Mitigating GPS Vulnerabilities to Maintain Synchrophasor Timing Requirements

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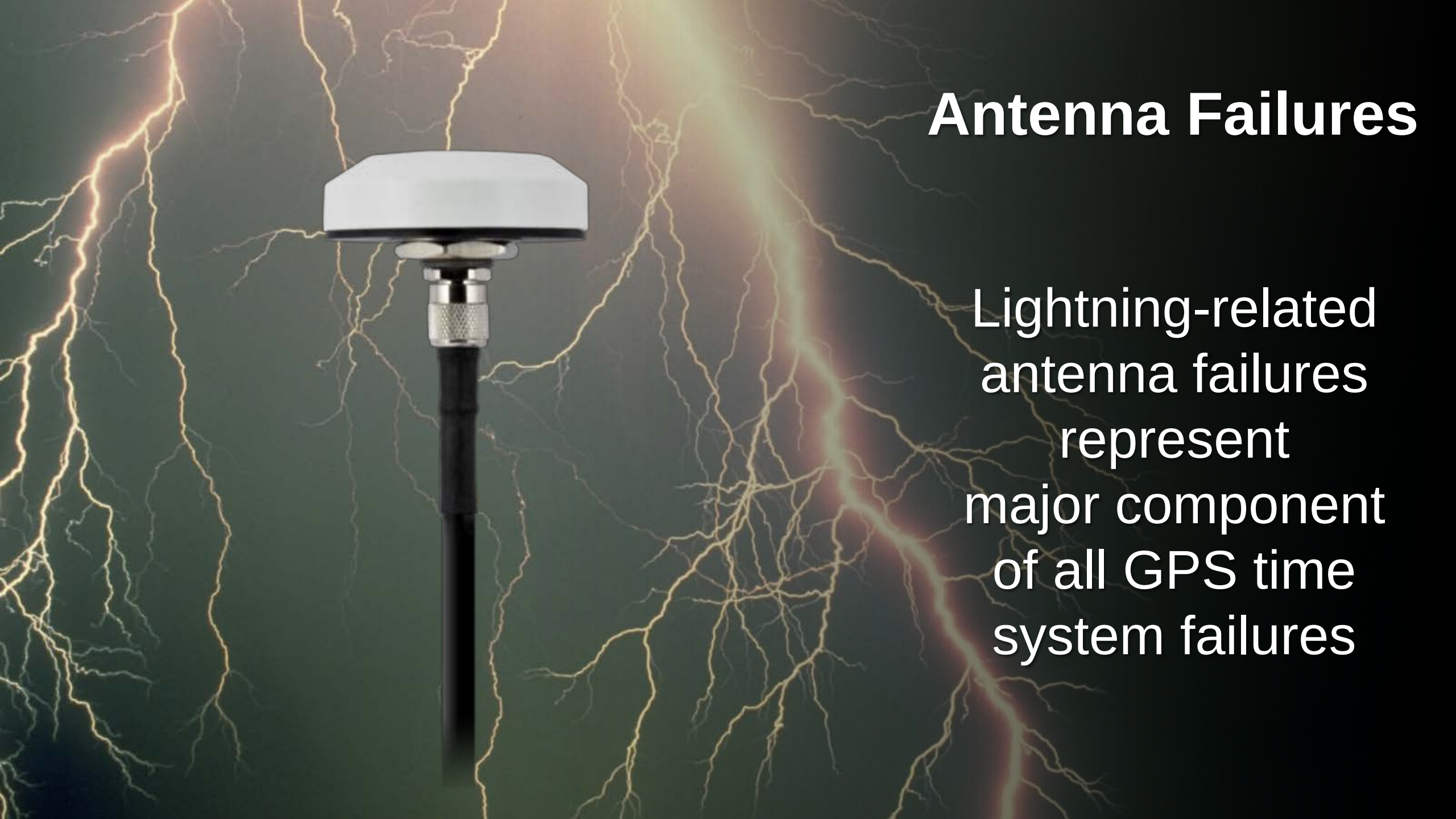
Timing Requirements for Synchrophasors
IEEE C37.118.2-2011

- Standard requires ≤1% total vector error for entire system
  - 0.01 radians (0.57 degrees)
  - ±26 µs in 60 Hz system
- Time source must be highly reliable
  - Standard assumes accurate time
  - Phasor measurement units (PMUs) require 1 µs accuracy

