Resilience of APNT systems compared with traditional PNT systems

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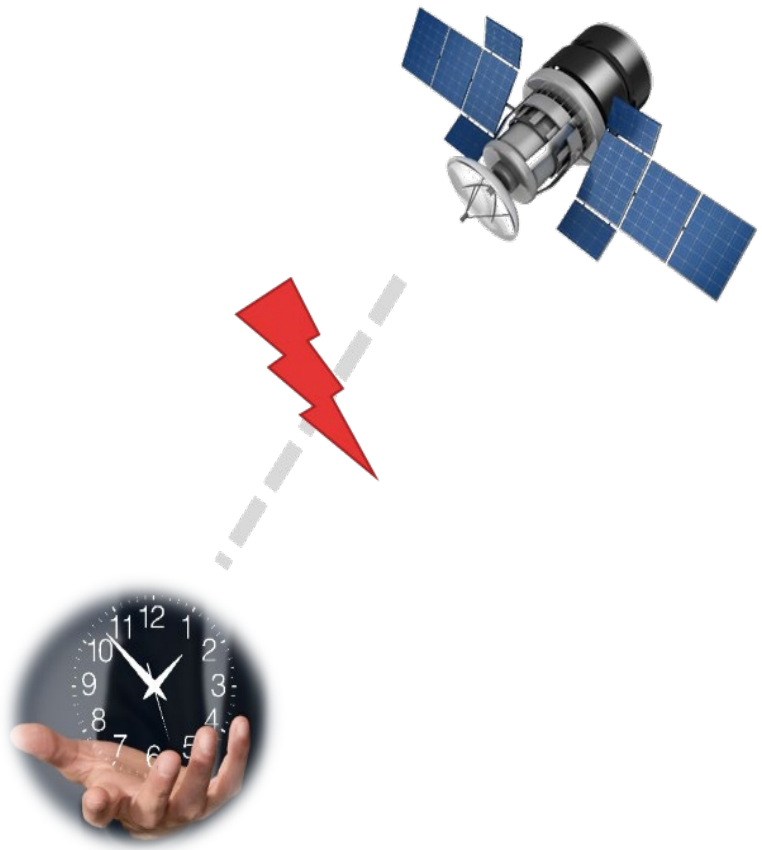
Precise time source – Global Navigation Satellite System (GNSS)



- Maintains highly accurate UTC for PNT
  (Position, Navigation and Timing)
- Free for everyone – victim of its own success
- Mcode Military Receiver (US warfighter and Allies)
- Critical infrastructure will not scale with ever increasing amount of GNSS Antennas
- Vulnerable source, weak signal – need alternative

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What are the PNT cyberthreats & GNSS vulnerabilities?

