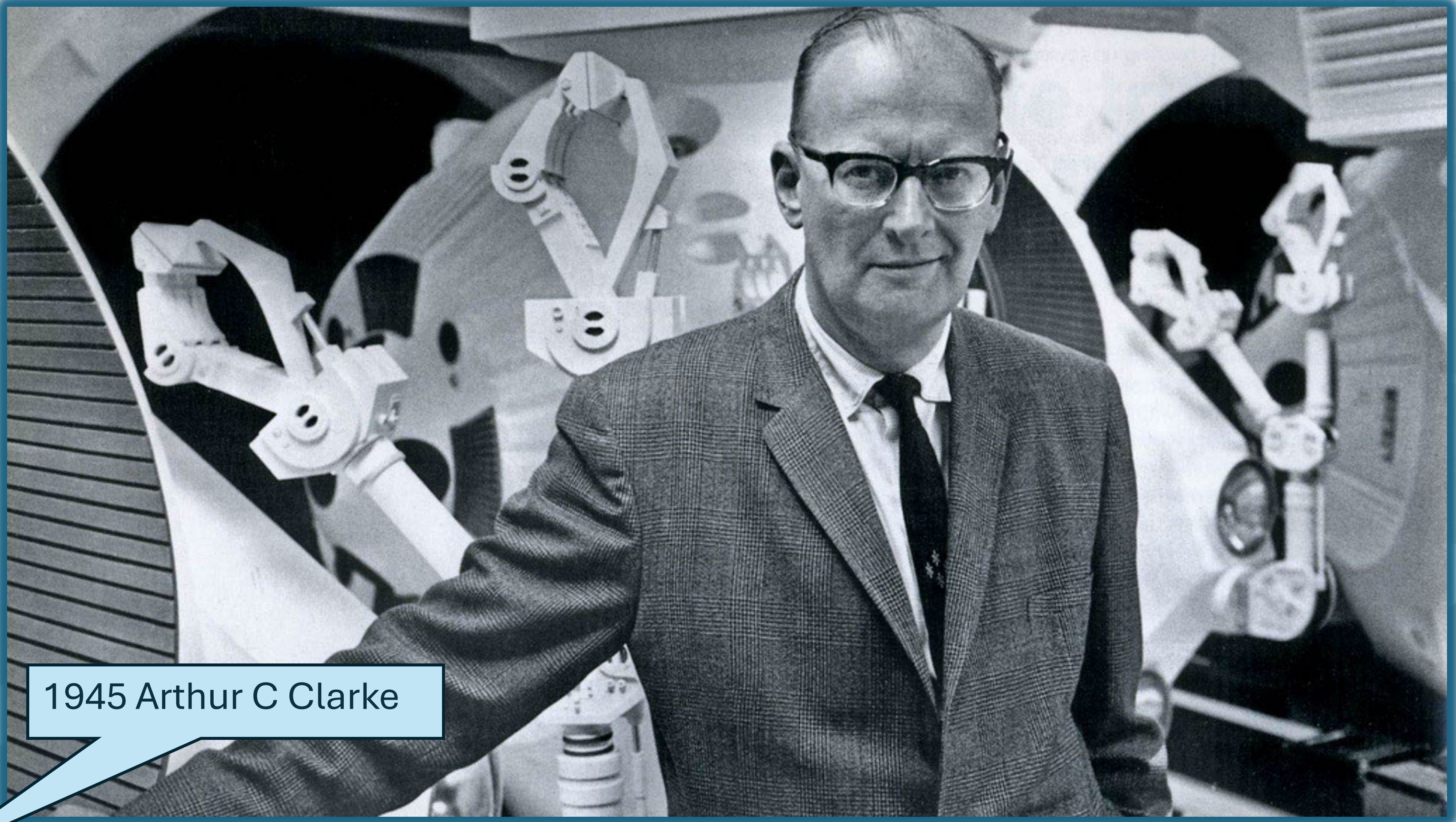
China National Space Administration

Global Navigation Satellite Systems (GNSS)





GNSS History



1945 Arthur C Clarke

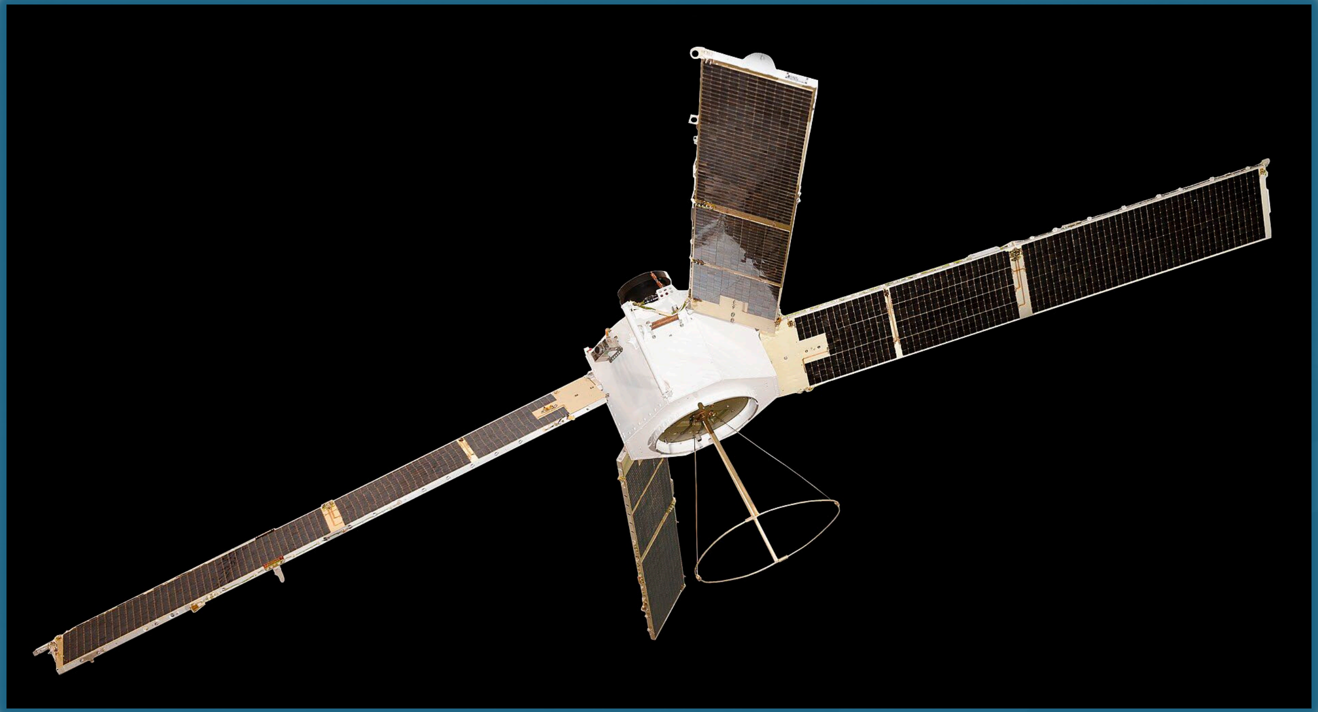
1940 1950 1960 1970 1980 1990 2000 2010 2020 2030

GNSS History

1957 Sputnik launched

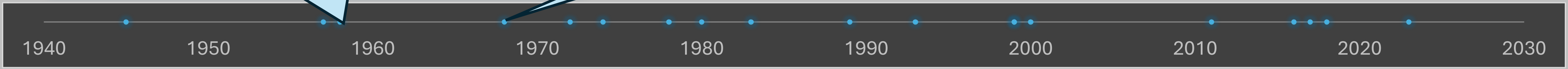
1940 1950 1960 1970 1980 1990 2000 2010 2020 2030

GNSS History



1968 Transit operational

1958 Transit developed



GNSS History

1972 US Air Force oversees satellite navigation program

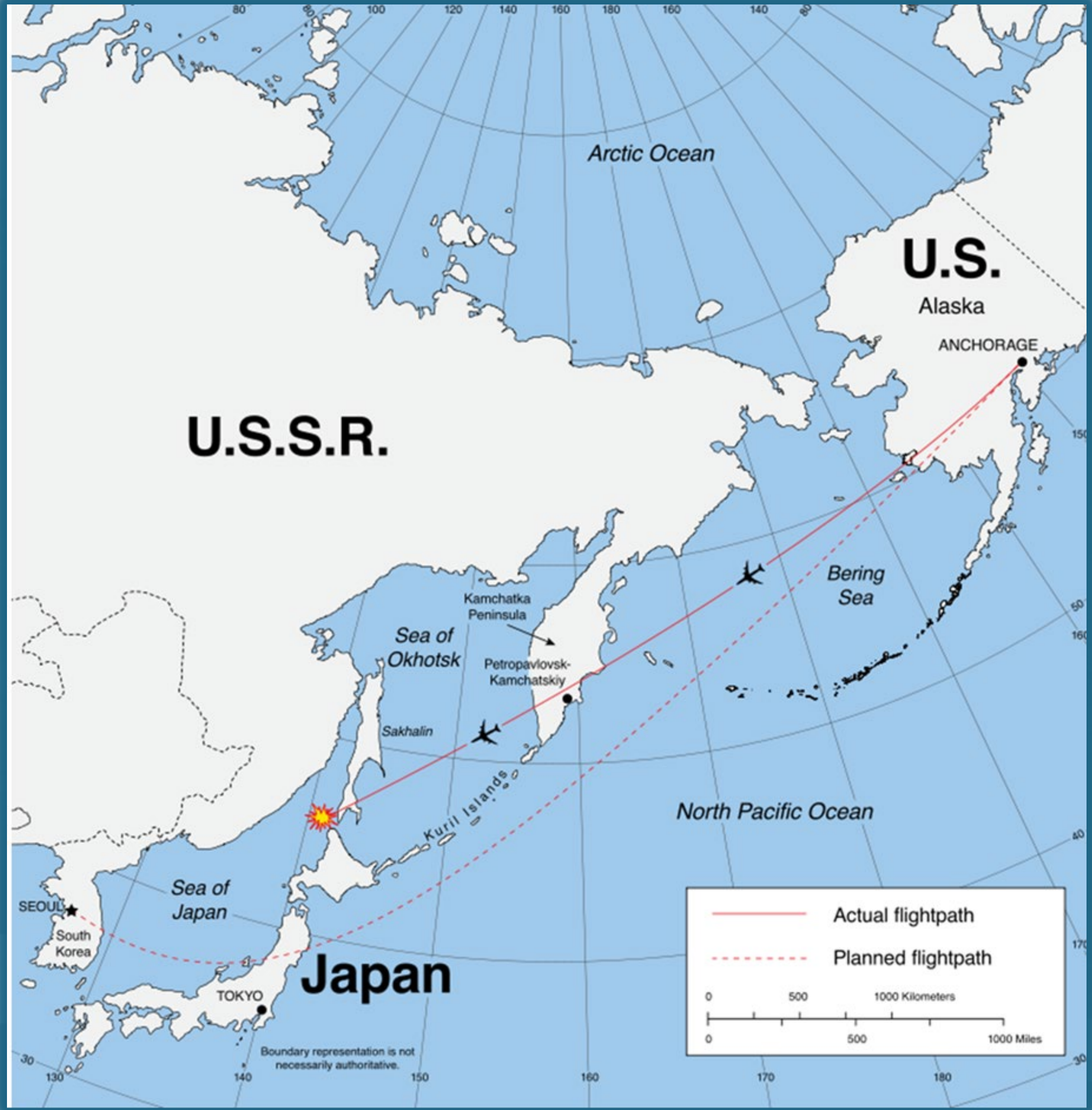
1975 Navstar developed

1978 First Block I Navstar satellite launched

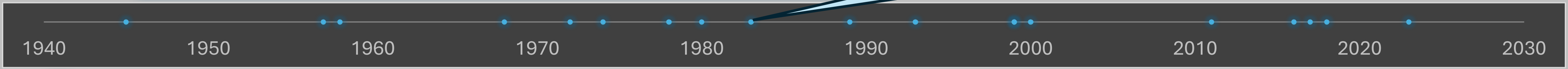
Early 1980's GPS Block I demonstration satellites launched

