

The Changing Landscape of Time Scale Systems



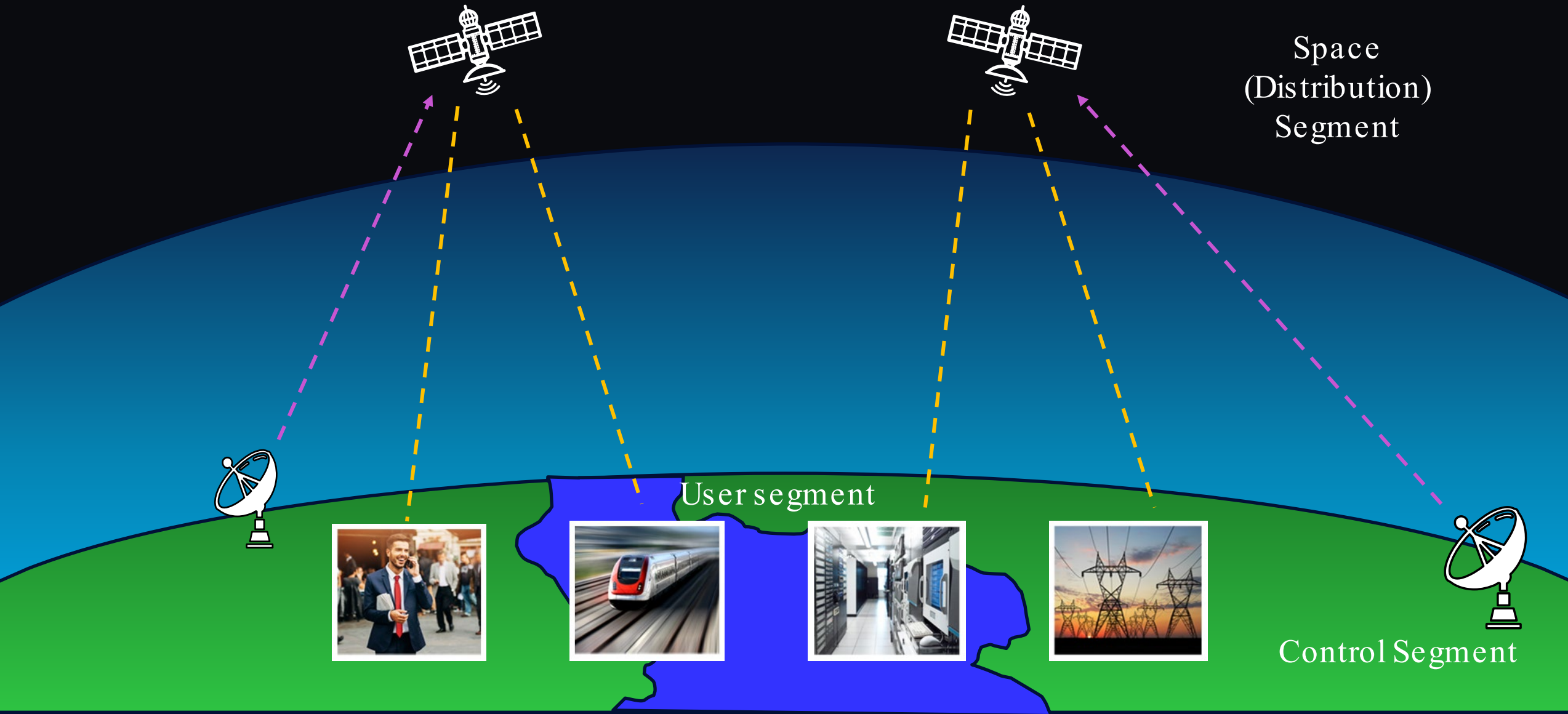
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Keila Mohan, Danielle Kravits

