Over-the-Air Clock Comparison

A Leading Provider of Smart, Connected and Secure Embedded Control Solutions

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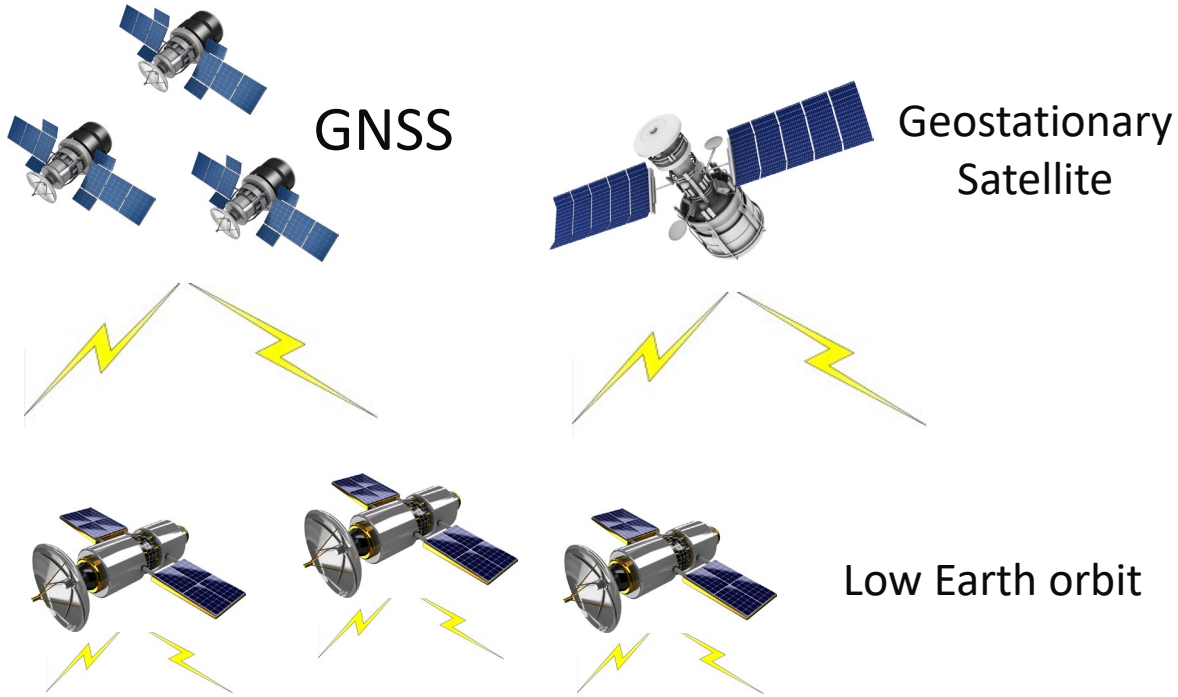
Agenda

- **Multi-layered approach to time resilience**
- **Over-the-Air Two-Way Time Transfer**
  - Two-Way Satellite Time Transfer (TWSTT)
  - Common view GNSS time transfer
- **Summary**

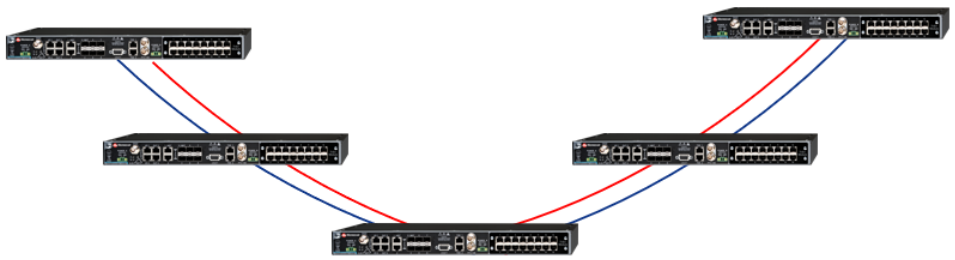
Time Resilience
Multi-Layered Approach



- **Space**
  - GNSS
  - GNSS (Common view)
  - Two-Way Satellite Time Transfer
  - Low Earth Orbit (LEO)