Global Navigation Satellite System (GNSS) Vulnerabilities

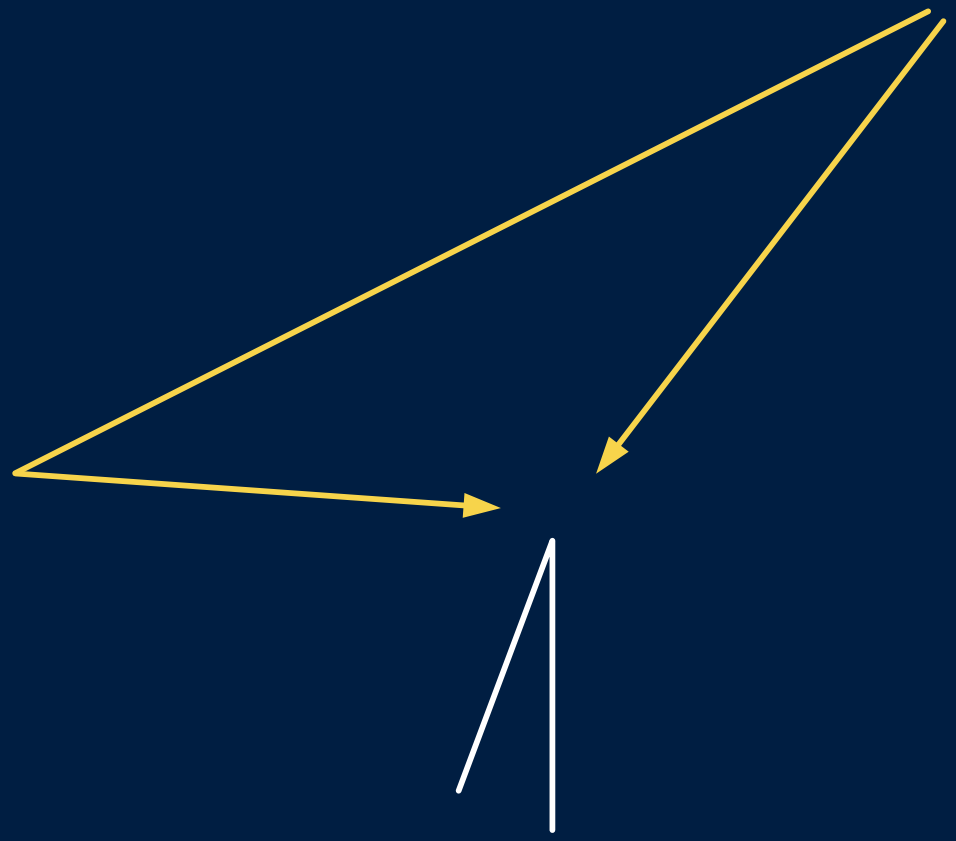
- Localized or global
- Constellation-specific or universal
- Accidental or malicious



Antenna Failures

Lightning-related antenna failures represent major component of all GPS time system failures