GNSS Vulnerabilities



GNSS Vulnerabilities

Let's Learn From GNSS History

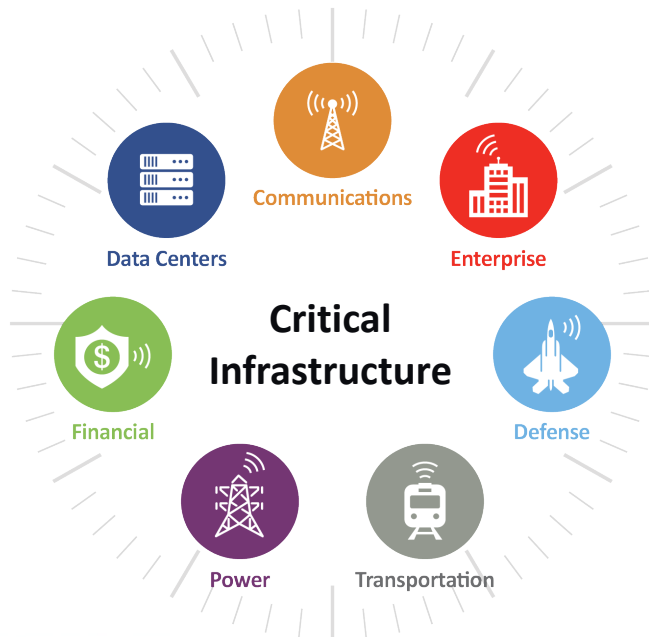
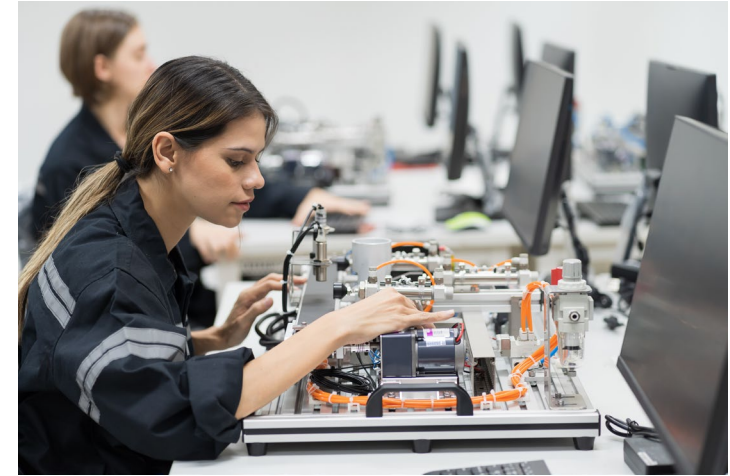
- **GNSS model: control, space (distribution), user segments**
 - Jamming, spoofing, meaconing
- **Progress to improve the resilience of the user segment**
 - IEEE® P-1952 standard
- **Path to greater resilience should address all three segments**