Over-the-Air Clock Comparison

- **Terrestrial RF**
  - eLoran
  - Radio, Wi-Fi, other



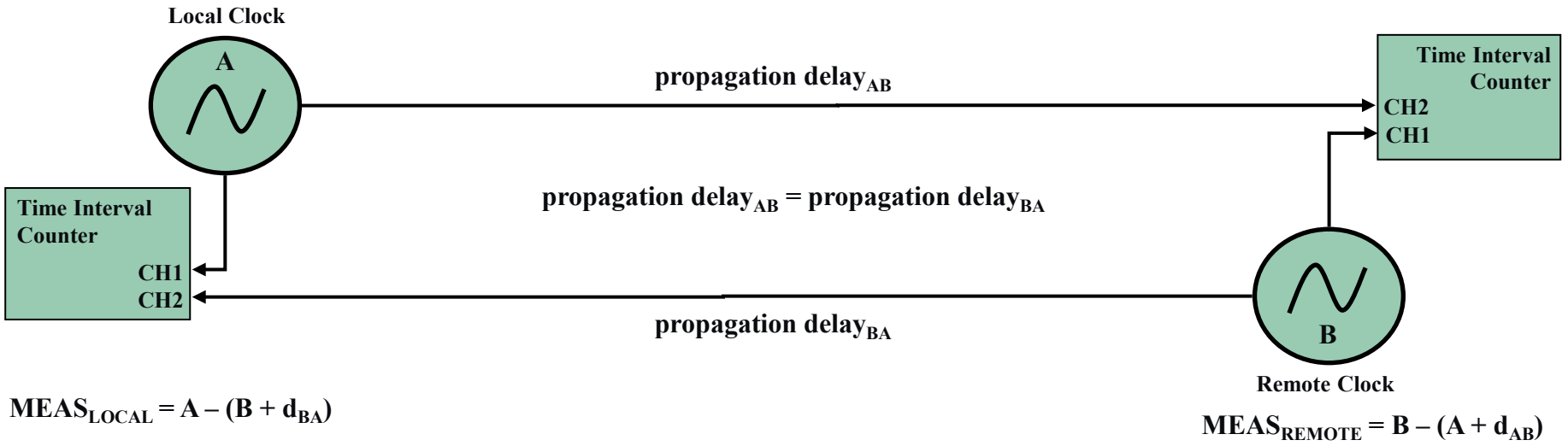
- **Terrestrial Network**
  - PTP with Fiber
  - White Rabbit

Why is Over-the-Air Clock Comparison needed?

- **Enables clocks in diverse geographical locations to be compared with high accuracy**
- **Enables global synchronization without a single point of failure**
- **Augments terrestrial (optical) time distribution**
  - Provides more redundancy which enables better resilience
- **Provides traceability to UTC authorities (BIPM, NIST, PTB, other)**

Two-Way Time Transfer (TWTT)

The basis for over-the-air clock comparison



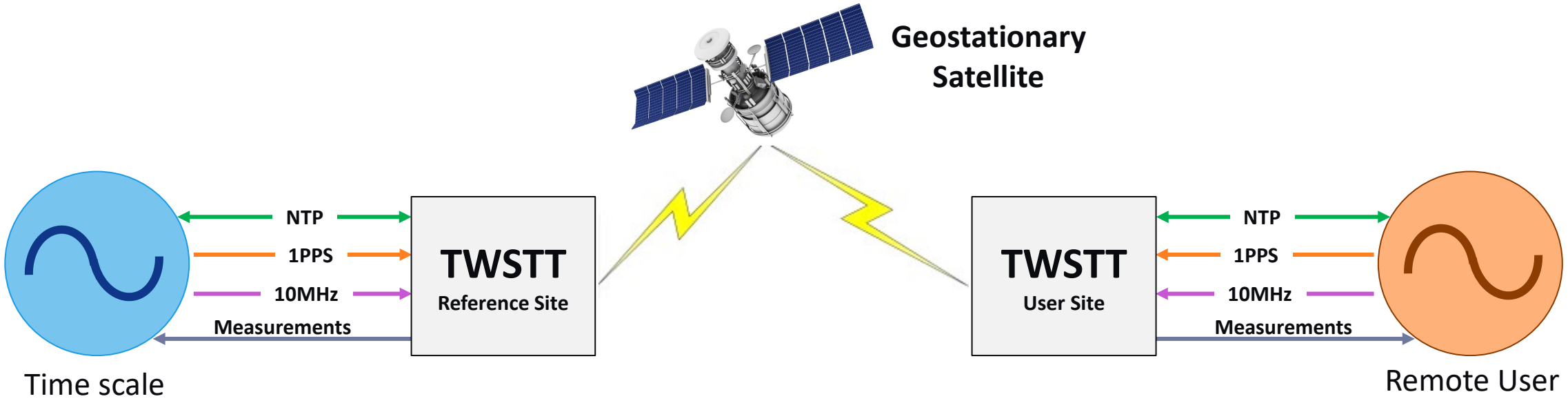
$$(MEAS_{REMOTE} - MEAS_{LOCAL}) / 2 = B - A = \text{Remote Clock Delay}$$