PNT cyberthreats

External GPS/GNSS level

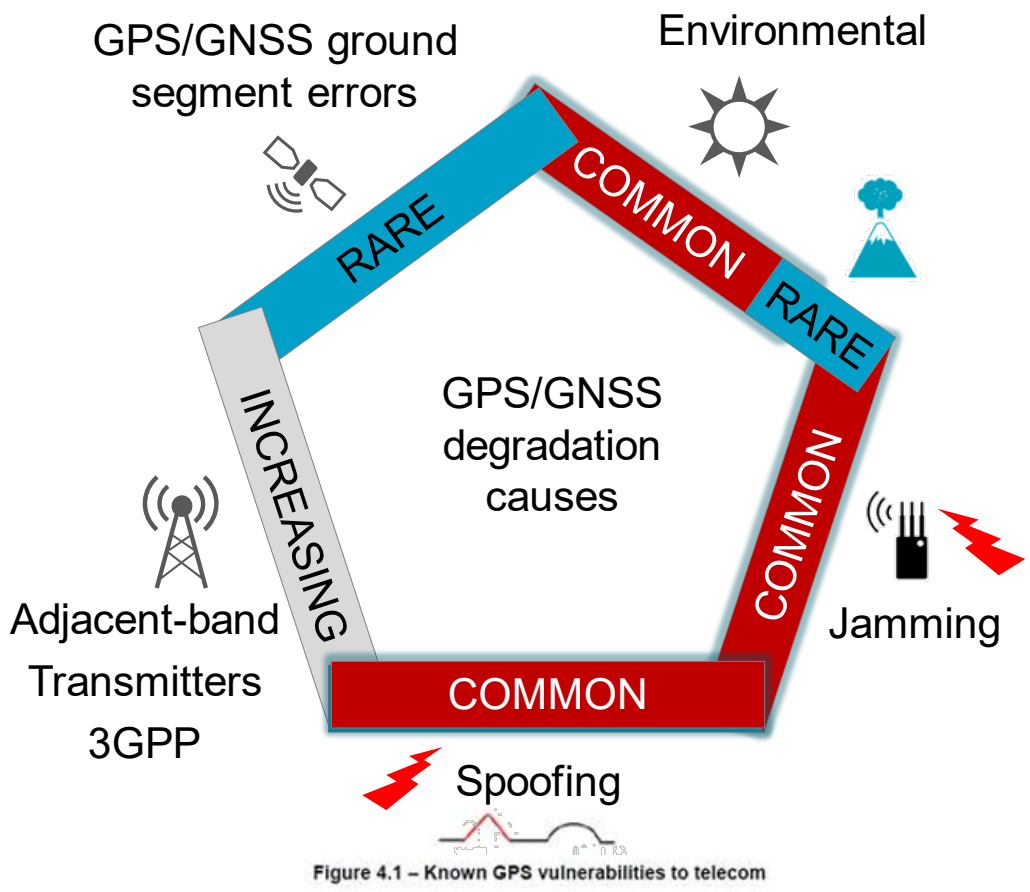
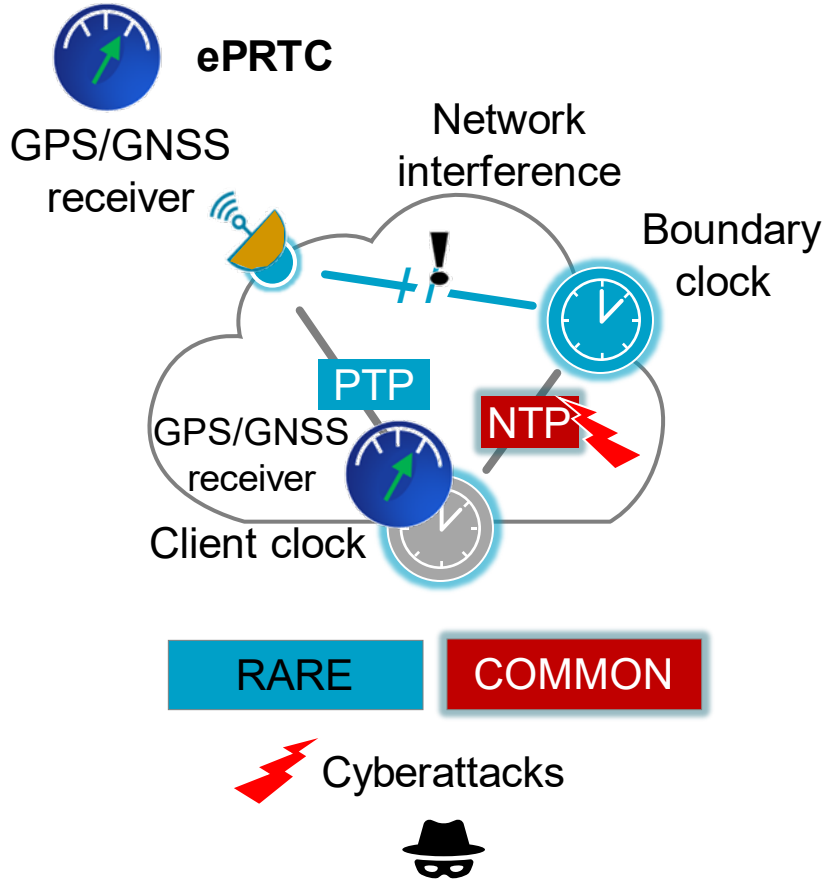