Growing Interest in Time Scale Systems

Let's learn from GNSS history

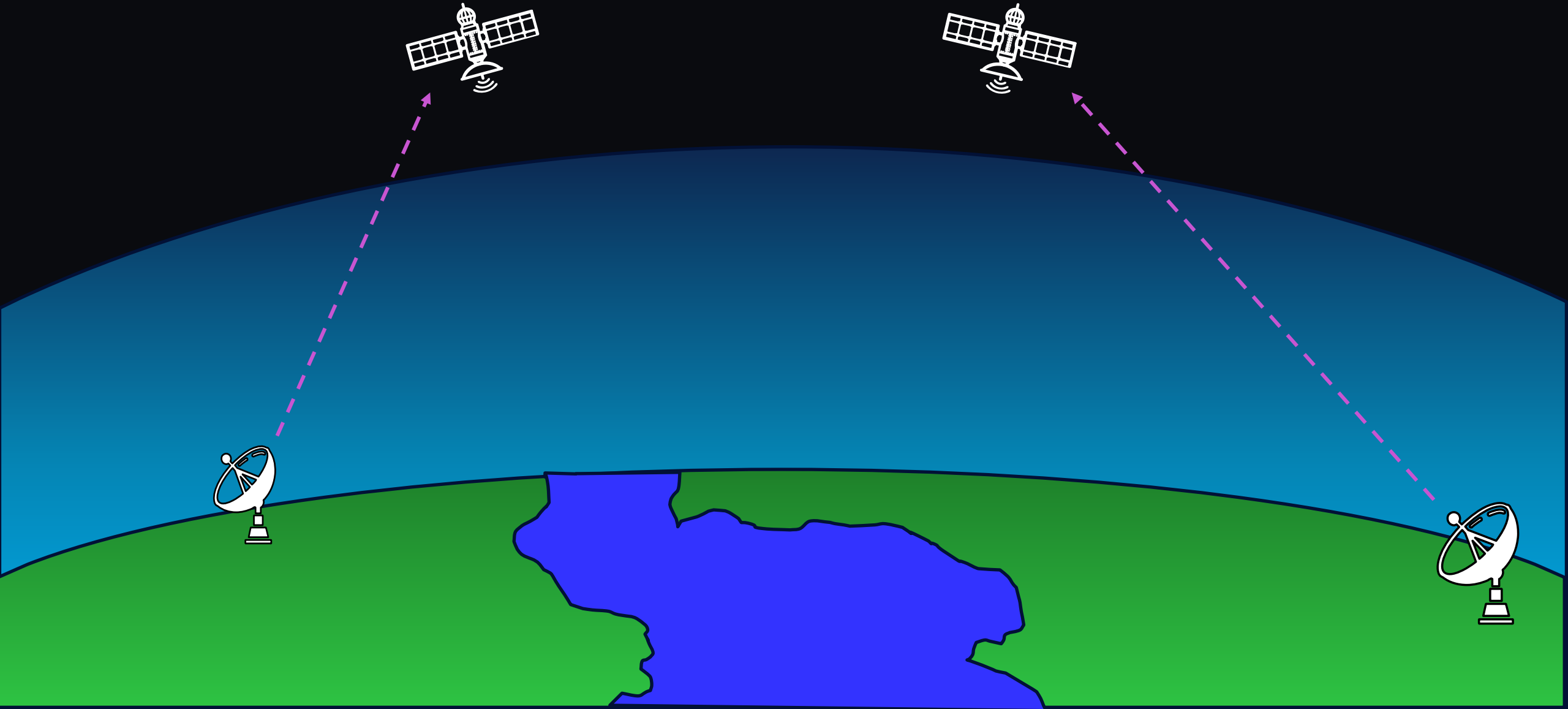
From metrology labs to:

- **Country governments**
- **Militaries**
- **Research institutions and universities**