- **Two-Way Time Transfer (TWTT) works by measuring the time difference between transmitting a signal to and receiving a signal from a remote clock**
  - Measurements are exchanged between the two clocks and used to keep the systems synchronized
- **Process requires that the propagation delay is equal in both directions of signal travel**
  - The TX/RX Paths cancel out
- **Link calibration compensates for fixed asymmetric propagation delays**

MICROCHIP

Two-Way Satellite Time Transfer (TWSTT)

- **Key Benefits**
  - GNSS independent time transfer, typically within +/- 3 ns
  - Supports two-way (peer-to-peer) and one-way (broadcast) time transfer modes
- **Use Cases**
  - Use measurements for quality control by comparing clocks on both ends of the link
  - Use measurements to steer the remote clock to the local clock (GNSS independent)



TWSTT Network – Working as a Group

Control Channel

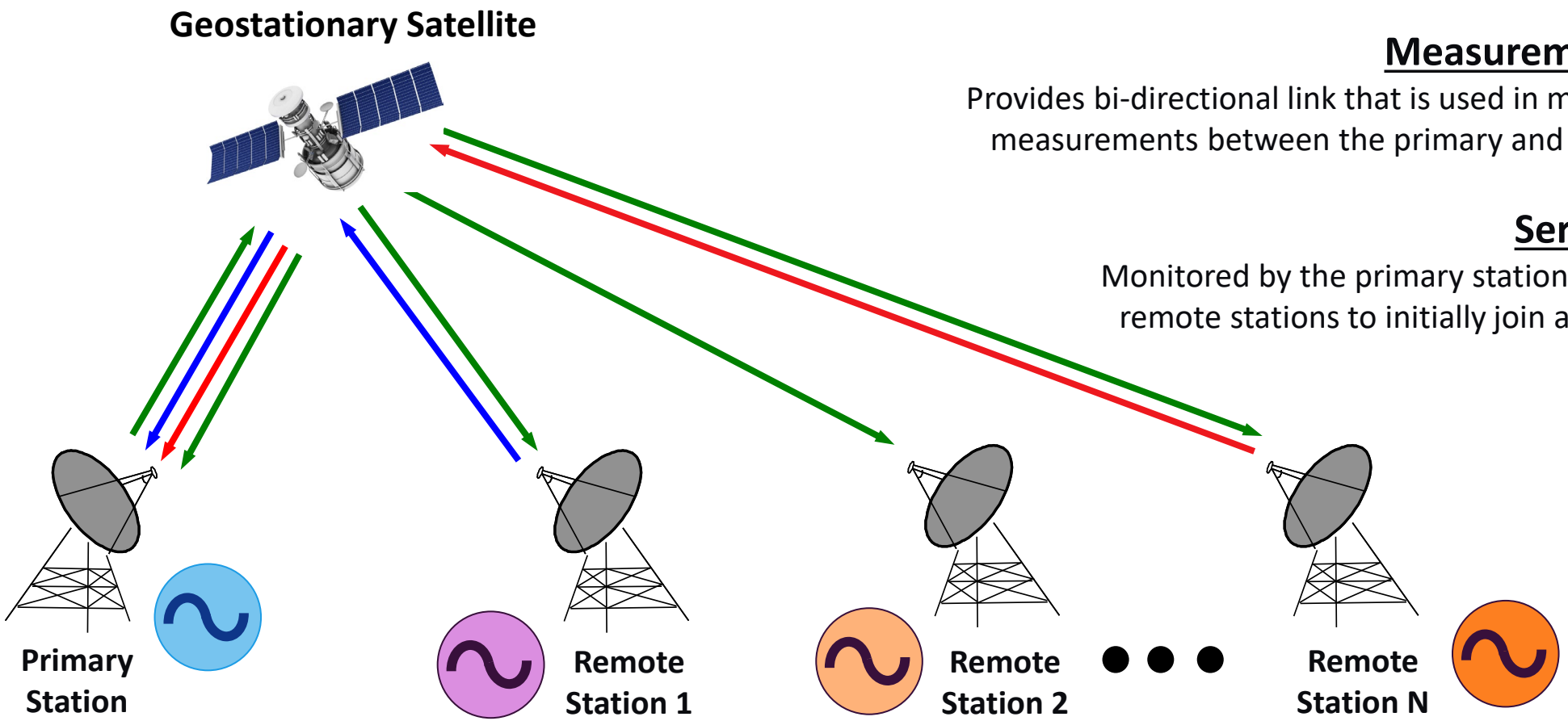
Transmitted by the primary station and provides all communications from the primary to the remote stations