1940 1950 1960 1970 1980 1990 2000 2010 2020 2030

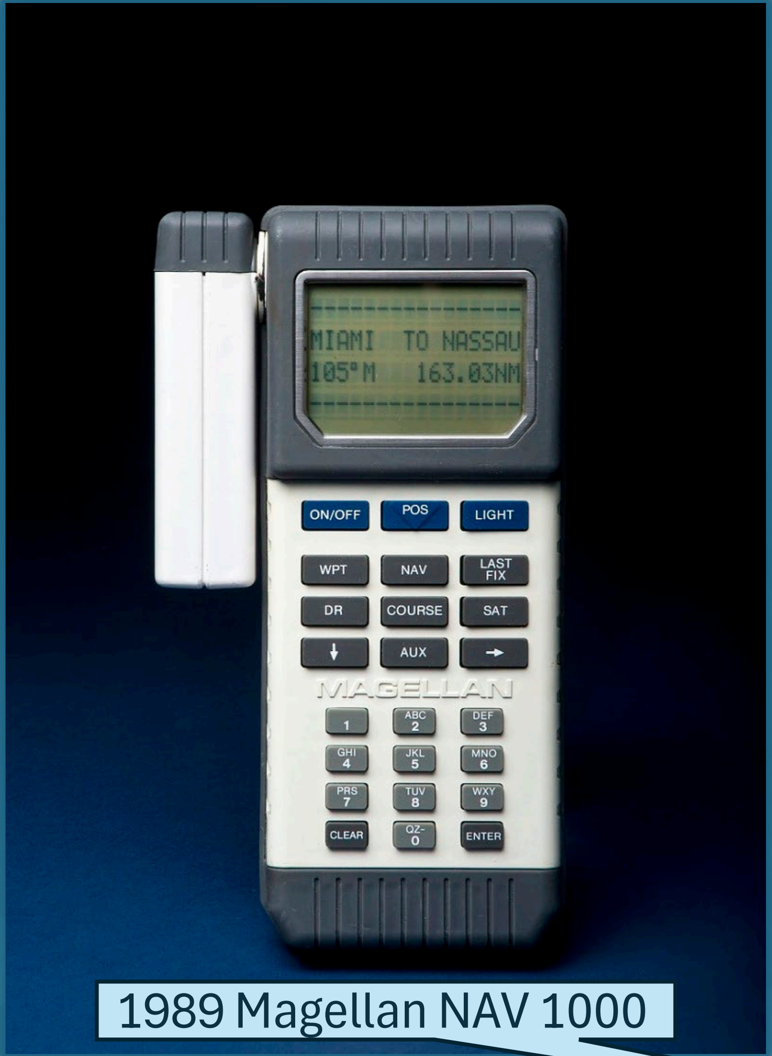
GNSS History



1983 KAL shot down by Soviets



GNSS History



1989 Magellan NAV 1000

1999 Benefon Esc!

1993 GPS constellation achieves full operational capacity

1940 1950 1960 1970 1980 1990 2000 2010 2020 2030

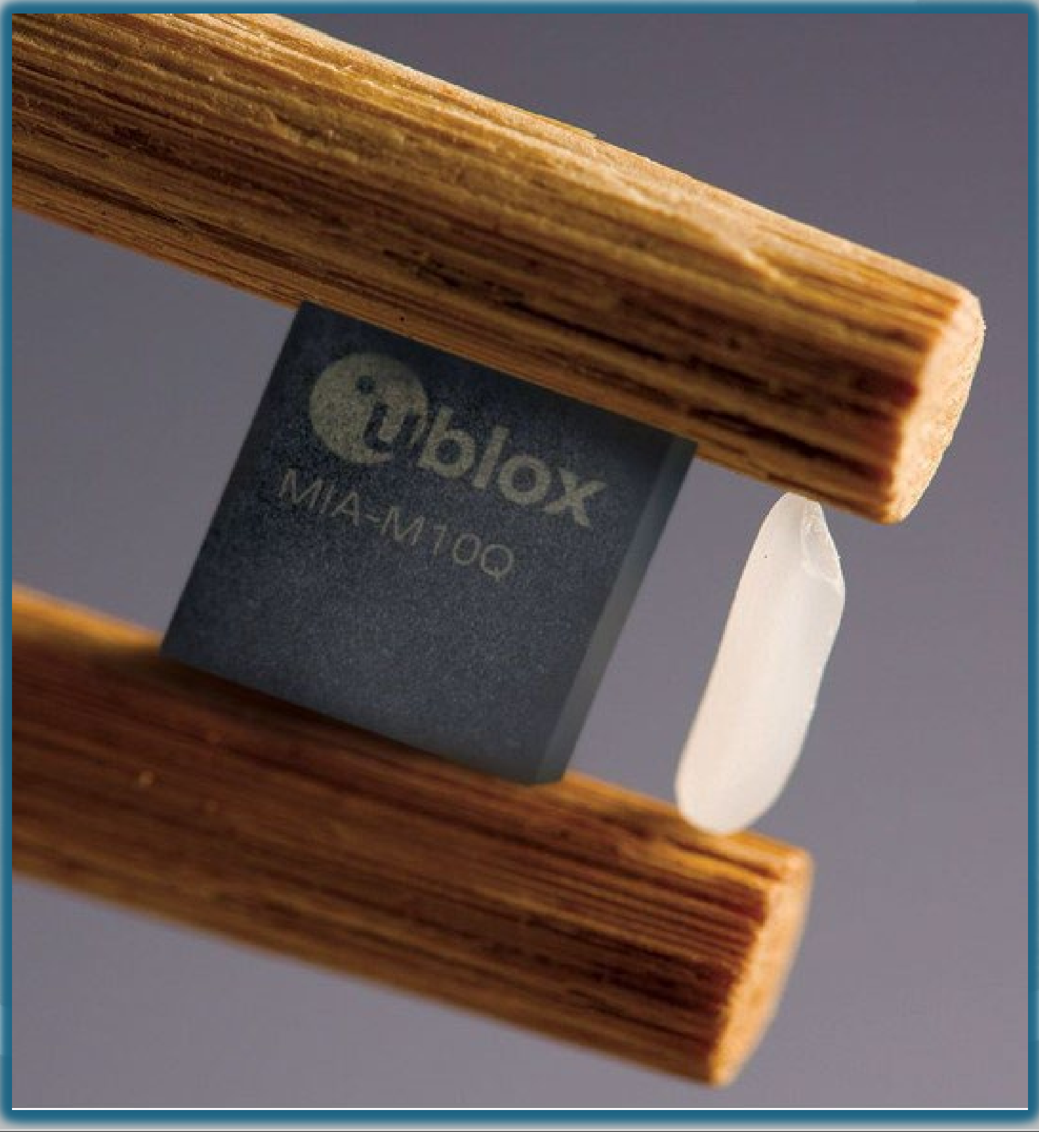
GNSS History

2000 GPS III development

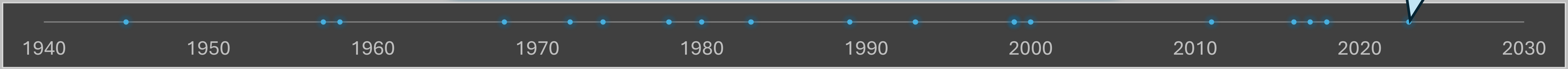
2018 First GPS III satellite launched

1940 1950 1960 1970 1980 1990 2000 2010 2020 2030

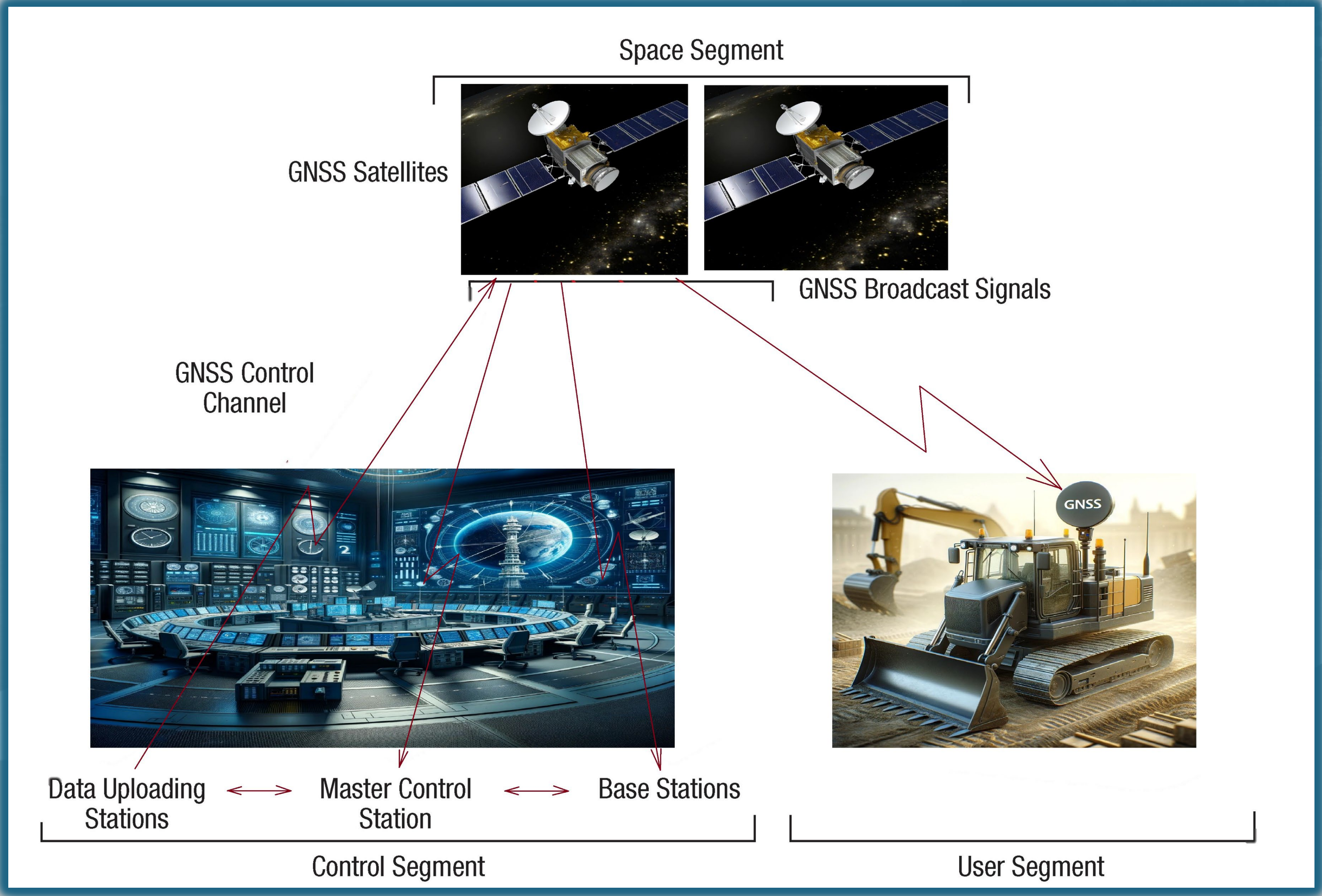
GNSS History



2024 GNSS chips miniaturized