Multipath Errors



Reflected GPS signals can cause errors in GPS information

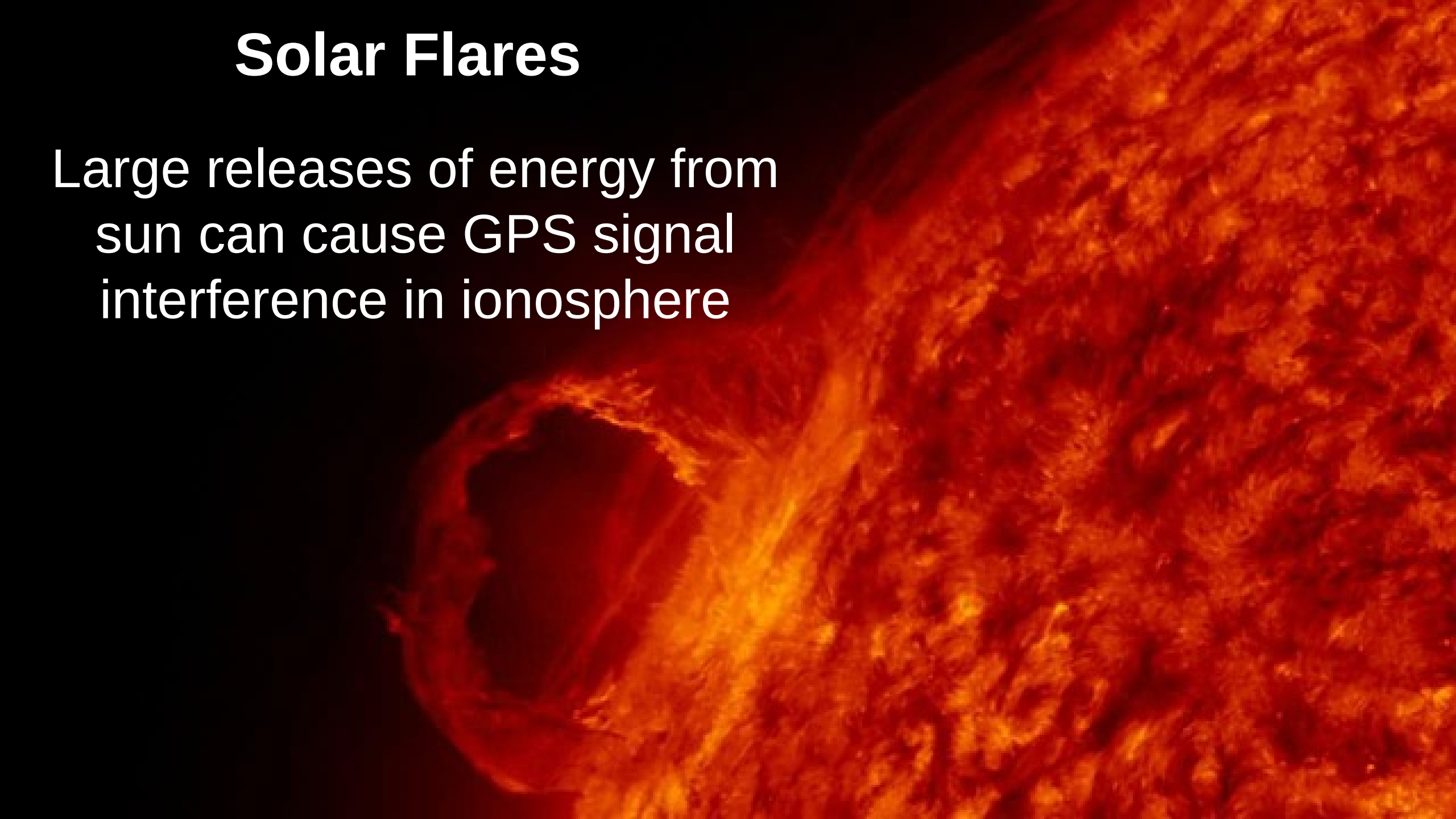
Photo courtesy of
Imperial Eagle DmCC

Jamming

GPS jammers generate noise in the 1.57542 GHz frequency range to prevent reception of GPS signals

Solar Flares

Large releases of energy from sun can cause GPS signal interference in ionosphere