Measurement Channel

Provides bi-directional link that is used in making the TWTT measurements between the primary and remote stations

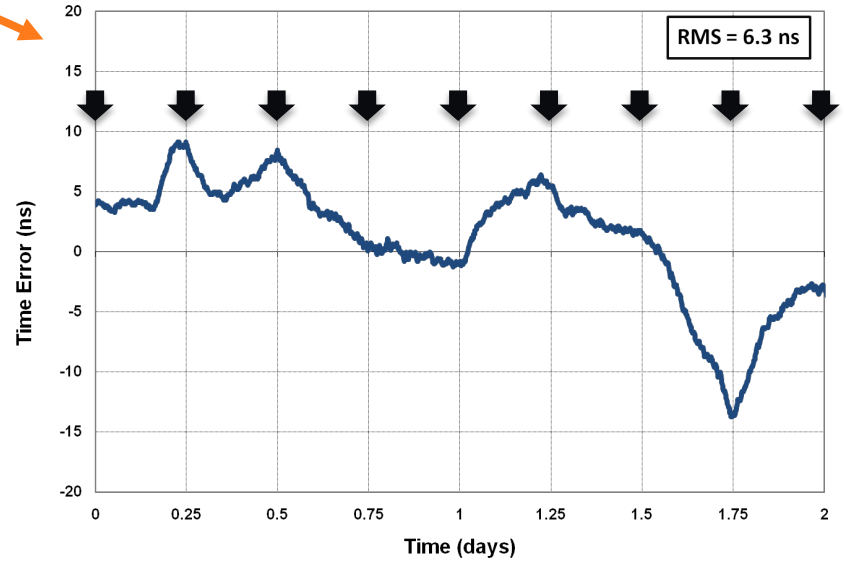
Service Channel

Monitored by the primary station and used by the remote stations to initially join a TWSTT network