GNSS How it Works



GNSS How it Works

GNSS How it Works

GNSS How it Works

User Segment

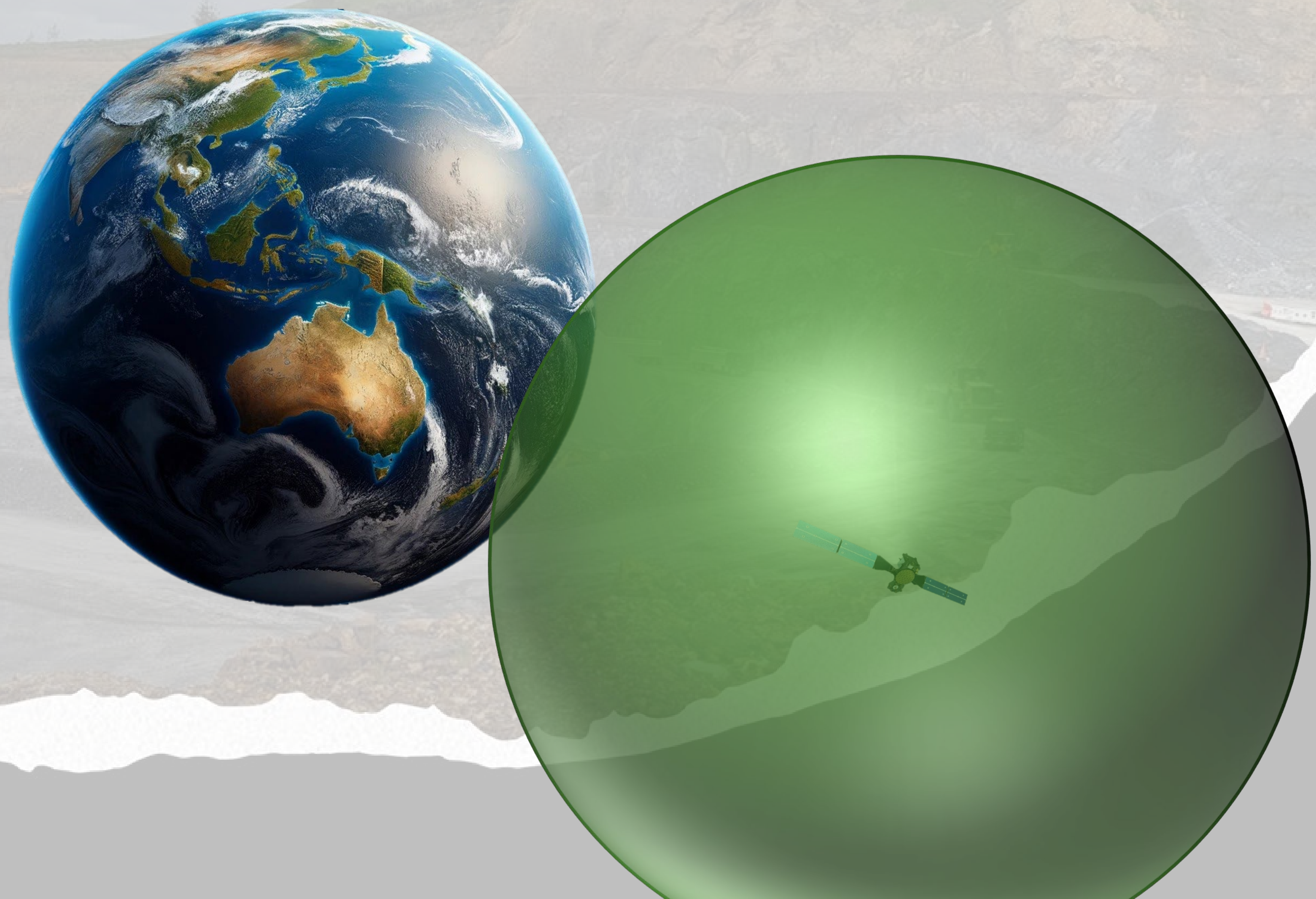
GNSS How it Works

Trilateration

Measured distance = signal travel time x speed of light

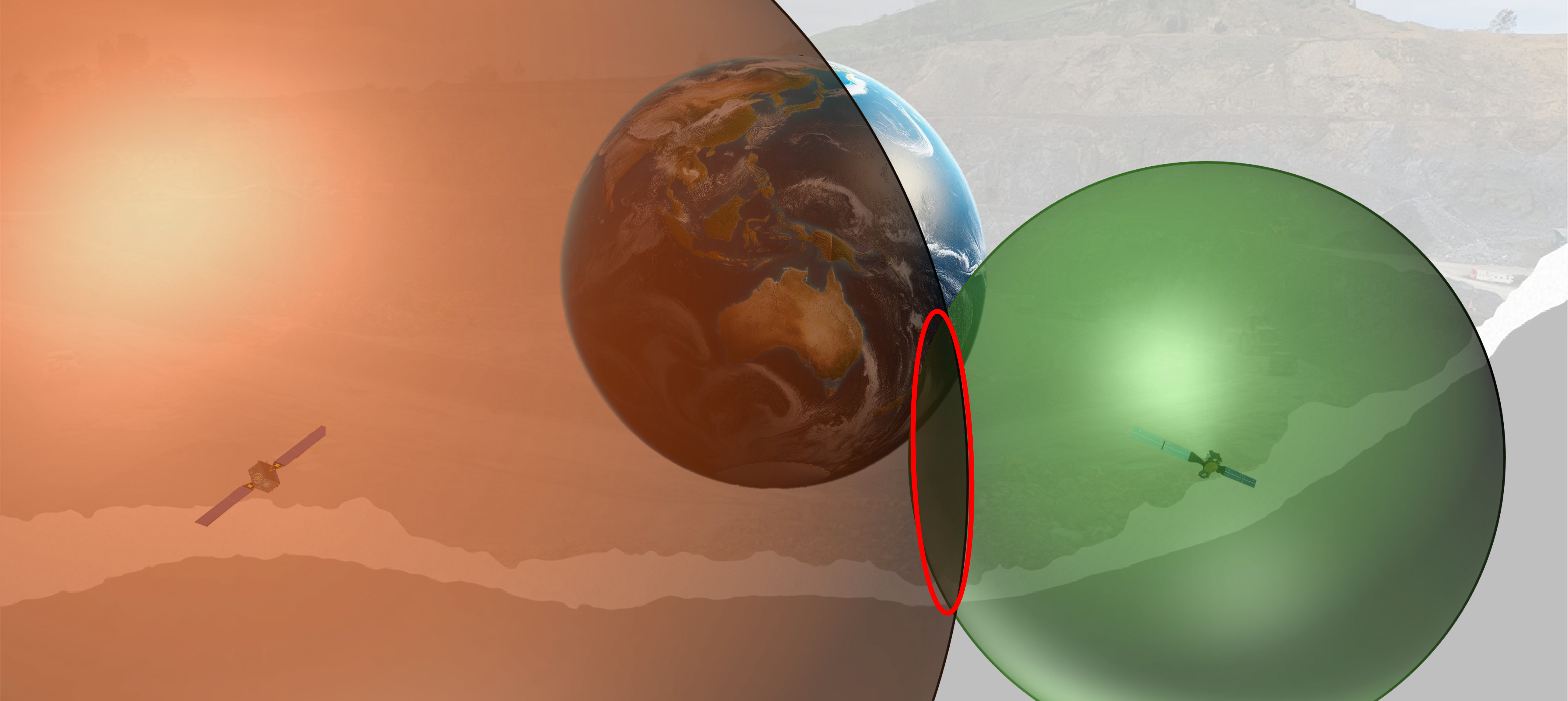
GNSS How it Works

Trilateration



GNSS How it Works

Trilateration



GNSS How it Works

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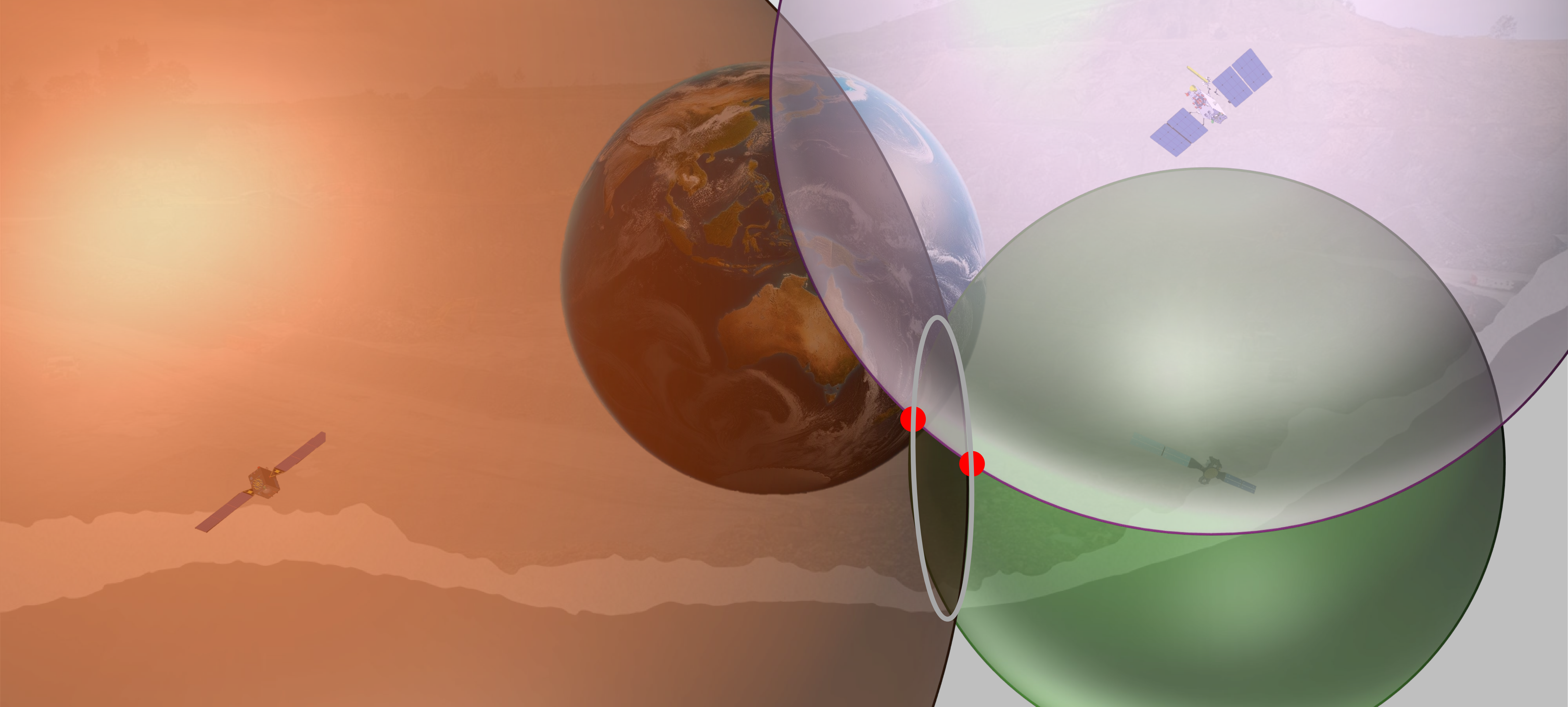

GNSS How it Works

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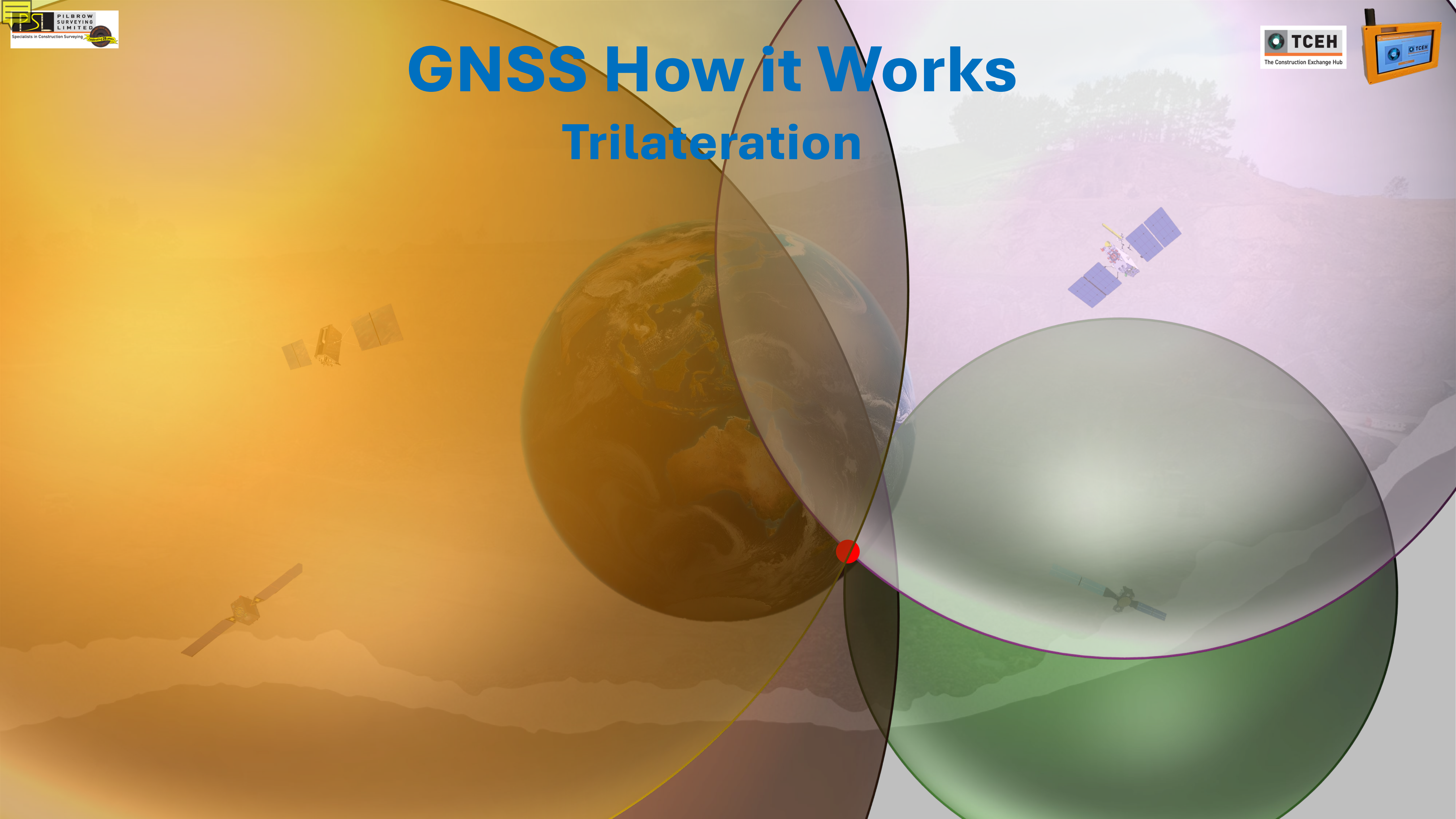
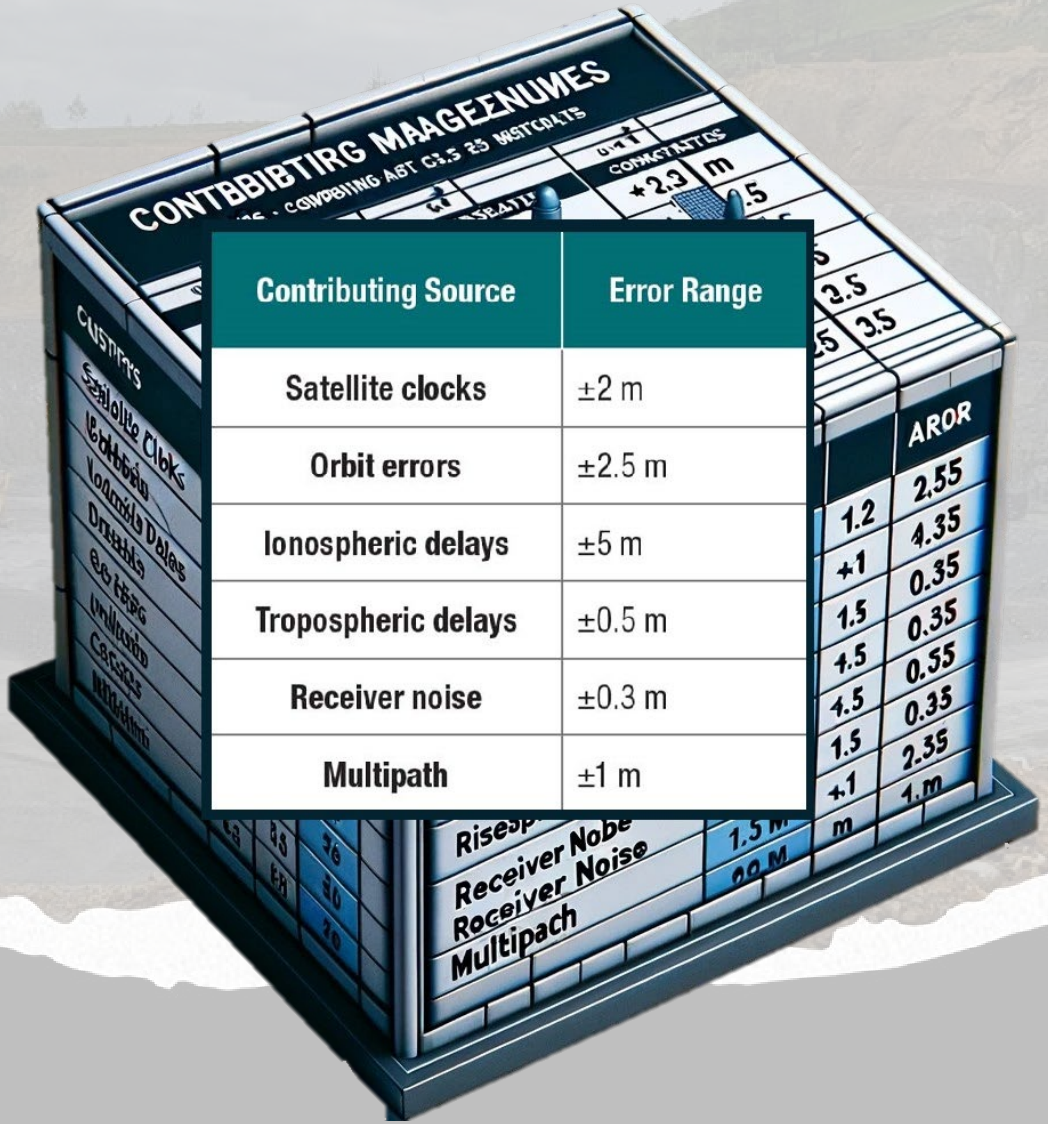