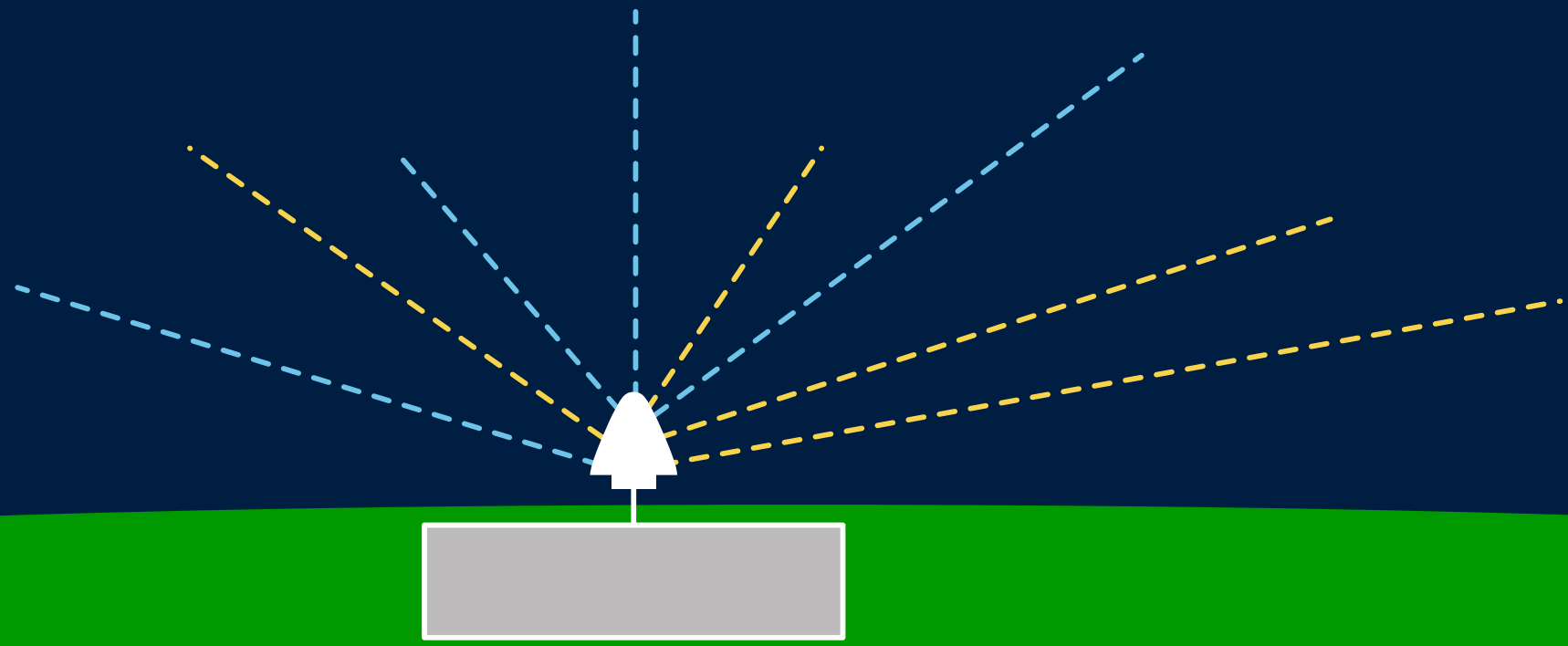
Spoofing

Attacker Mimics and Manipulates GPS Signals

Mitigating GNSS Vulnerabilities

- Multiple constellation comparison
- Wide-area time distribution with time source verification
- Stable holdover
- Ruggedized equipment