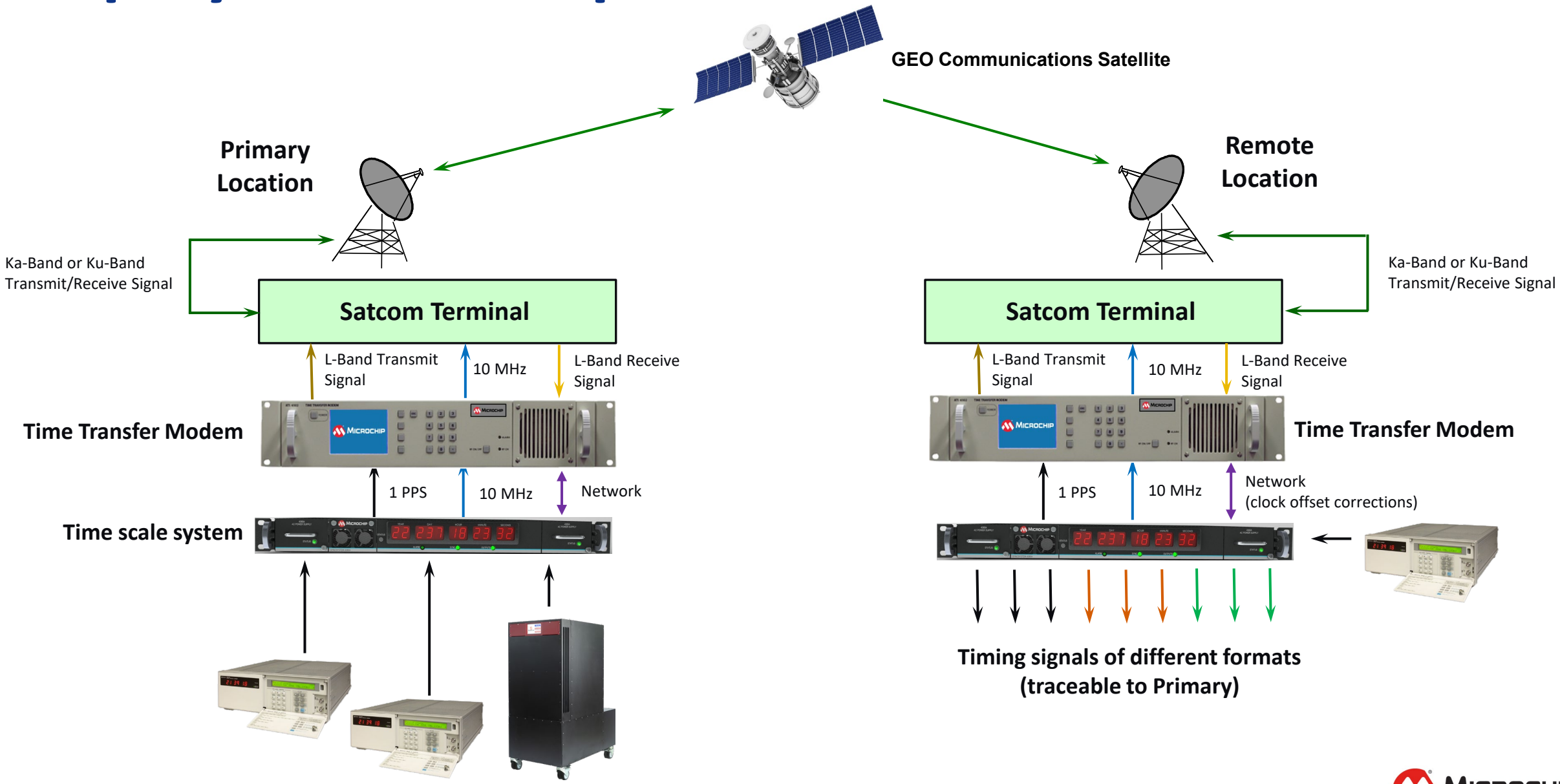
Time Scale Algorithm

- **Using a time scale algorithm, system time can be maintained if link is disrupted**
  - Time offset measurements from a truth source (such as BIPM, NIST, or other) can be used to characterize the current phase and frequency
  - Local time scale is then steered to align with the truth source (which can be located anywhere)
  - Steer interval can be set to variable periods of time



Steer interval can be spread out

Deployment Example

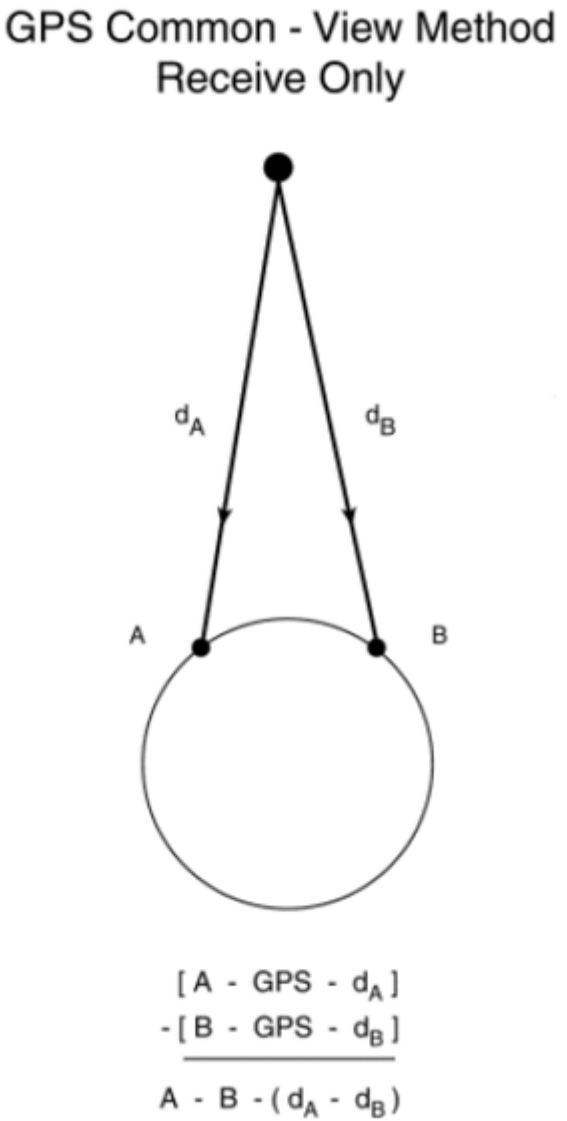


GNSS Common View Principles

- **Time of arrival measurements made on the GNSS signal by the two sites are used to calculate a time difference between them**
- **The equations depend on accurate knowledge of both satellite and site antenna position**
- **For highest accuracy, delays in the transmission paths must be accounted for and corrected**