Control Segment: GNSS

Ground stations

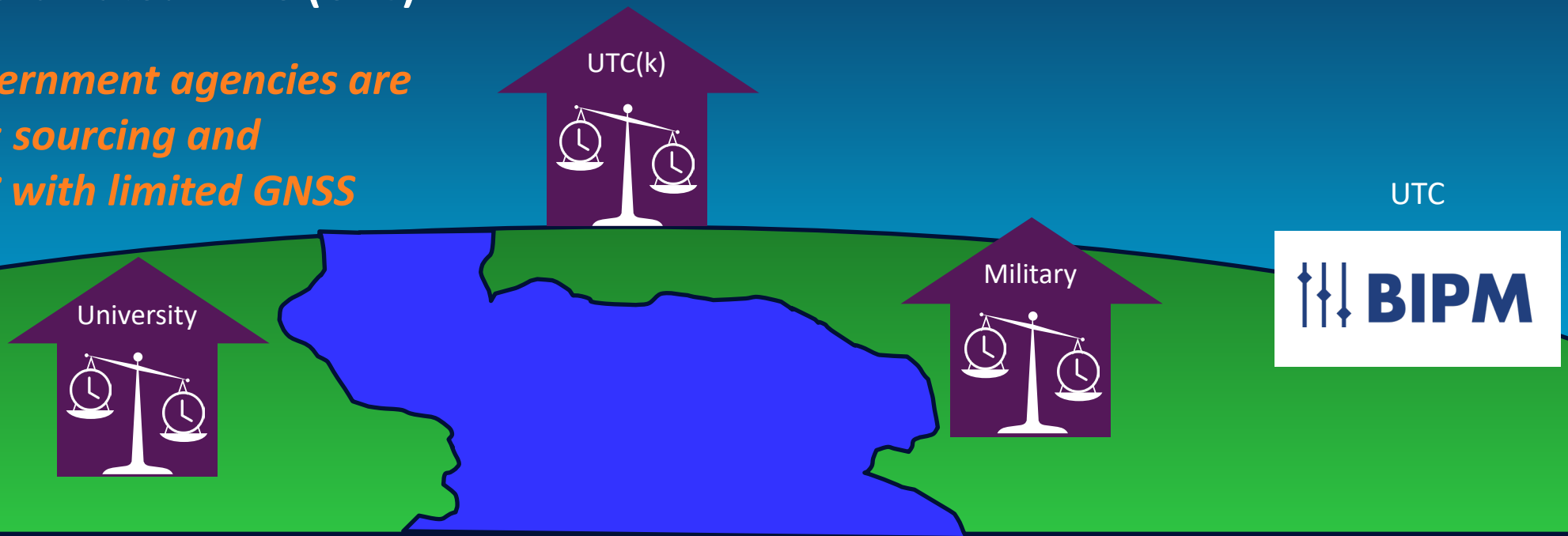


Control Segment: International Timing Infrastructure

Time scales connected to BIPM's UTC

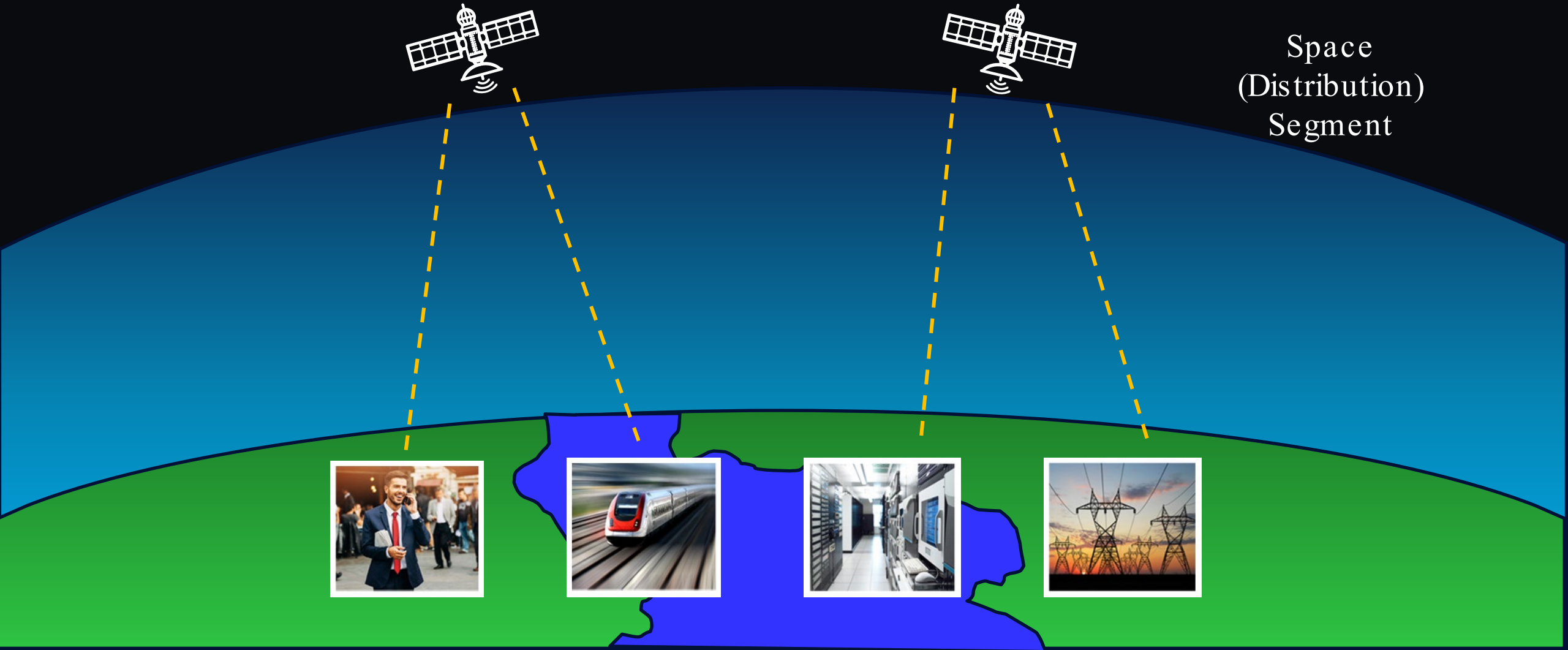
- Threats to GNSS has created the need for an alternative way to source UTC time
- The Bureau International des Poids et Mesures (BIPM) is responsible for Universal Coordinated Time (UTC)