Multiple Constellation Comparison

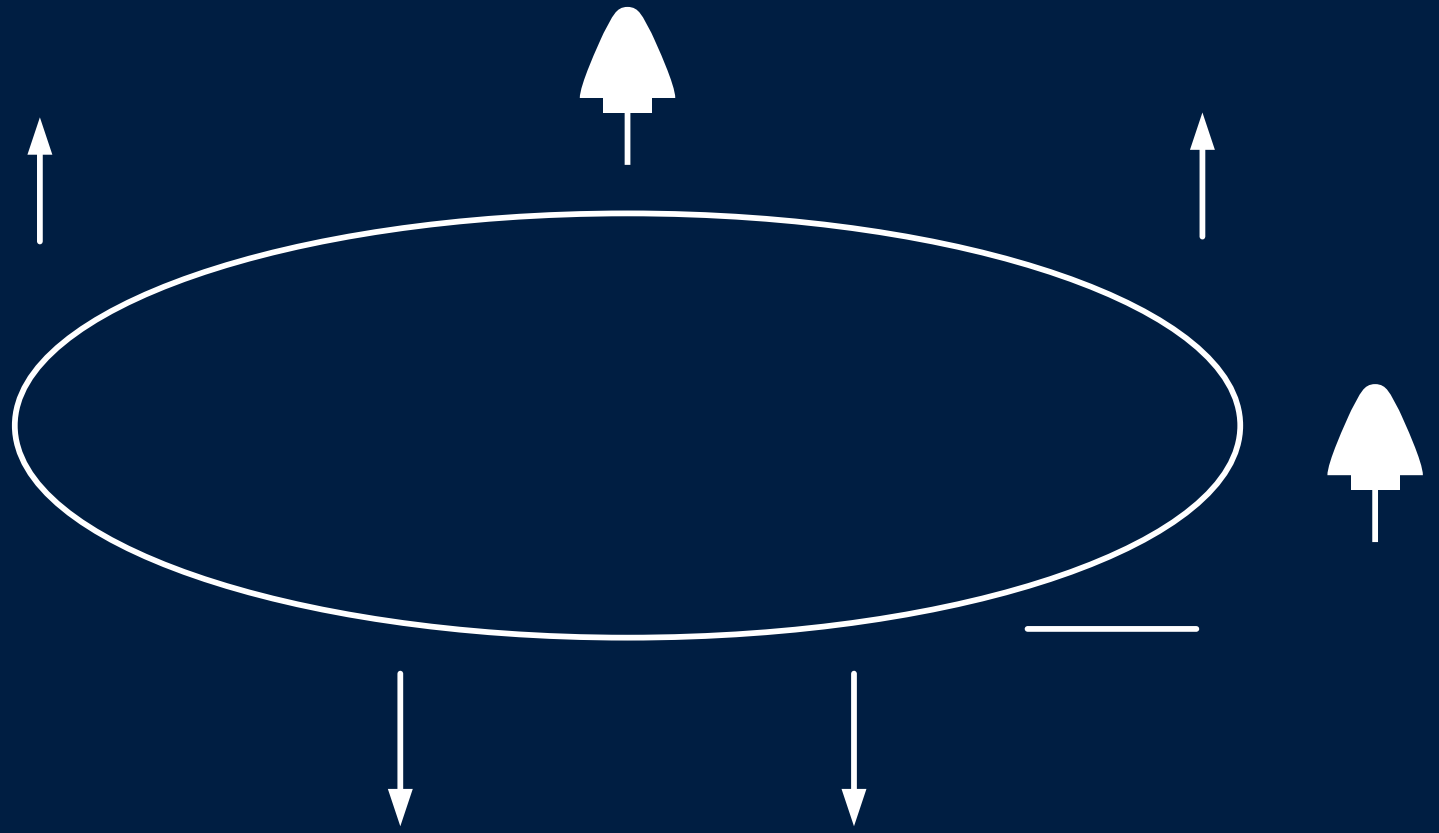


- Receive signals from two satellite constellations
- Verify pulses per second, date