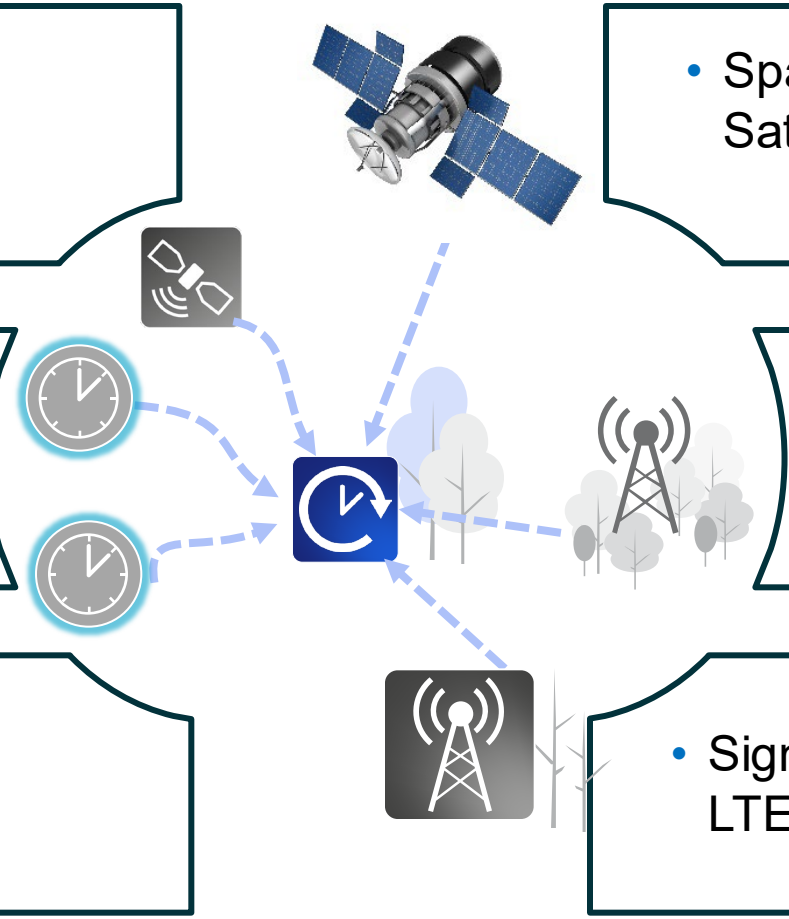
Figure 4.1 – Known GPS vulnerabilities to telecom

Internal network level



What are alternative PNT sources?

- GPS/GNSS is not the only source of PNT
- Focus is resiliency and zero trust
- Complimentary source NOT replacement



- Space based PNT (GPS/GNSS, Satelles, Xona, TWSTFT)
- Non-Space-Based PNT & User Equipment (eLORAN, NextNav, Locata, cesium clocks)
- Signals of Opportunity (WiFi, LTE/4G, 5G, Broadcast)

****List of examples is not exhaustive*

Additional measures must be taken for resiliency

Securing a resilient future - $1B/day at a time

As Threats in Space Mount, U.S. Lags in Protecting Key Services

GPS has become essential for modern life, but its satellites and signals are vulnerable to attack. China is years ahead in developing alternatives.

NY Times, March 2024

Senior US official warns of security threat amid reports of Russian nuclear capability in space

The Guardian, Feb 2024

Russia is starting to make its superiority in electronic warfare count – The Economist

by Editor | Nov 27, 2023 | Blog

Electronic Warfare Confounds Civilian Pilots, Far From Any Battlefield – NY Times

by Editor | Nov 23, 2023 | Blog

The Russians Installed A GPS-Jammer In Ukraine. The Ukrainians Blew It Up – With A GPS-Guided Bomb: Forbes