GNSS How it Works

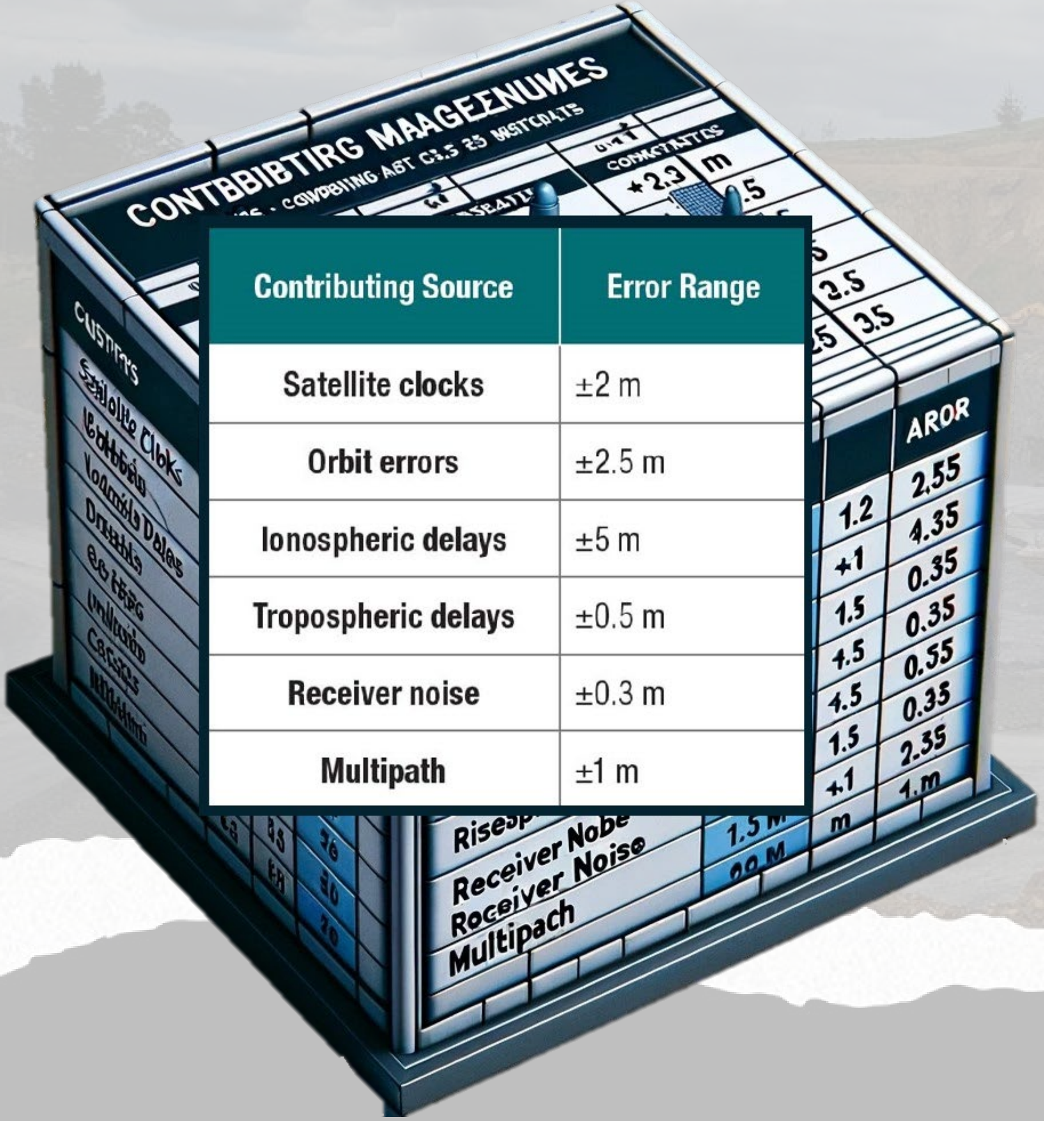
Error Sources



Contributing Source	Error Range
Satellite clocks	±2 m
Orbit errors	±2.5 m
Ionospheric delays	±5 m
Tropospheric delays	±0.5 m
Receiver noise	±0.3 m
Multipath	±1 m

GNSS How it Works

Error Sources



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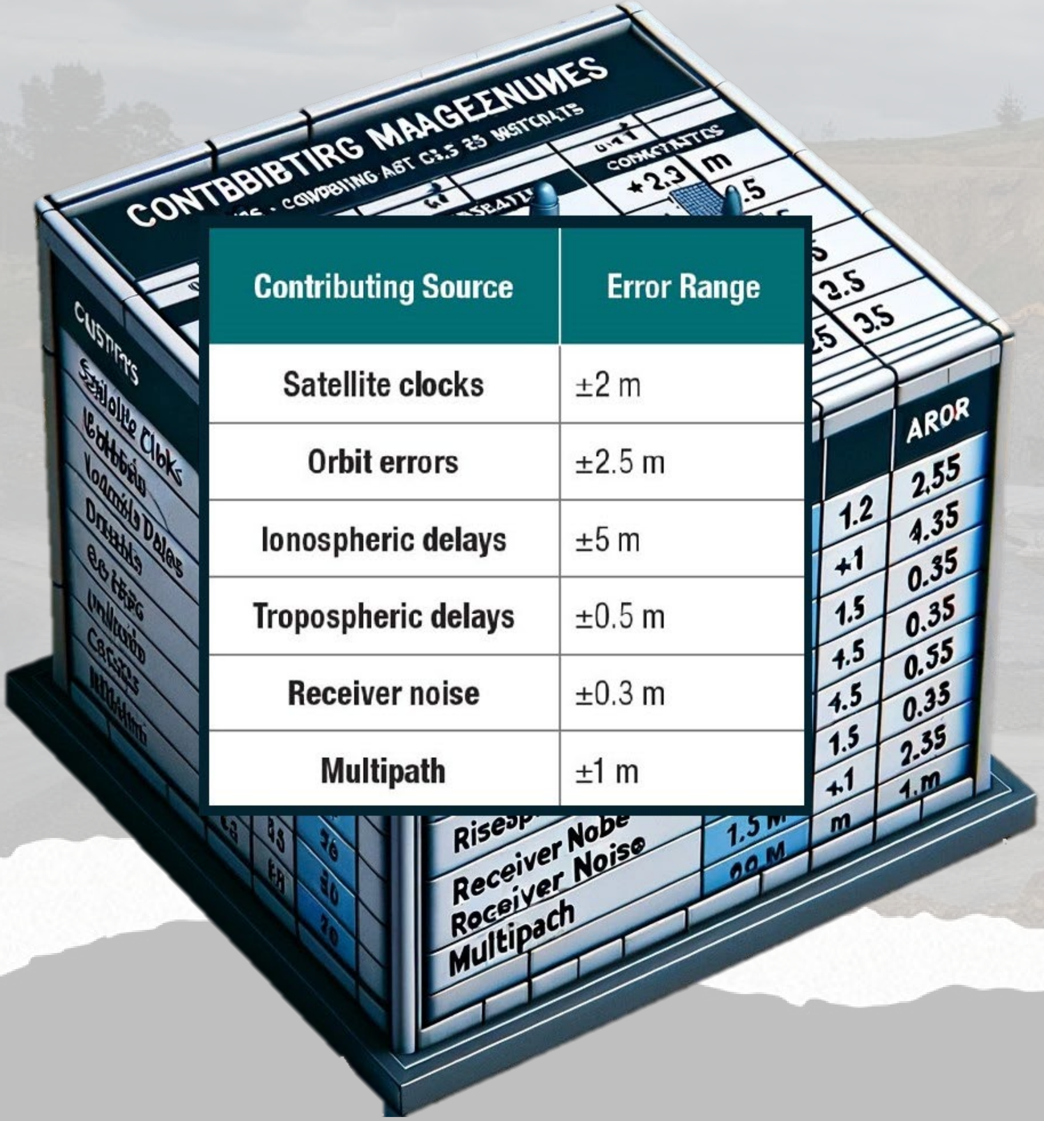
Satellite clocks

- Accurate to ±5 parts in 100,000,000,000
- 10 nanoseconds of time error is 3m of position error
- Monitored by GNSS Ground Control Segment
- Provides estimate of clock offset