and time, and location

Redundant Clocks

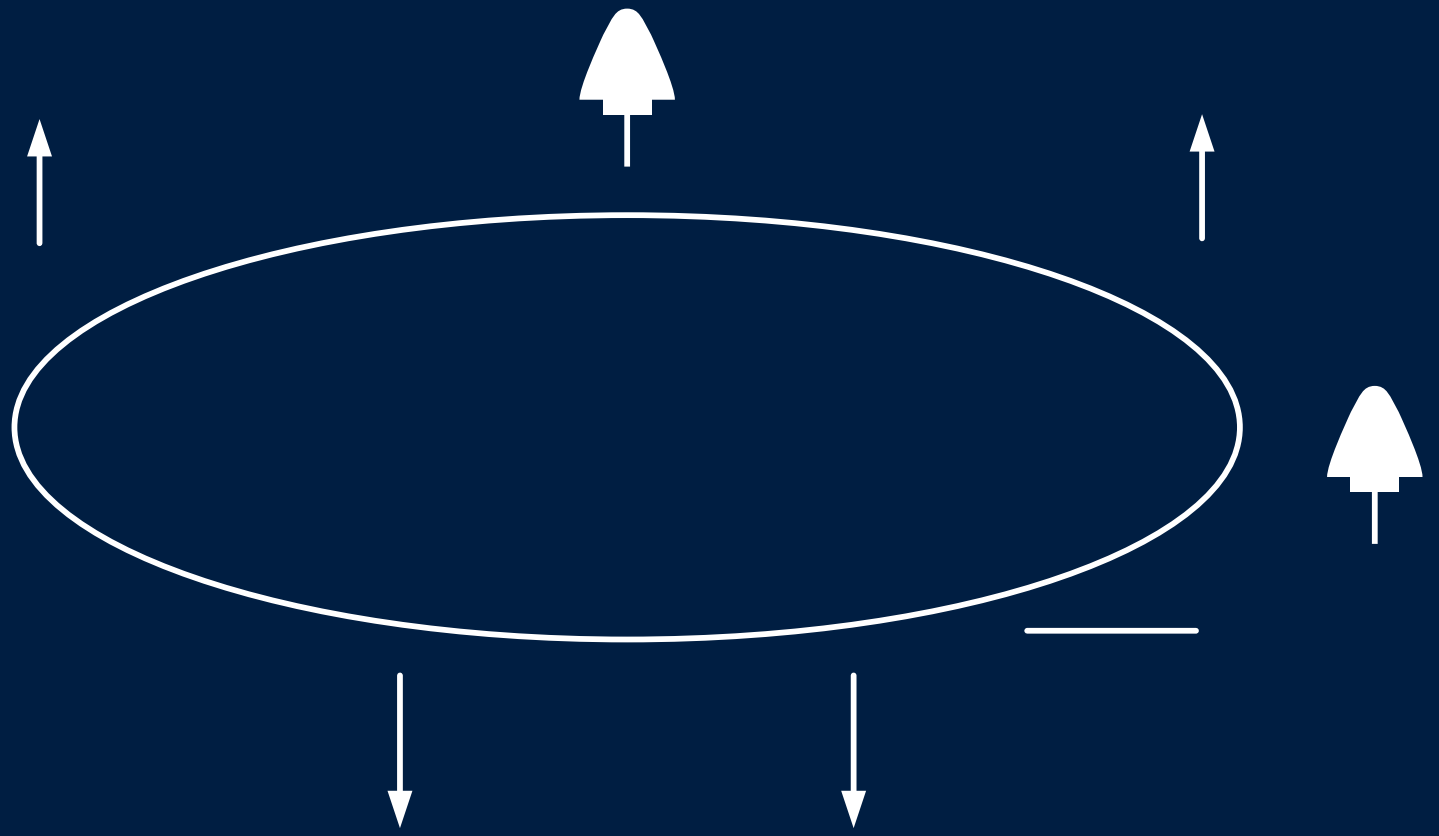
Signals are received by GPS clocks that are installed in different locations