by Editor | Nov 1, 2023 | Blog

Additional measures must be taken for resiliency

Space based alternatives for resilient PNT

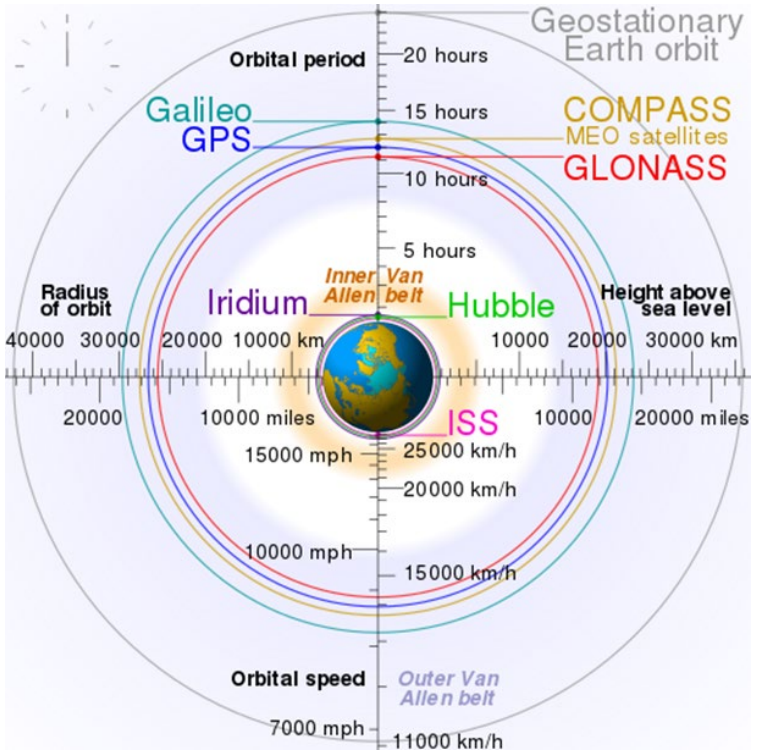
Galileo PNT service options

- Open service for public use, 30 satellites in use
- Positional accuracy is better than GPS 1 meter vs 3 meters
- Timing accuracy is 25ns

Xona

- 1 Satellite operates,
- 2nd is scheduled, 250-300 total
- Integration with existing receivers

DEMO



Satelles/Iridium LEO PNT alternative to GPS

- Satellite Time and Location signals operate indoors
- STL are transmitted from Iridium's 66 LEO PNT, signal is 1,000x stronger
- STL Service is available globally and is not dependent in GNSS
- Dual band antenna for GPS/STL
- Timing stability compared to GPS per NIST study, Traceable to UTC(NIST/USNO)

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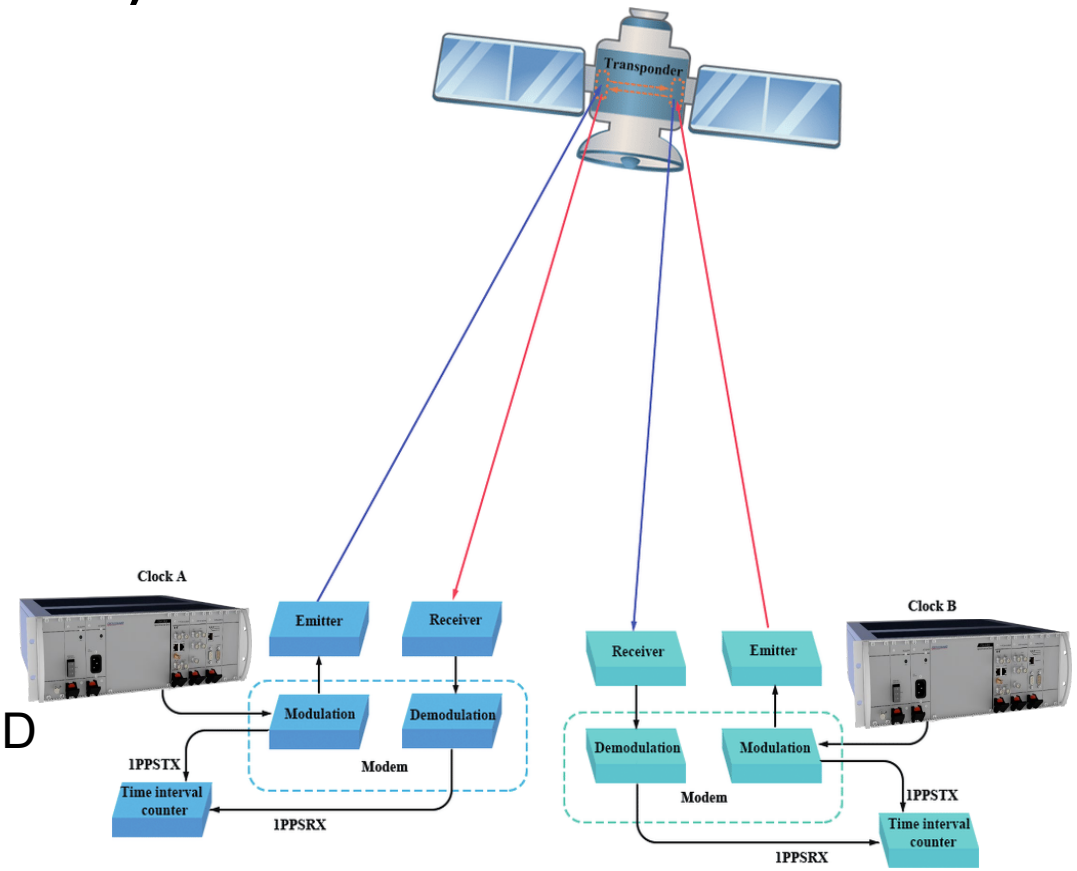
Space based alternatives for resilient PNT