GNSS How it Works

Error Sources



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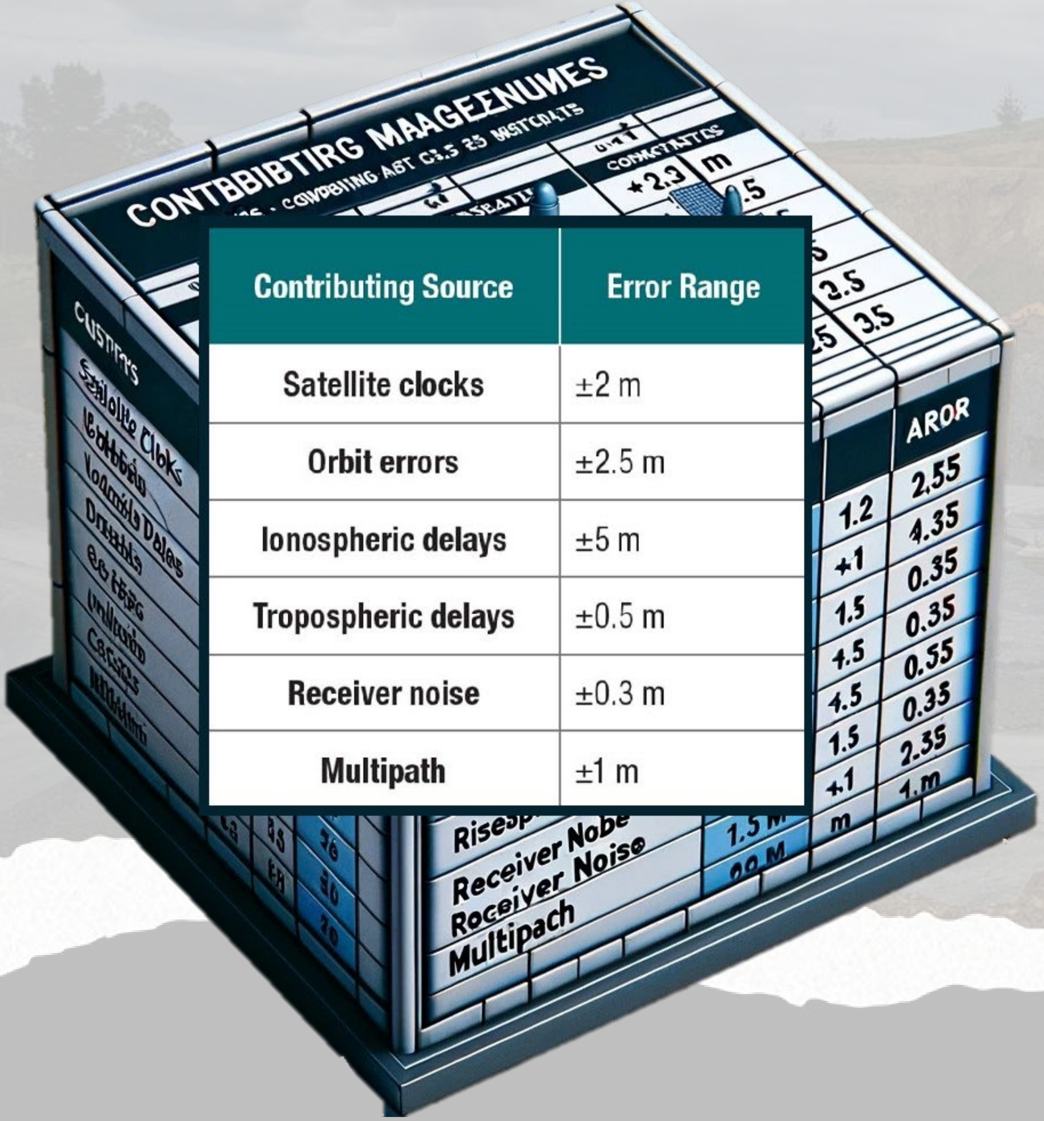
Orbit errors

- Medium earth orbit highly stable and predictable
- Gravitational effects
- Pressure of solar radiation
- Monitored by GNSS Ground Control Segment
- Corrections made when needed

GNSS How it Works

Error Sources



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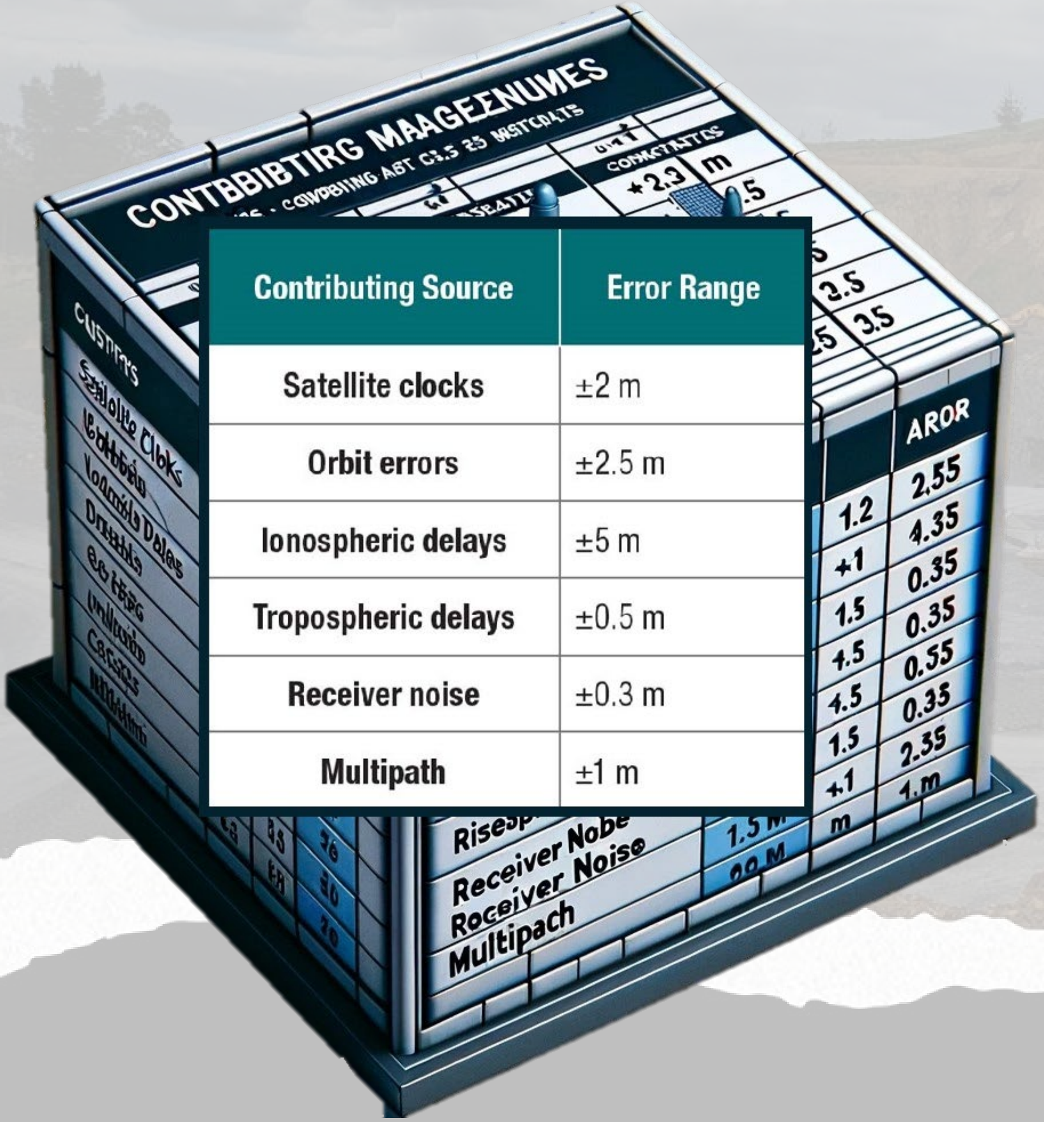
Ionospheric delays

- Atmosphere between 80km and 600km above the earth
- Ions delay satellite signals
- Varies with solar activity, time of year, season, time of day, and location
- Delay varies with different radio frequency
- Tracking more than one frequency allows for correction

GNSS How it Works

Error Sources



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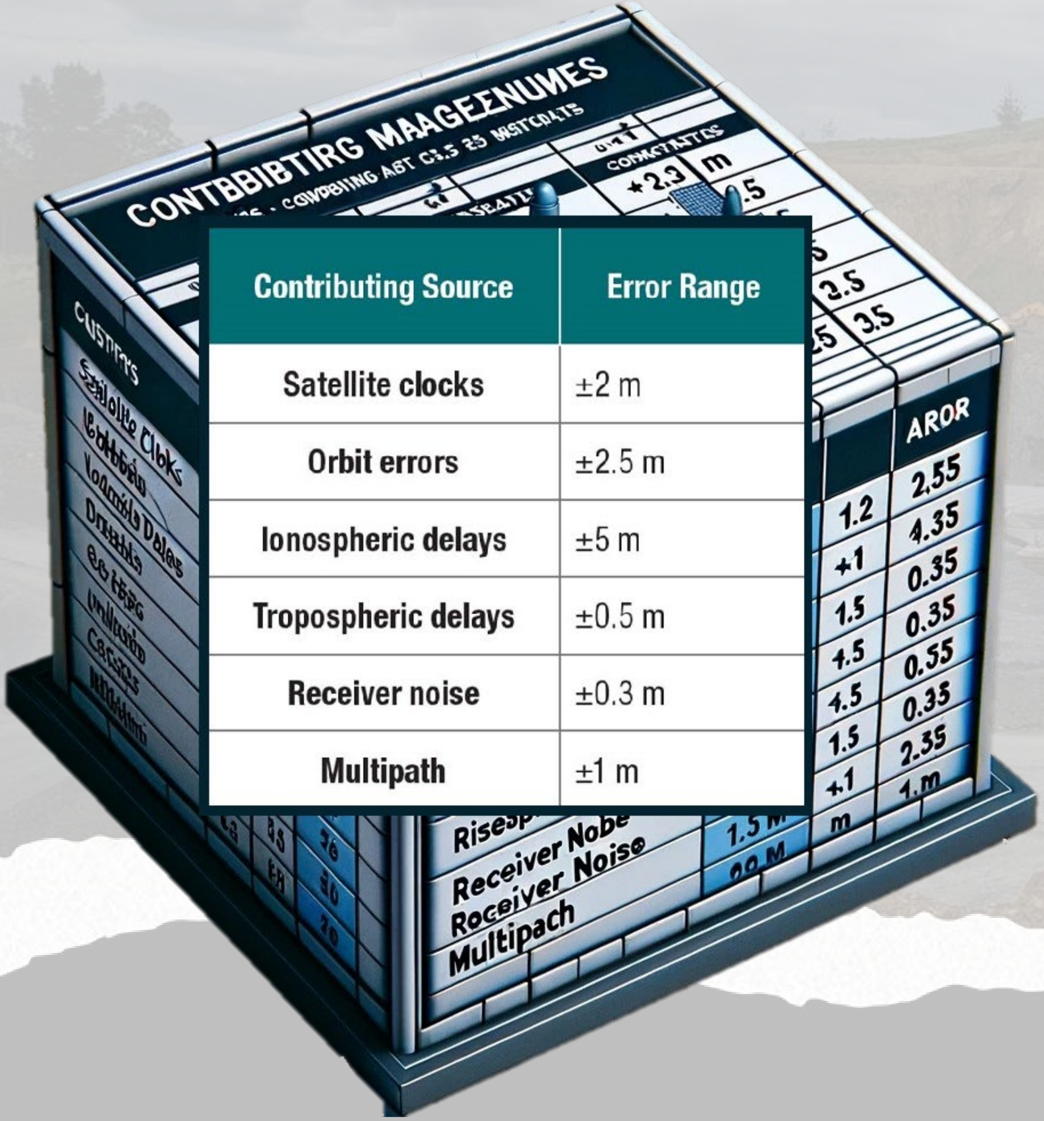
Multipath	±1 m

Tropospheric delays

- Atmosphere closest to the earth’s surface
- Varies with humidity, temperature, atmospheric pressure
- Conditions are similar within a local area
- Allows RTK systems to compensate for delay

GNSS How it Works

Error Sources



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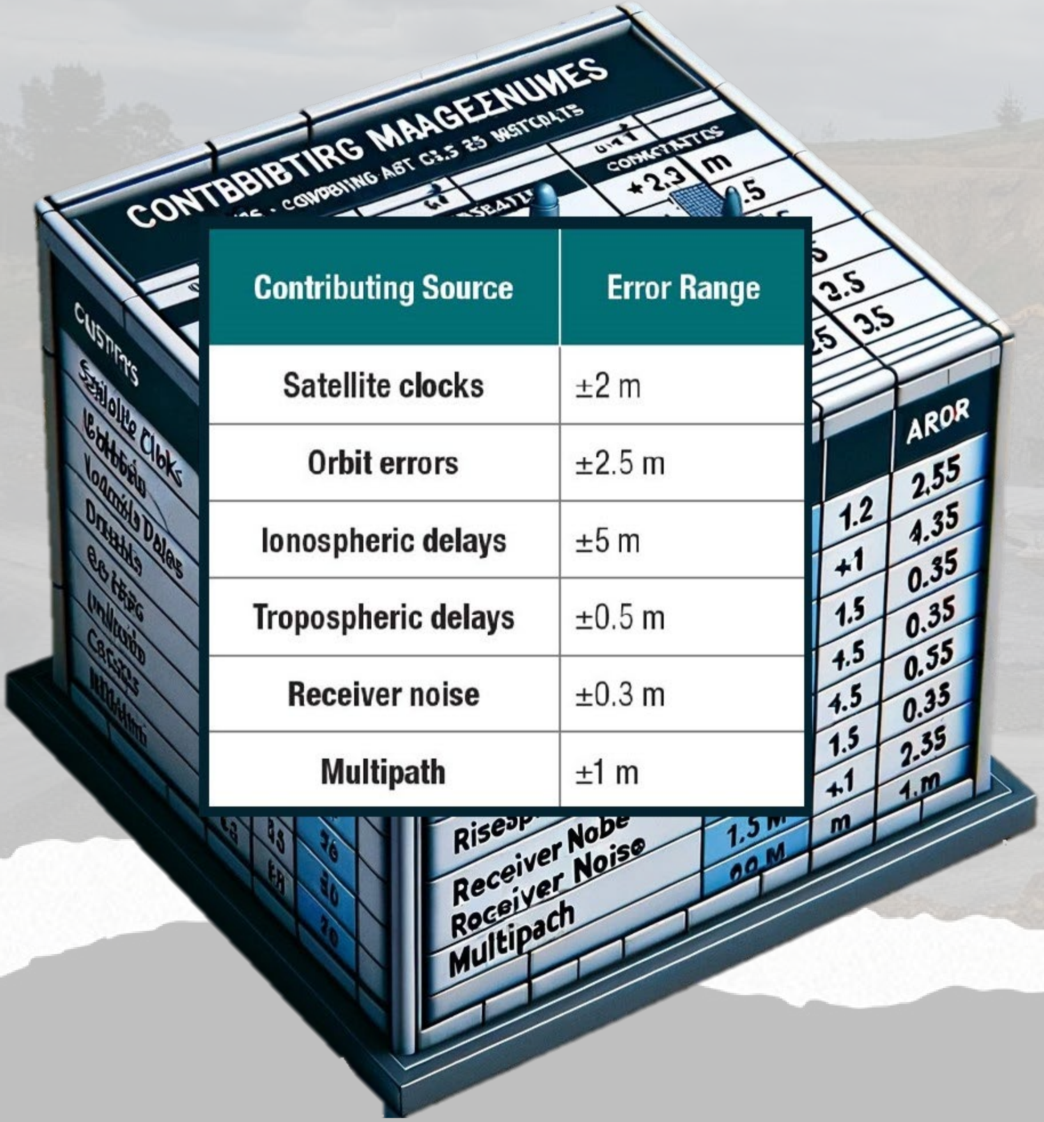
Multipath	±1 m