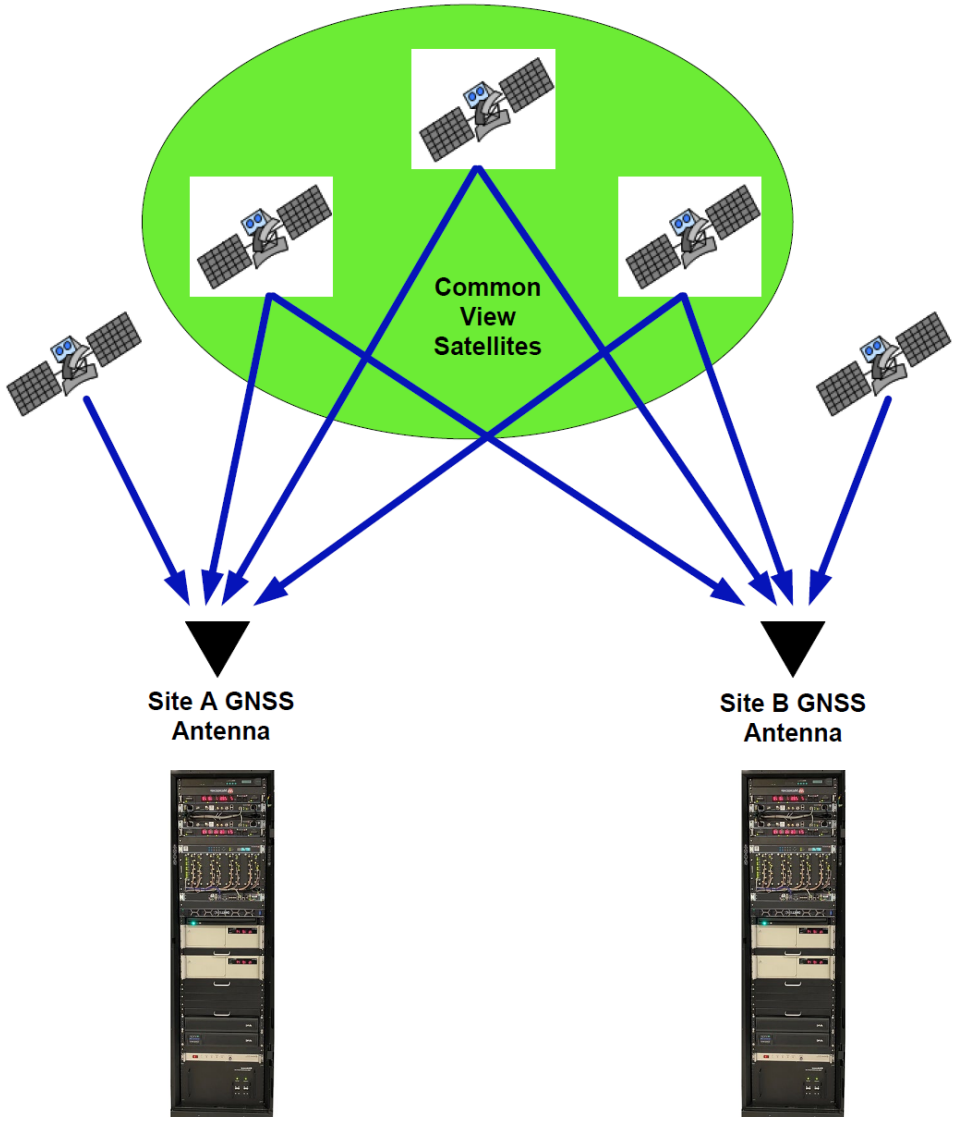
Items to be accounted for in transmission path:

- Cable delays
- Antenna coordinates
- Multipath
- Ionosphere
- Troposphere
- Calibration