Wide-Area Time Distribution
Using Synchronous Optical Networks (SONETs)

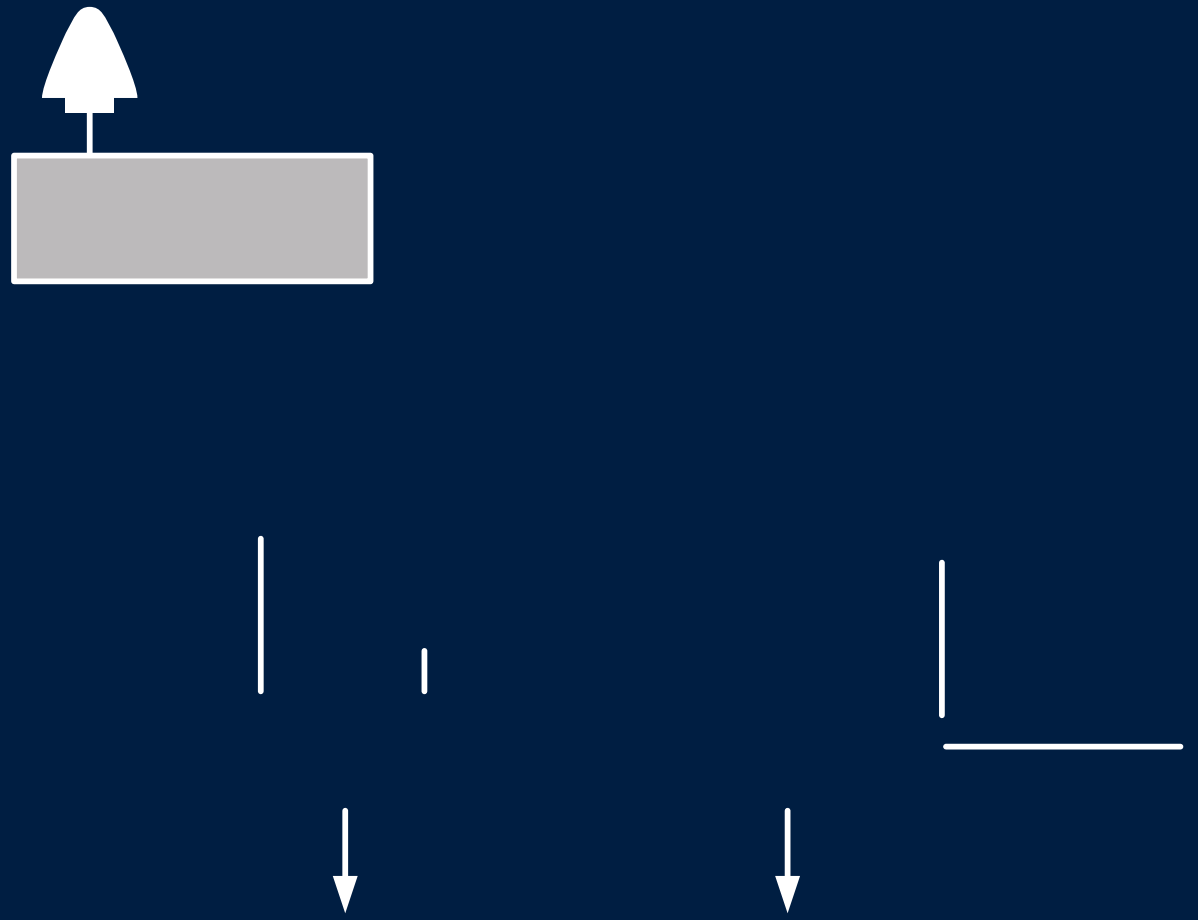


Wide-Area Time Distribution

Mitigates Local Vulnerabilities

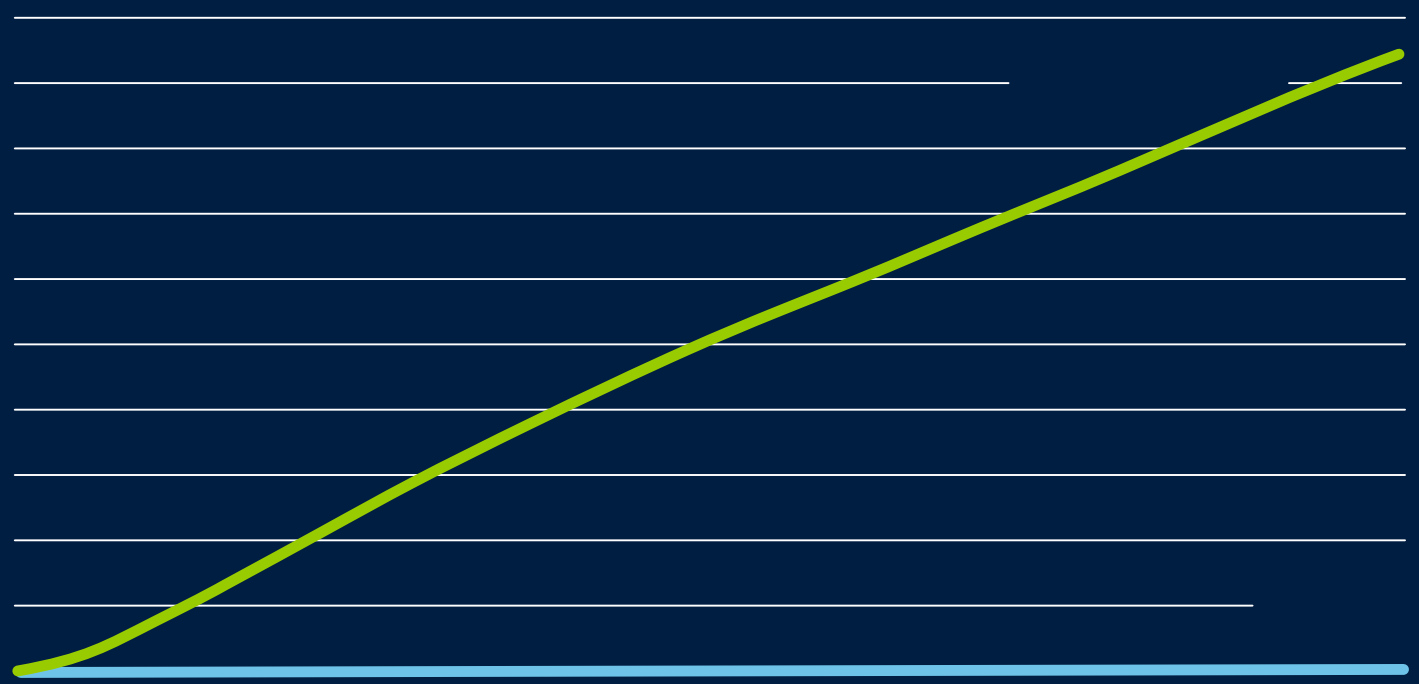


Wide-Area Time Distribution
Using IEEE 1588 Precision Time Protocol (PTP)