Receiver noise

- Position error caused by GNSS receiver hardware and software
- High end GNSS less noise
- Low cost GNSS more noise

GNSS How it Works

Error Sources



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Multipath

- Occurs when GNSS signal is reflected off an object
- Highwalls, structures, buildings, trees can cause multipath
- Reflected signal delayed causing incorrect position calculation
- Reduce multipath by keeping antenna away from deflecting surfaces

GNSS How it Works

Making it more Accurate

Code Based Positioning

- Uses pseudorandom codes
- 1m to 10 m accuracy

Carrier Based Ranging

- Real Time Kinetic (RTK)
- 1cm to 3 cm accuracy

GNSS How it Works

Single Base RTK

Base Station

- Location accurately known
- Receives GNSS signals
- Determines range errors
- Transmits corrections

GNSS Satellite

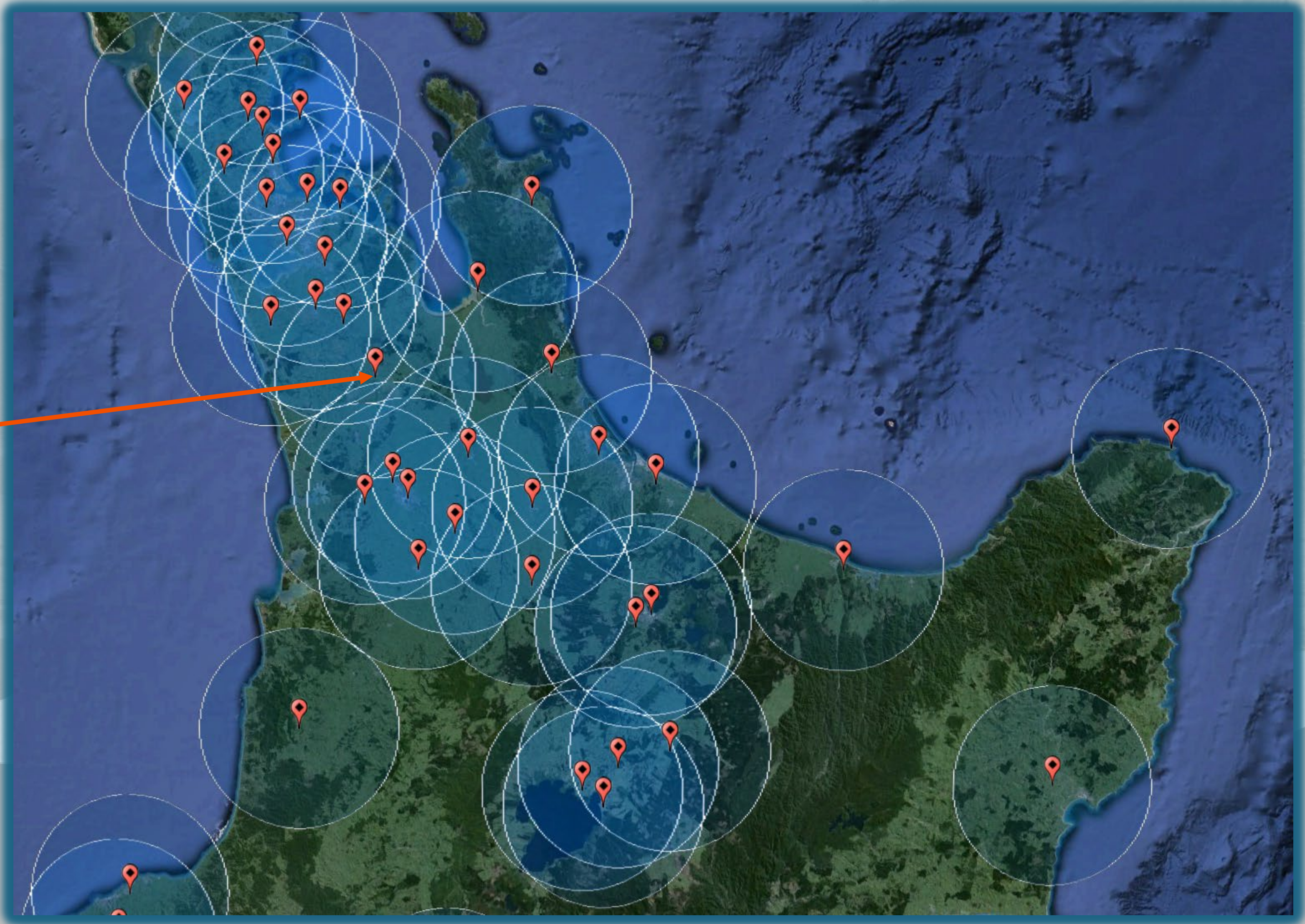
- Sends GNSS signals

Rover

- Receives GNSS signals
- Receives corrections
- Applies corrections
- Determines position

GNSS How it Works

Network RTK



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GNSS How it Works

RTK Baseline distance error

Single Base RTK: Hz 8 mm + 1 ppm / V 15 mm + 1 ppm

Network RTK: Hz 8mm + 0.5 ppm / V 15 mm + 0.5 ppm

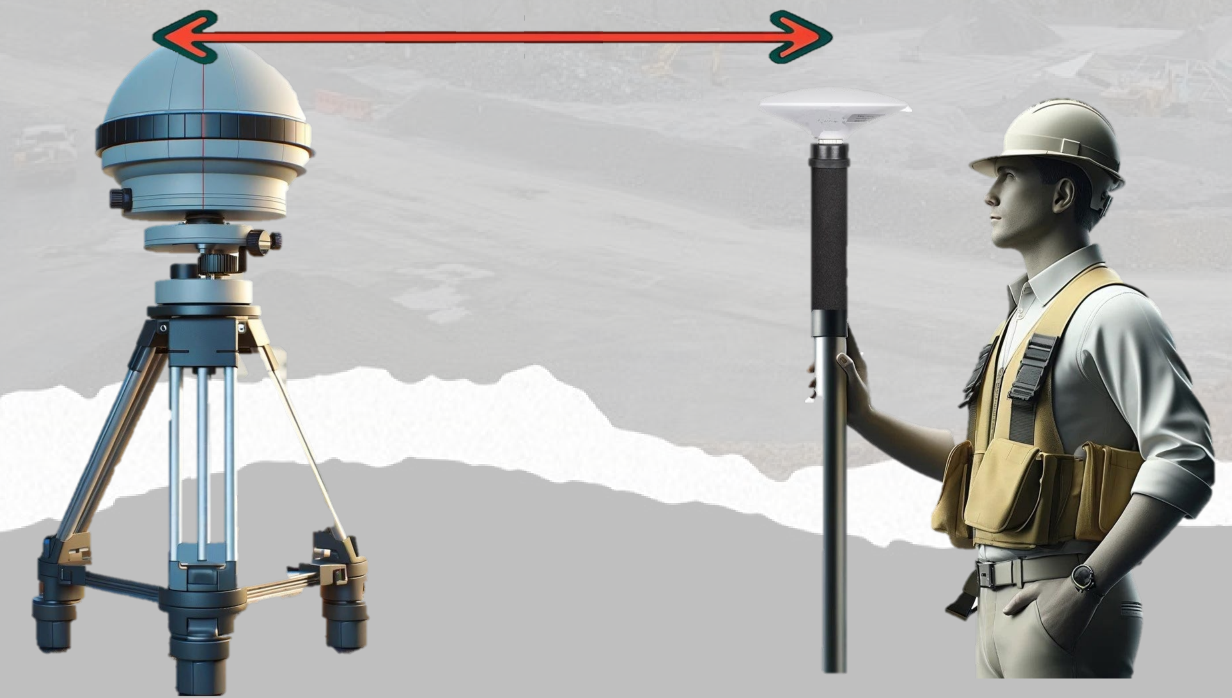
GNSS How it Works

RTK Baseline distance error

Single Base RTK: Hz 8 mm + 1 ppm / V 15 mm + 1 ppm
Network RTK: Hz 8mm + 0.5 ppm / V 15 mm + 0.5 ppm

Error at 1km

Single Base RTK: Hz 9 mm / V 16 mm
Network RTK: Hz 8.5mm / V 15.5 mm



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GNSS How it Works

RTK Baseline distance error

Single Base RTK: Hz 8 mm + 1 ppm / V 15 mm + 1 ppm
Network RTK: Hz 8mm + 0.5 ppm / V 15 mm + 0.5 ppm

Error at 10km

Single Base RTK: Hz 18 mm / V 25 mm
Network RTK: Hz 13mm / V 20 mm

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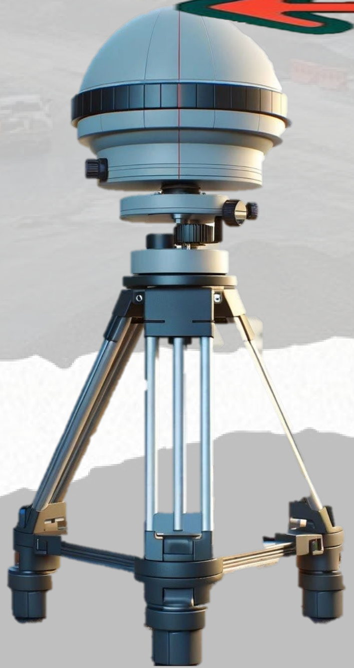
GNSS How it Works

RTK Baseline distance error

Single Base RTK: Hz 8 mm + 1 ppm / V 15 mm + 1 ppm
Network RTK: Hz 8mm + 0.5 ppm / V 15 mm + 0.5 ppm