Civilian and government agencies are moving towards sourcing and distributing UTC with limited GNSS dependency



Space (Distribution) Segment: GNSS

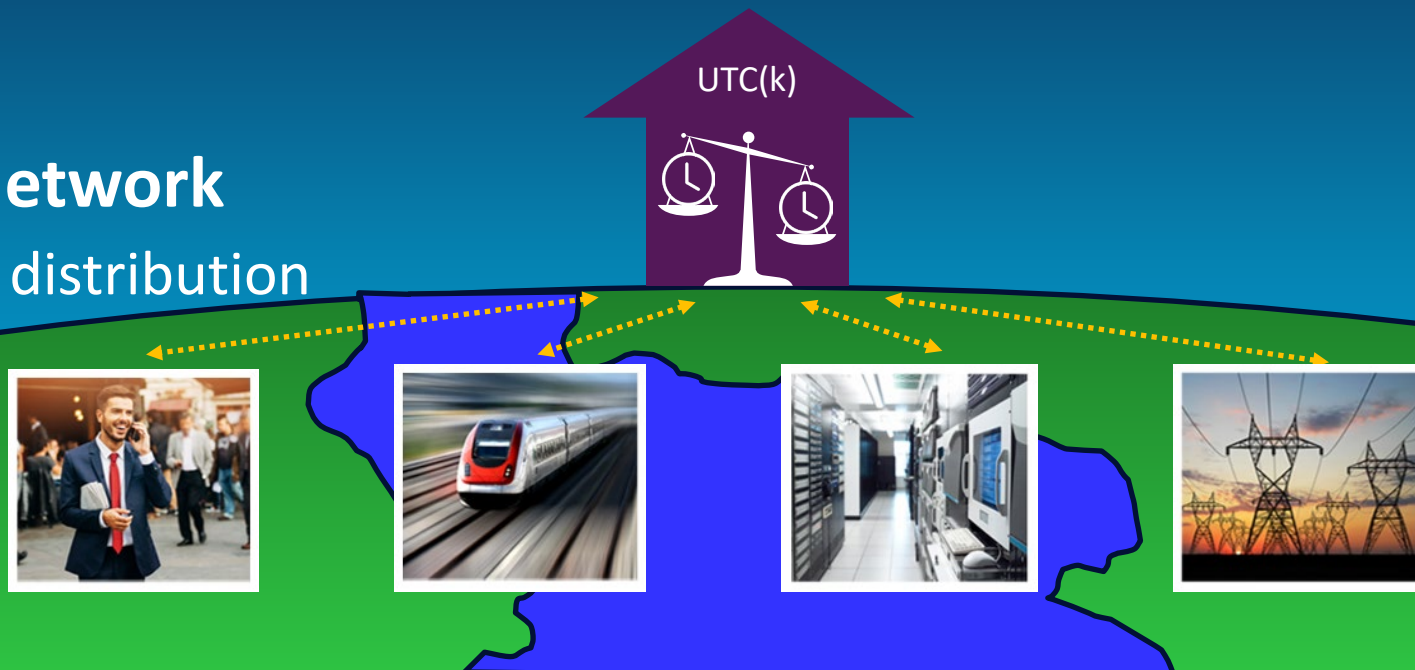
Satellites



Space (Distribution) Segment: Not Always in Space

Multiple Forms of Time Dissemination

- **Space**
 - GNSS
 - Iridium
 - Other Low Earth Orbit (LEO)
- **Terrestrial RF**
 - eLoran
 - Radio
- **Terrestrial Network**
 - Fiber-based distribution