Holdover Is Significant for Synchrophasors

Oscillator Comparison

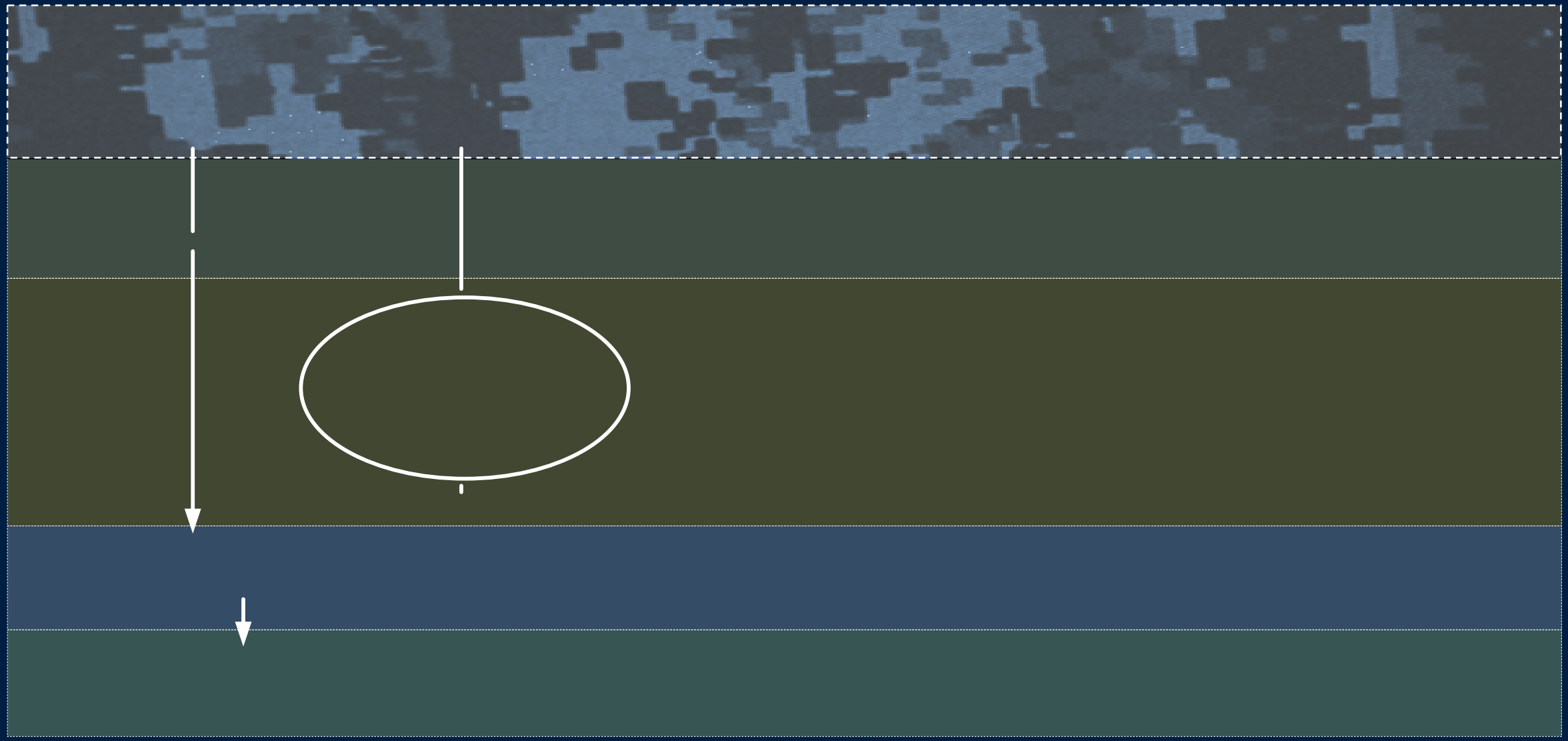


Cesium or Rubidium oscillators can be even more accurate

Rugged Equipment

- Antennas are **most vulnerable** part of any GNSS timing system, so look for antennas that
  - Are manufactured in quality environments
  - Meet rigorous standards for surge and weather resistance (IEC 61000 and IP68)
- Look for clocks and communications products that meet substation standards (IEEE 1613)

Layered Approach to Time Integrity



Questions?