Error at 30km

Single Base RTK: Hz 38 mm / V 45 mm
Network RTK: Hz 23mm / V 30 mm



GNSS How it Works

RTK Baseline distance error

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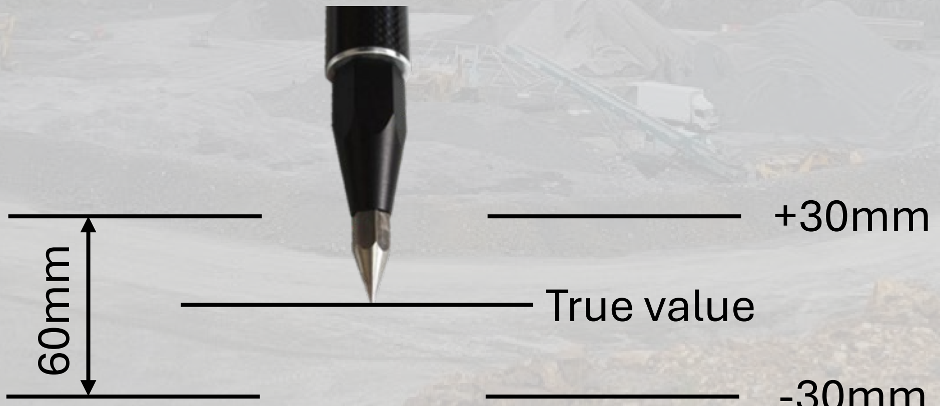
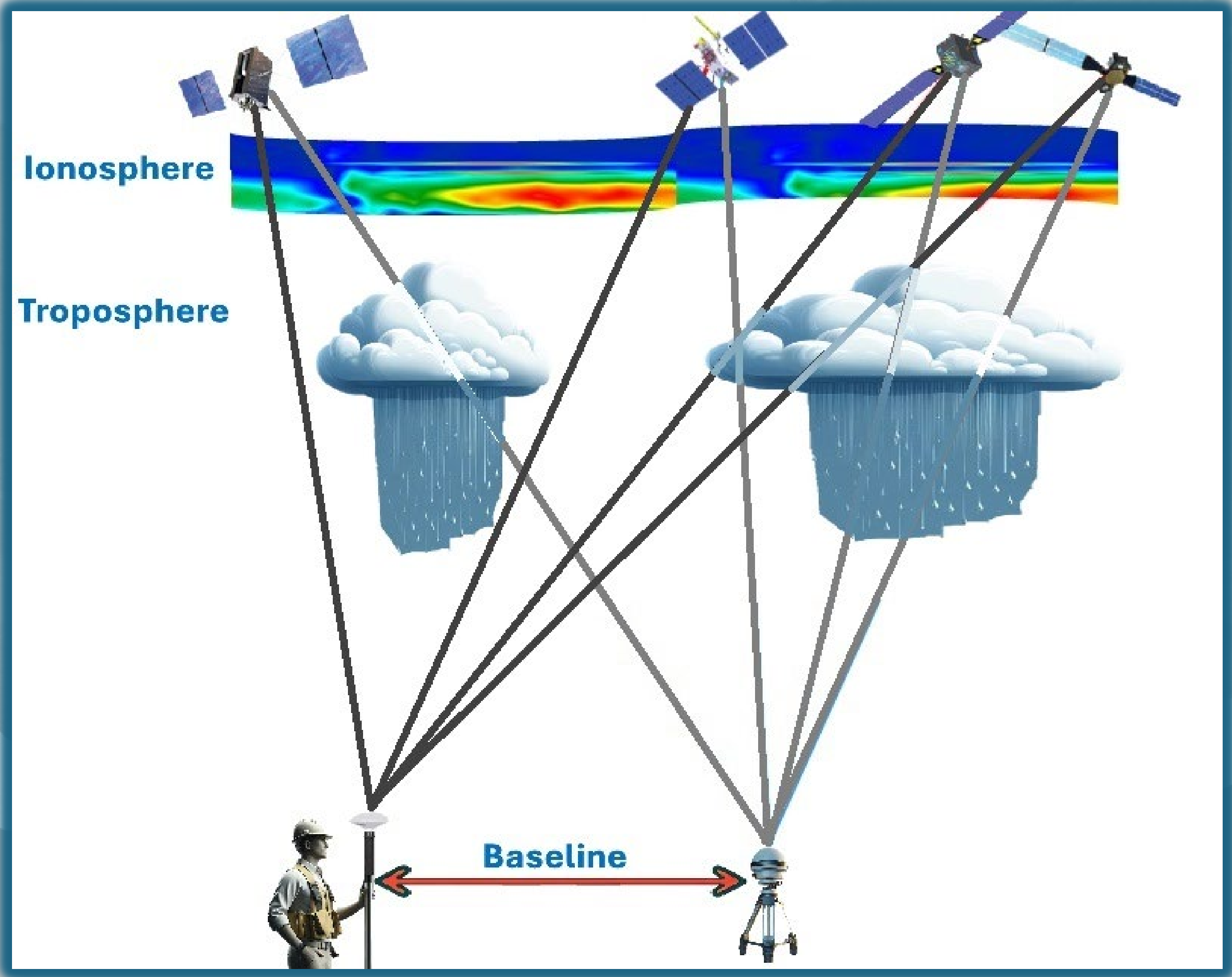


GNSS How it Works

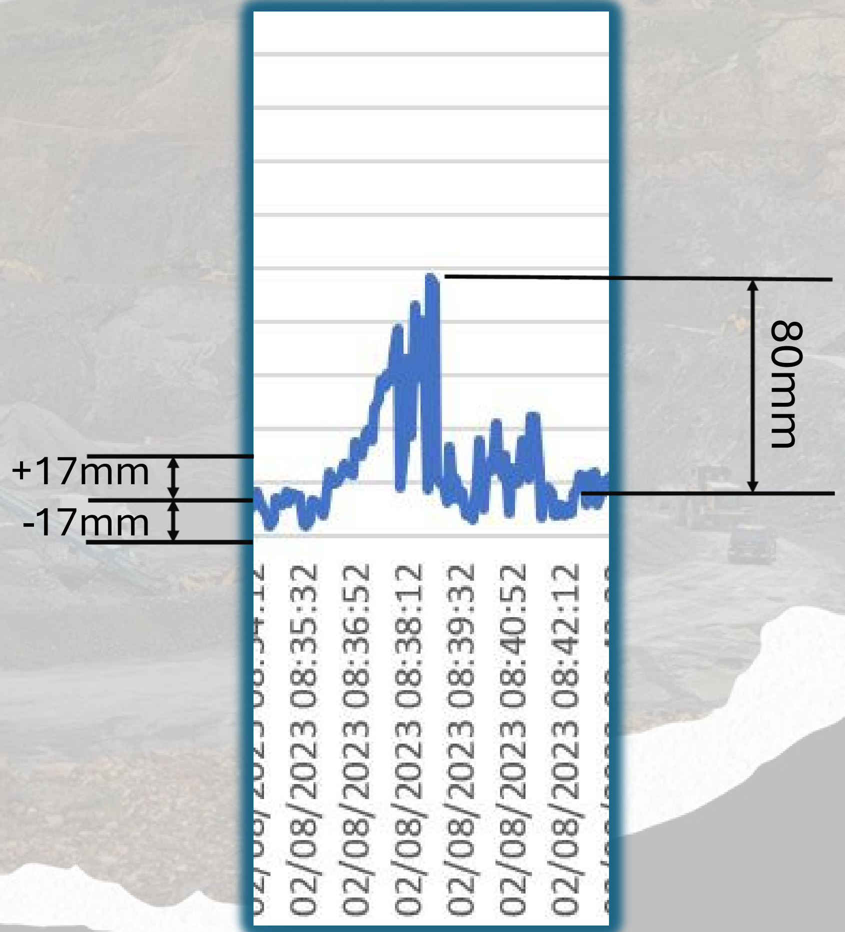
RTK Base and Rover Conditions



GNSS How it Works

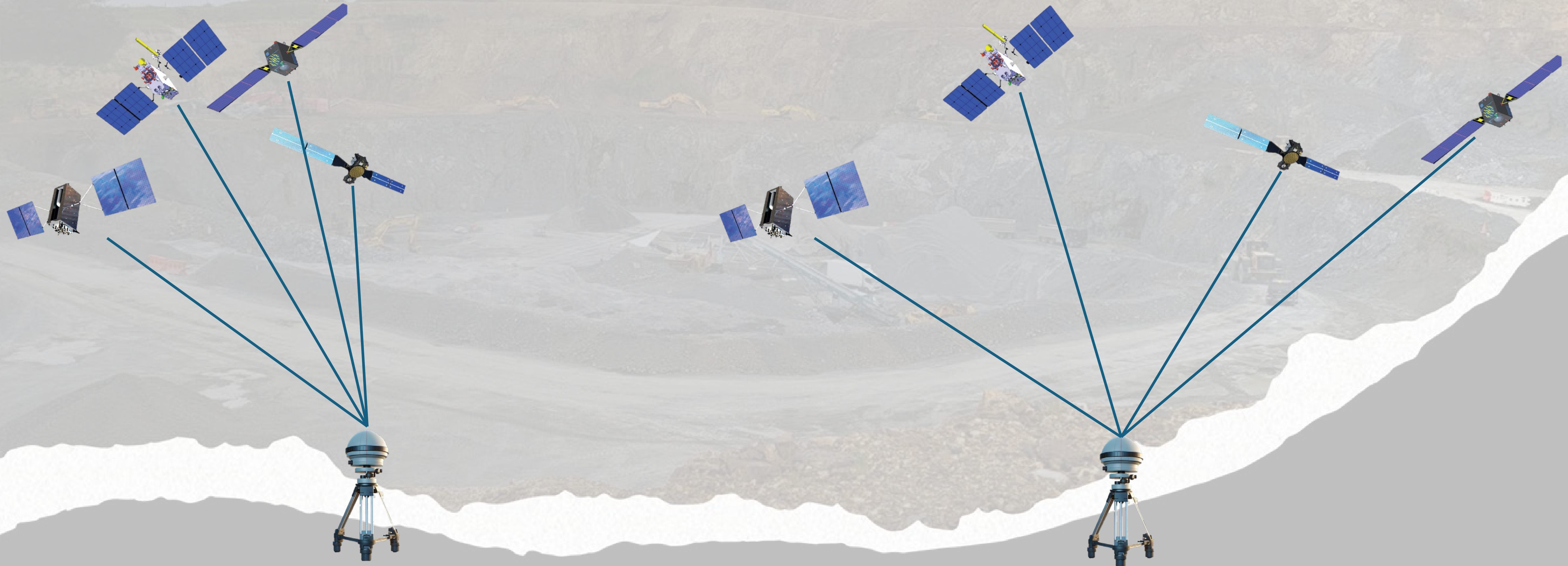
RTK Base and Rover Conditions

Network RTK:
Error at 17km
Hz 17mm
V 23 mm



GNSS How it Works

Dilution of Precision (DoP)

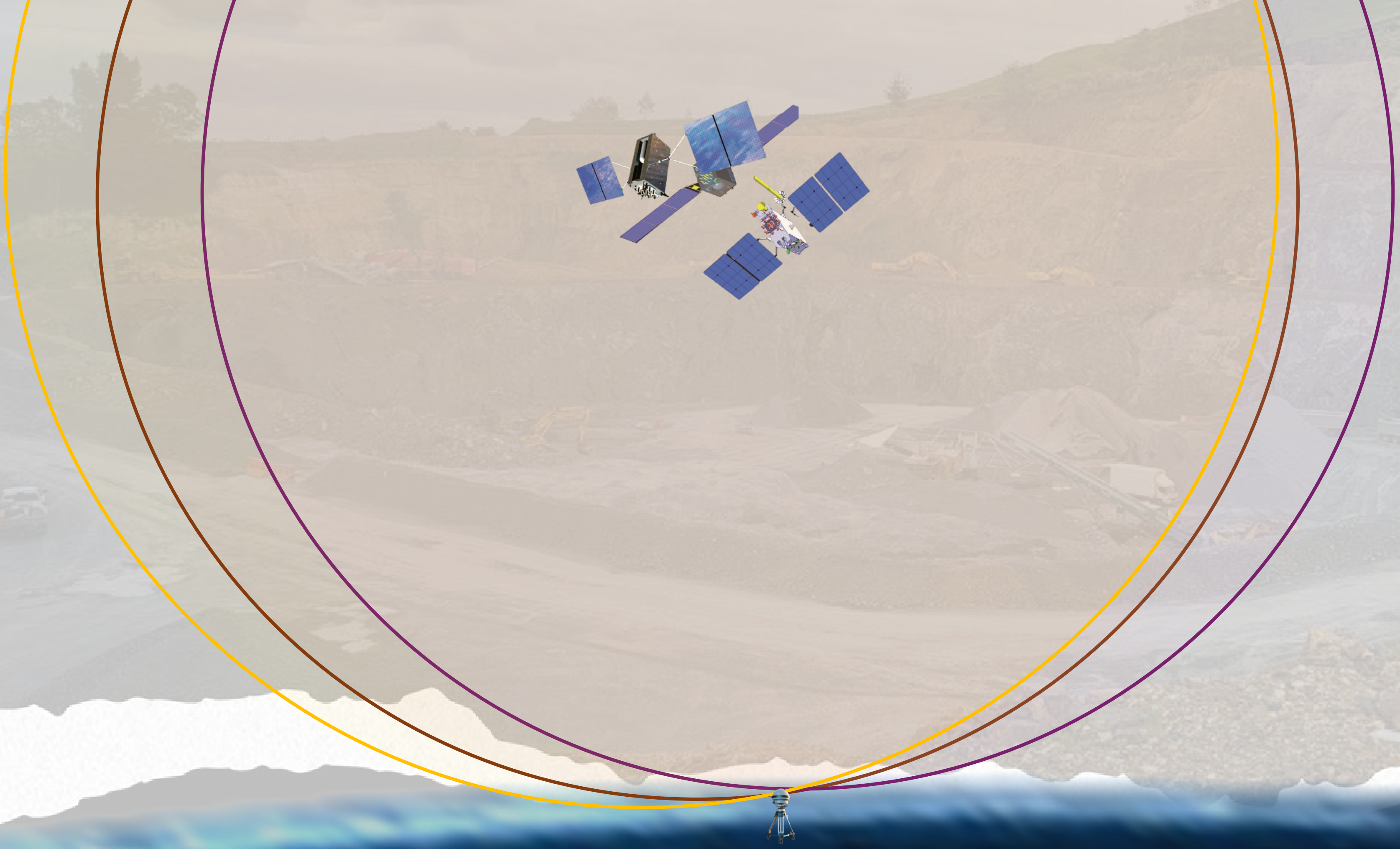


Bad DoP

Good DoP

GNSS How it Works

Dilution of Precision (DoP)