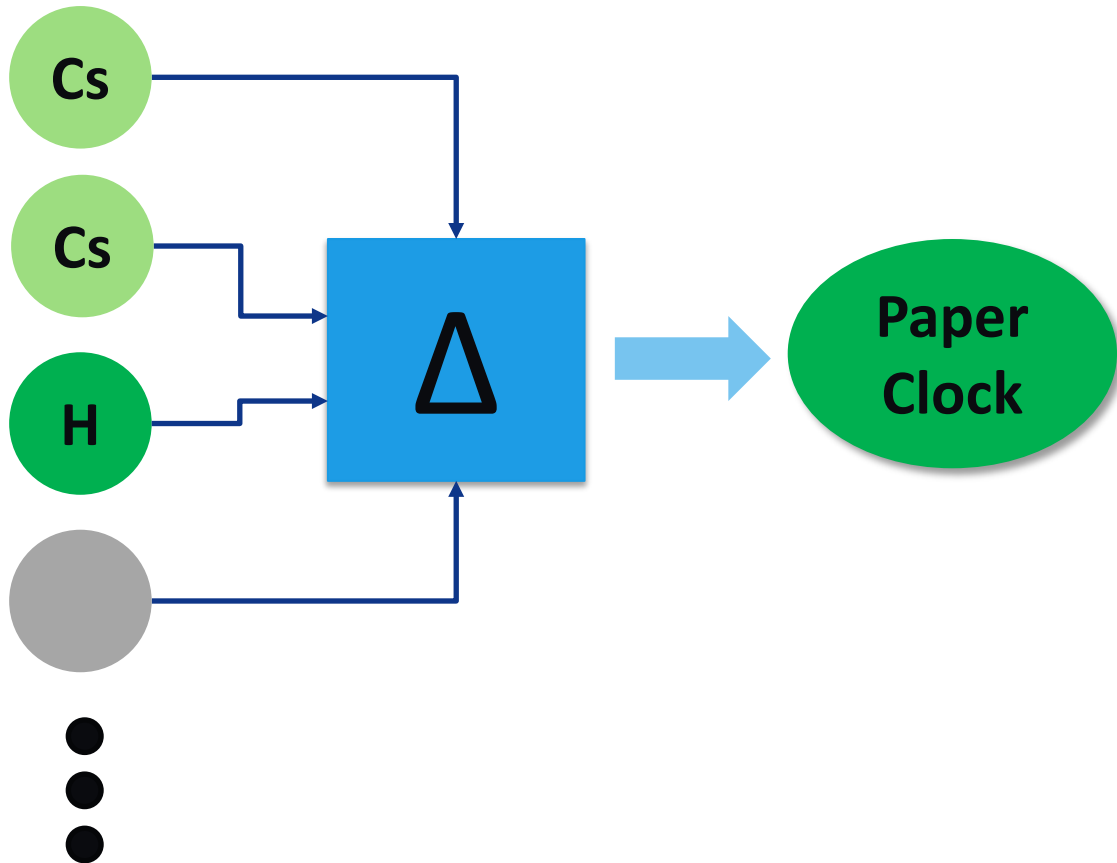
UTC(k)



Basic Time Scale Architecture

Many Physical Clocks → One Time Scale

Physical Clocks



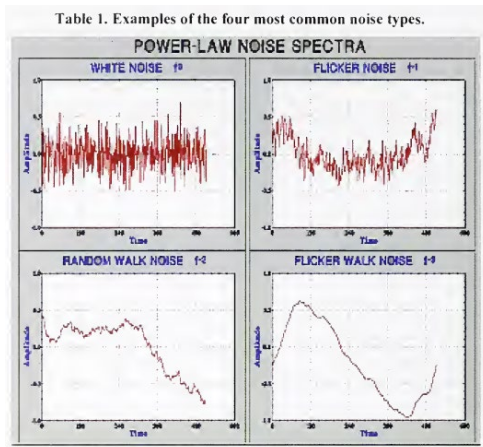
- Each clock is measured against each other, forming clock pairs
- Clock pair measurements are used to generate a 'paper clock'
 - Superior in accuracy and stability to any of the individual clocks
- 'Paper clock' is mathematically constructed