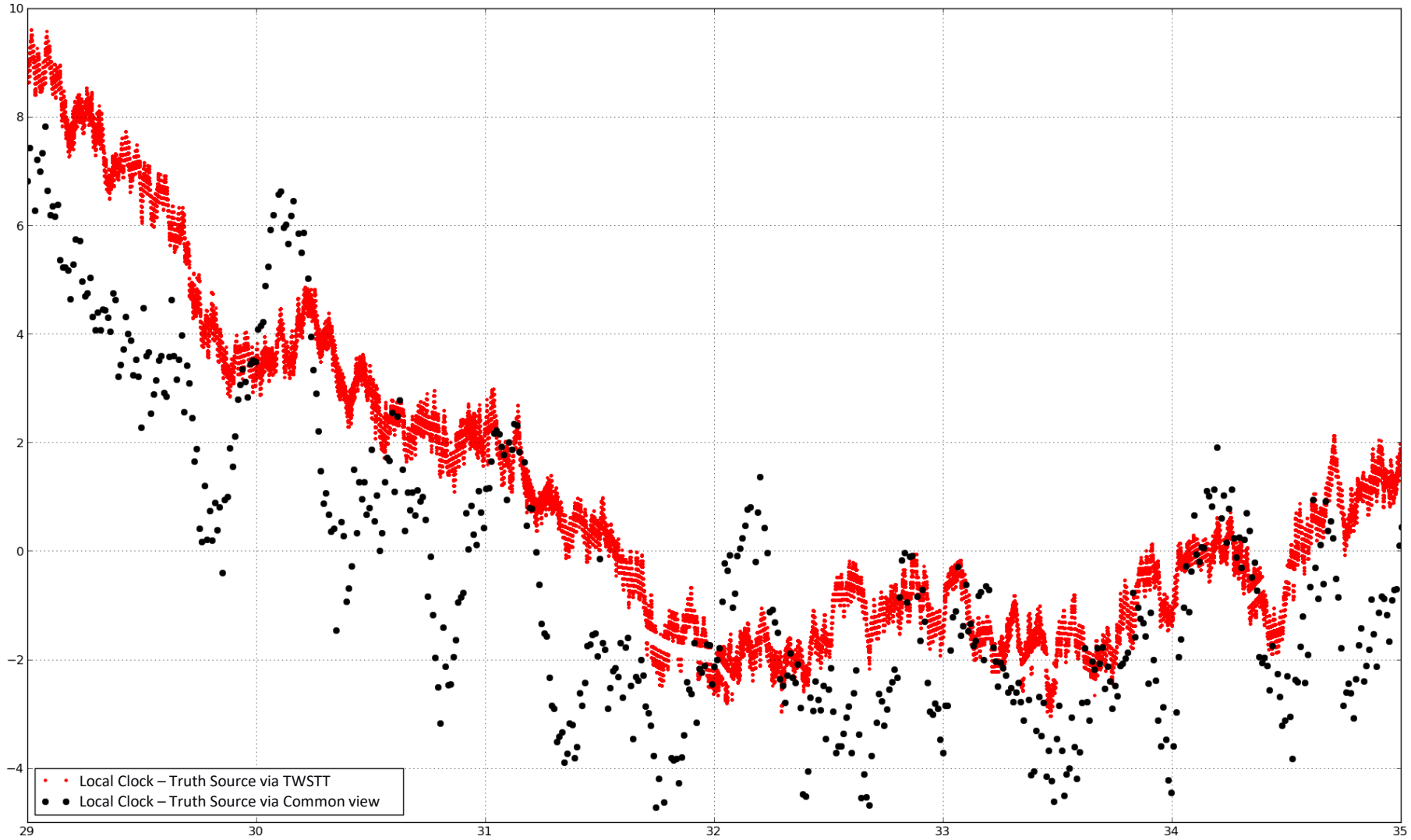


GNSS Common View

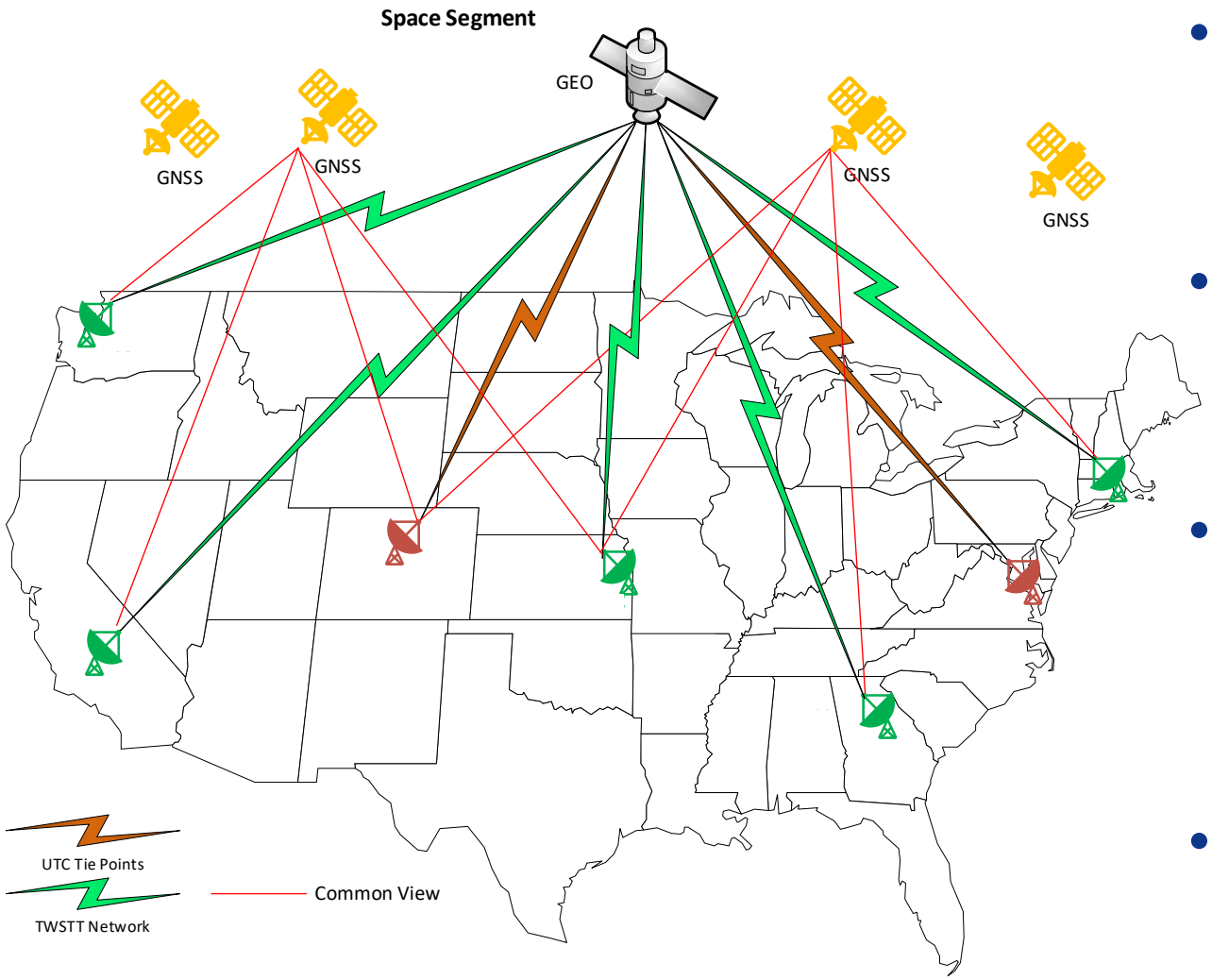
- **GNSS common view timing entails measuring the time of arrival of a common signal (in this case from a GNSS satellite) at two sites**
- **Requirements**
  - Measurements are combined between sites only for the satellites in common view
  - Measurements must be made simultaneously so satellite/site clock drift does not cause error
- **Allows sites to be measured and synchronized with superior accuracy (3 – 5 ns)**
- **Using GNSS versus GPS alone provides additional measurements to enhance reliability (more satellites)**



Example: TWSTT and Common View performance



Over-the-air Clock Comparison and Distribution



- **Two Way Satellite Time Transfer (TWSTT)**
  - Real time measurements of clocks at primary locations (UTC tie points)
- **TWSTT using Group Operation**
  - Alternate steer source - steer the remote clock to the TWSTT measurements (GNSS Independent)
- **Common view**
  - Common view used as a method of measuring remote clocks (~5nSec)
  - Augments TWSTT links
- **Benefits**
  - Multiple pathways
  - Minimal GNSS dependence
  - Enables a geographically separated time scale(s) with multiple clocks

Summary

- **Over-the-Air clock comparison provides an added layer of resilience for timing distribution**
  - Two-Way-Satellite-Time-Transfer (TWSTT) provides a highly accurate method for remote clock measurements that is GNSS independent
  - Common view is a well proven method for clock comparison that is low cost and well proven (uses GNSS but not in a continuous manner)
- **TWSTT and Common View can be used together to provide cost effective coverage for large geographies (including global coverage)**
- **Practical considerations for how these systems are calibrated and maintained must not be overlooked**

Thank You

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