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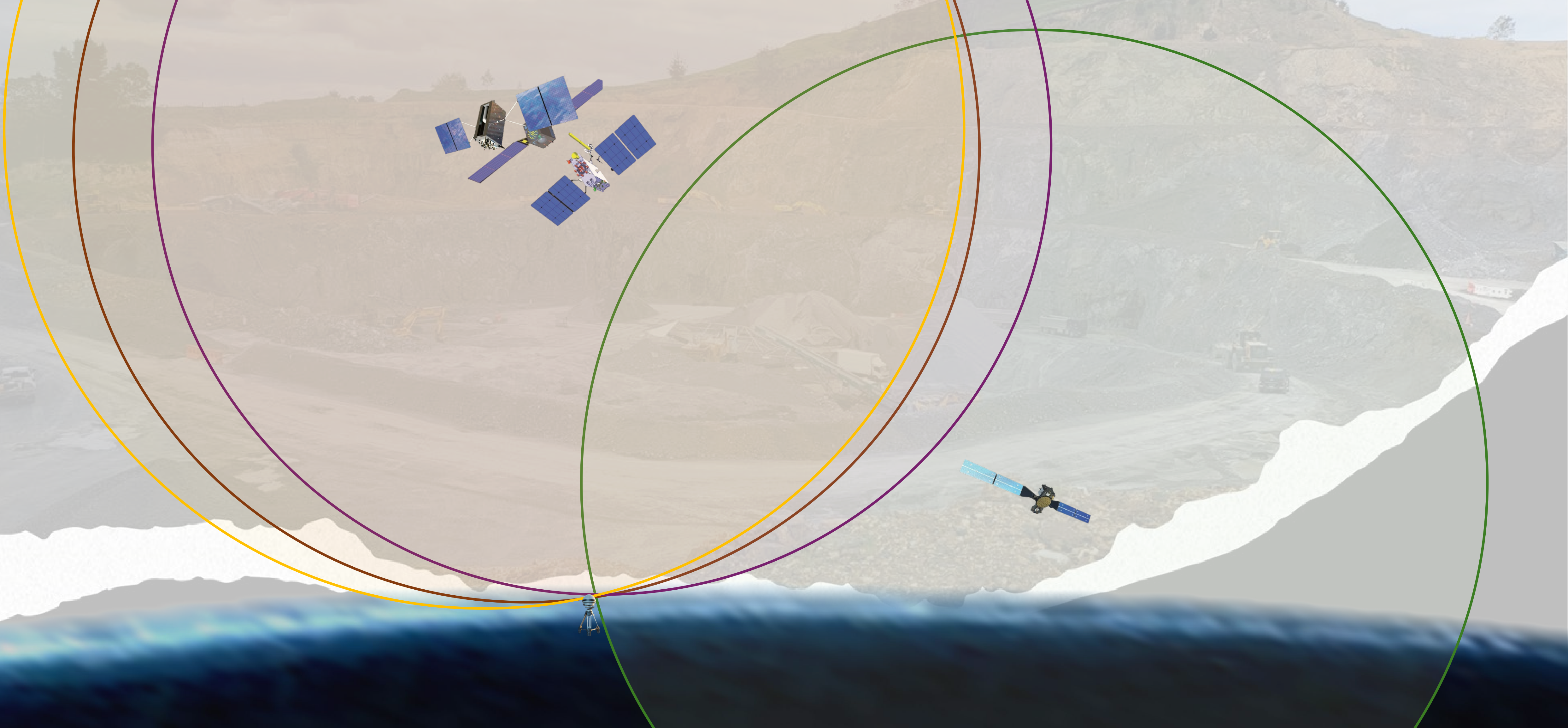


GNSS How it Works

Dilution of Precision (DoP)

DOP value	Rating	Description
<1	Ideal	Highest possible confidence level to be used for applications demanding the highest possible precision at all times.
1–2	Excellent	At this confidence level, positional measurements are considered accurate enough to meet all but the most sensitive applications.
2–5	Good	Represents a level that marks the minimum appropriate for making accurate decisions. Positional measurements could be used to make reliable in-route navigation suggestions to the user.
5–10	Moderate	Positional measurements could be used for calculations, but the fix quality could still be improved. A more open view of the sky is recommended.
10–20	Fair	Represents a low confidence level. Positional measurements should be discarded or used only to indicate a very rough estimate of the current location.
>20	Poor	At this level, measurements should be discarded.

GNSS How it Works

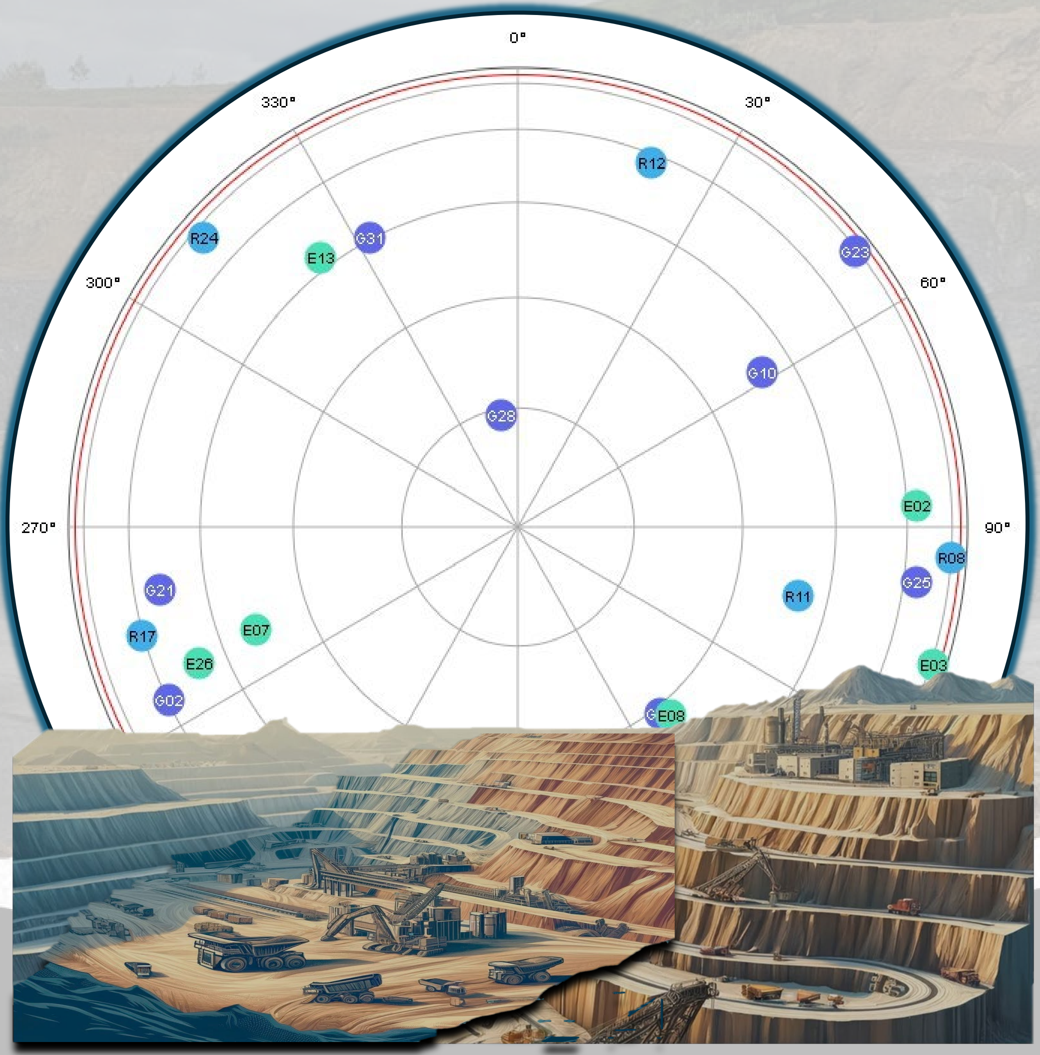
Multi-constellation

GNSS How it Works

Multi-constellation

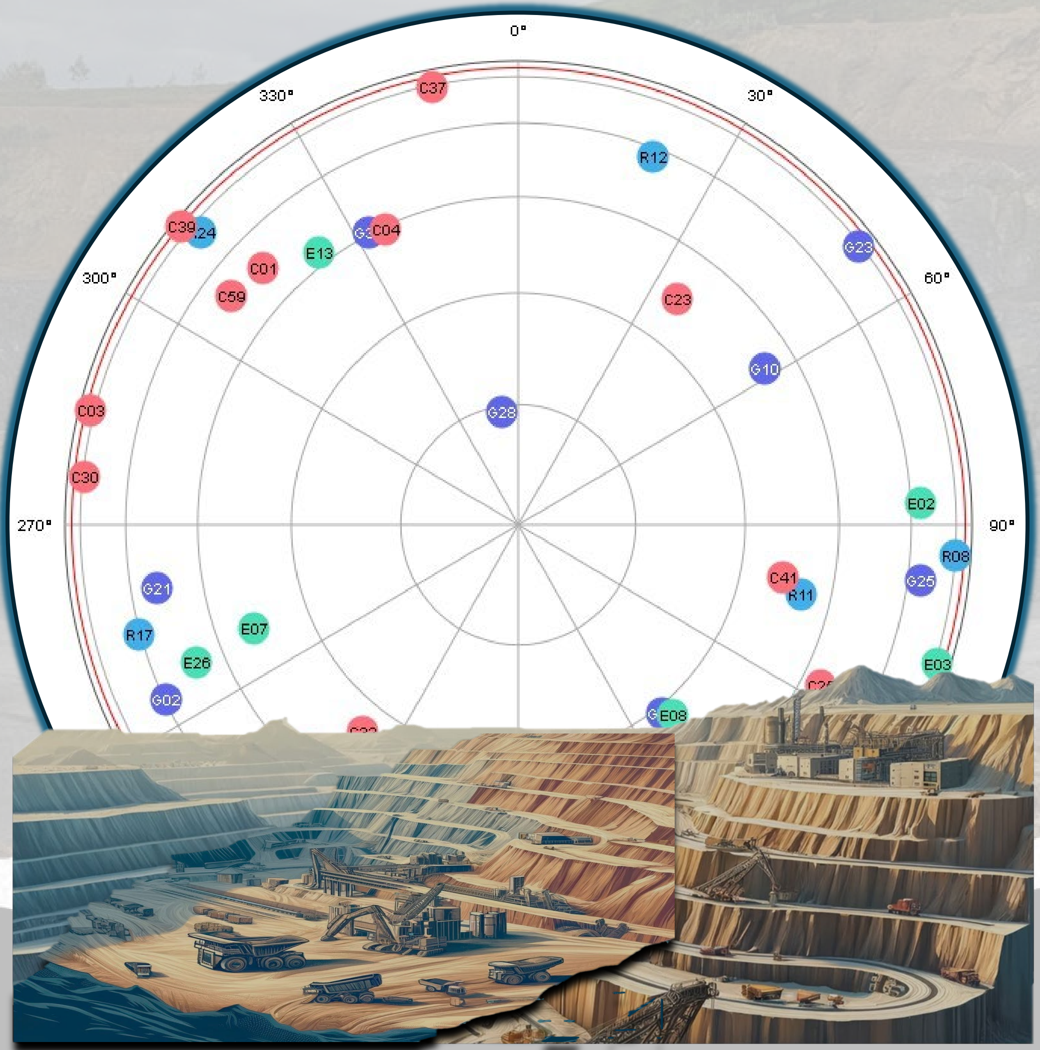
GNSS How it Works

Multi-constellation



GNSS How it Works

Multi-constellation



GNSS How it Works

Multi-constellation

- Reduces signal acquisition time
- Improved spatial distribution improves DoP
- Reduces problems caused by obstructions
- Deep Pits can still have problems

GNSS Applications

Consumer Grade GNSS

- Smartphone navigation
- Location-based search results

Survey Grade RTK GNSS

- Topographical surveys
- Geotechnical locations
- Setout of works
- Ground control points
- As built service locations

GNSS Applications

Drilling Rigs

- Fitted with GNSS
- Accurate location of drill holes
- Improved fragmentation
- Accurate heights better benches

GNSS Applications

Diggers

- Fitted with GNSS
- Loaded with the design model
- Quicker and more accurate
- Reduced mistakes and rework
- Reduces operating cost

GNSS Applications

Real-time Vehicle tracking

- Gather data about vehicle movements
- Optimise operation
- Improve planning
- Inform decision making
- Track material for quality control and reporting

GNSS Applications

Real-time Vehicle tracking

- Assess compliance to procedures
- Manage fuel use and tyre wear
- Track servicing schedules
- Improve safety
- Improve security

Quarrying in the Future

The Quarry of the Future

The Quarry of the Future

- Centralised Control Centre
- Fully autonomous machinery
- Automatic drone surveys
- GNSS reliant
- Highly efficient
- Precisely to design
- Unmatched safety
- Volumetric analysis

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Quarrying in the Future

The Quarry of the Future – Here Now?

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Quarrying in the Future

The Quarry Worker of the Future?

Quarrying in the Future

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The Future is Digital

GNSS pivotal to Navigating Shifts in Technology

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Questions?