Basic Time Scale Architecture

Two Types of Weighting

Noise-process Weighting

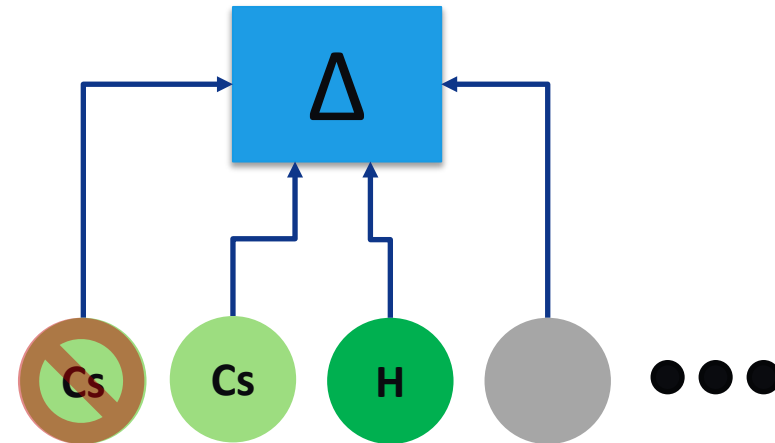
- Characterize the noise profile of different atomic clocks
- Weight the contribution of different clocks based on short-, mid-, and long-term noise profile



Clock-pair Weighting

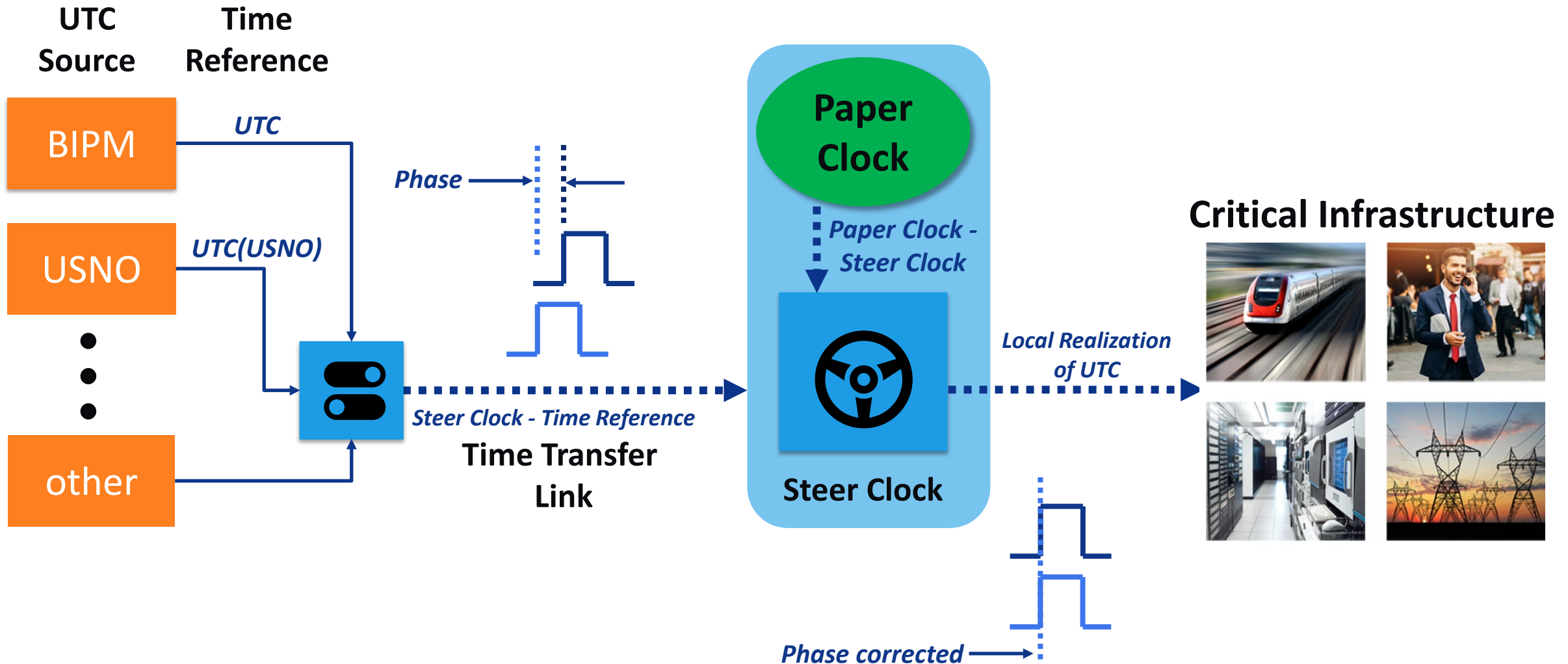
De-weight clocks affected by:

- Phase steps
- Measurement errors
- Clock failure

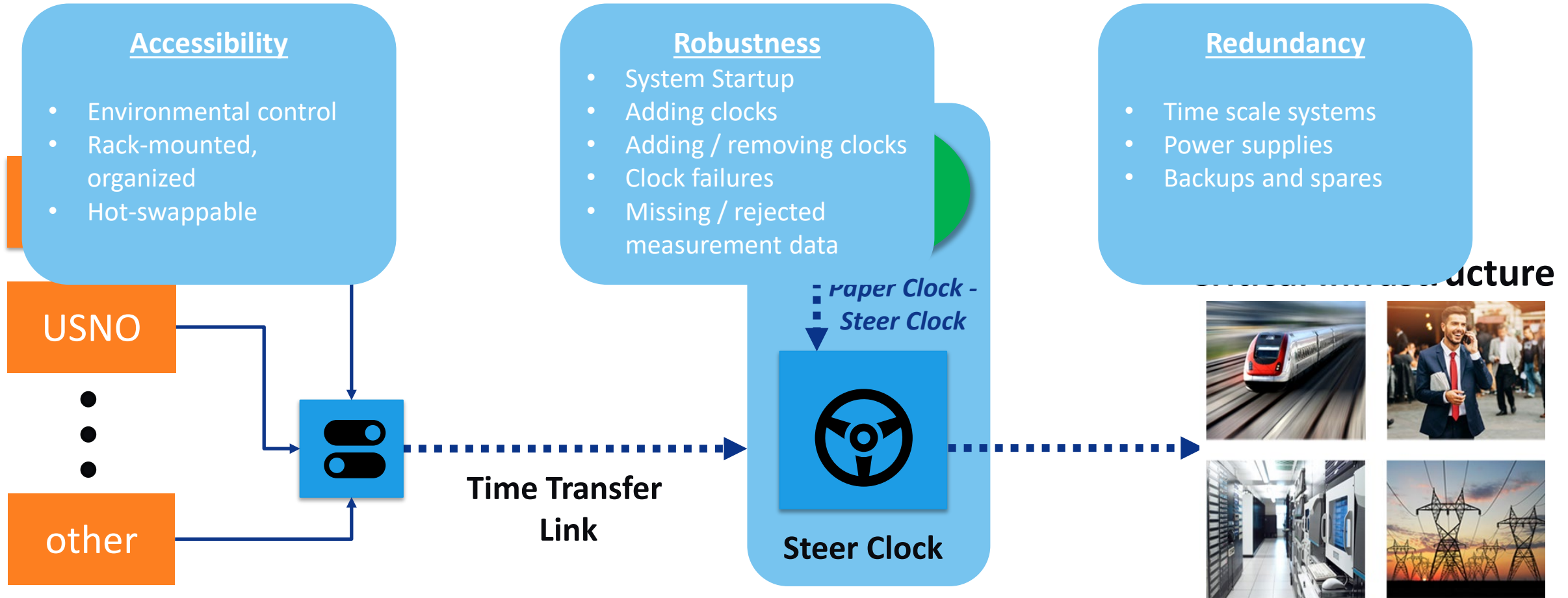


Basic Time Scale Architecture

Steering to Selected Time Reference



Best Practices for Time Scale Systems



Summary

- **Coordinated Universal Time (UTC)**
 - Time scale systems have traditionally been used as instruments reserved for scientific measurements performed by metrology labs
- **Time scale function**
 - With today's clock technologies, it's possible to maintain traceability to UTC without dependency on GNSS
- **Time scale considerations**
 - When constructing a time scale system, consideration should be given to both performance and practical characteristics if the goal is to serve national critical infrastructure
 - With the global threat of GNSS vulnerability on the rise, the role of a country's national time scale is changing from being a scientific measurement instrument to a vital part of a country's critical infrastructure

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Thank you