Two Way Satellite Time & Frequency Transfer (TWSTFT)

- Method used to compare the time and frequency of clocks or oscillators at different locations
- Signal Transmission/Satellite Relay/Signal Reception/Delay Correction
- Implemented and adopted by NIST & BIPM
- TWSTFT achieved better than 1ns stability over 24hr period
- Availability and implementation on a larger scale is reduced due to complexity and cost (satellite time)
- Commercial implementation is limited but major defense DOD contractors are working on space based TWTT and modem technology



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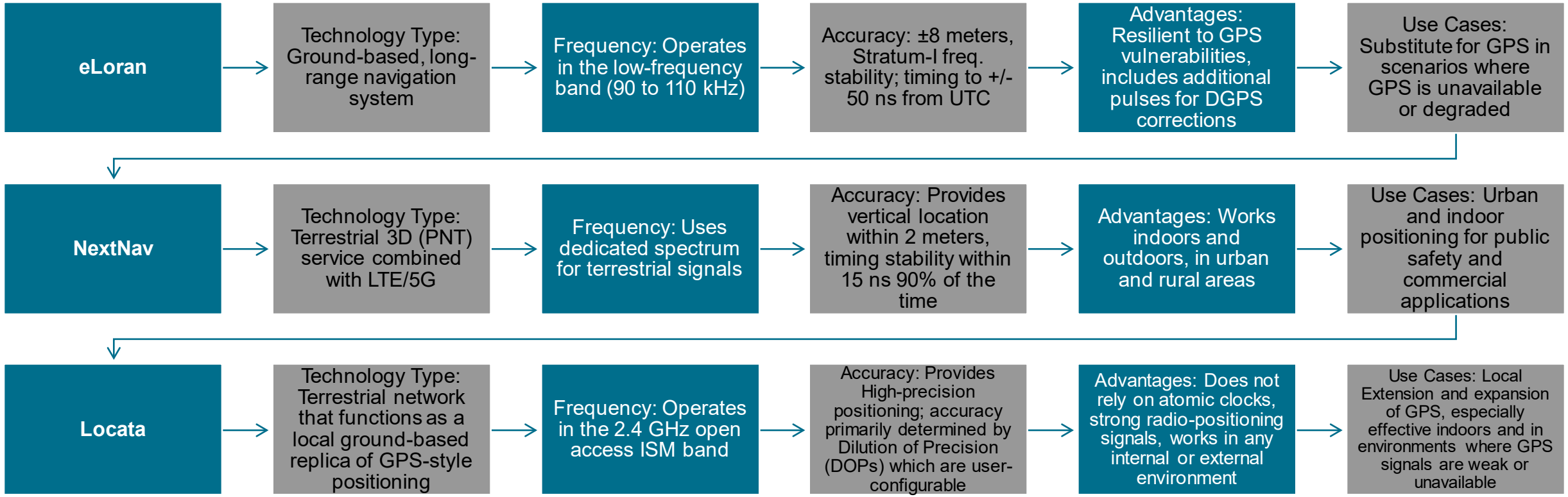
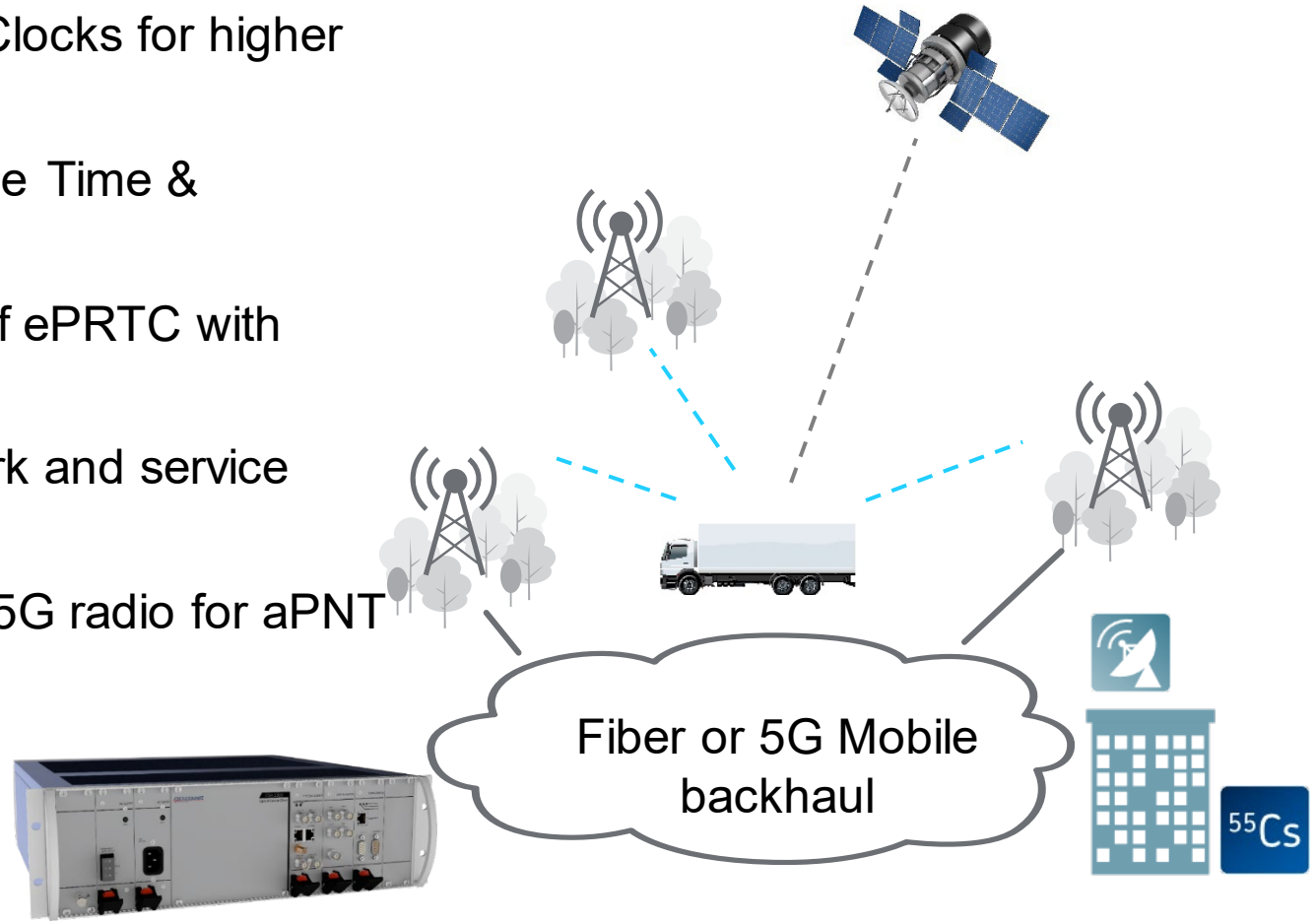
Non-Space Based Alternatives for resilient PNT



Relies on ground-based infrastructure investment

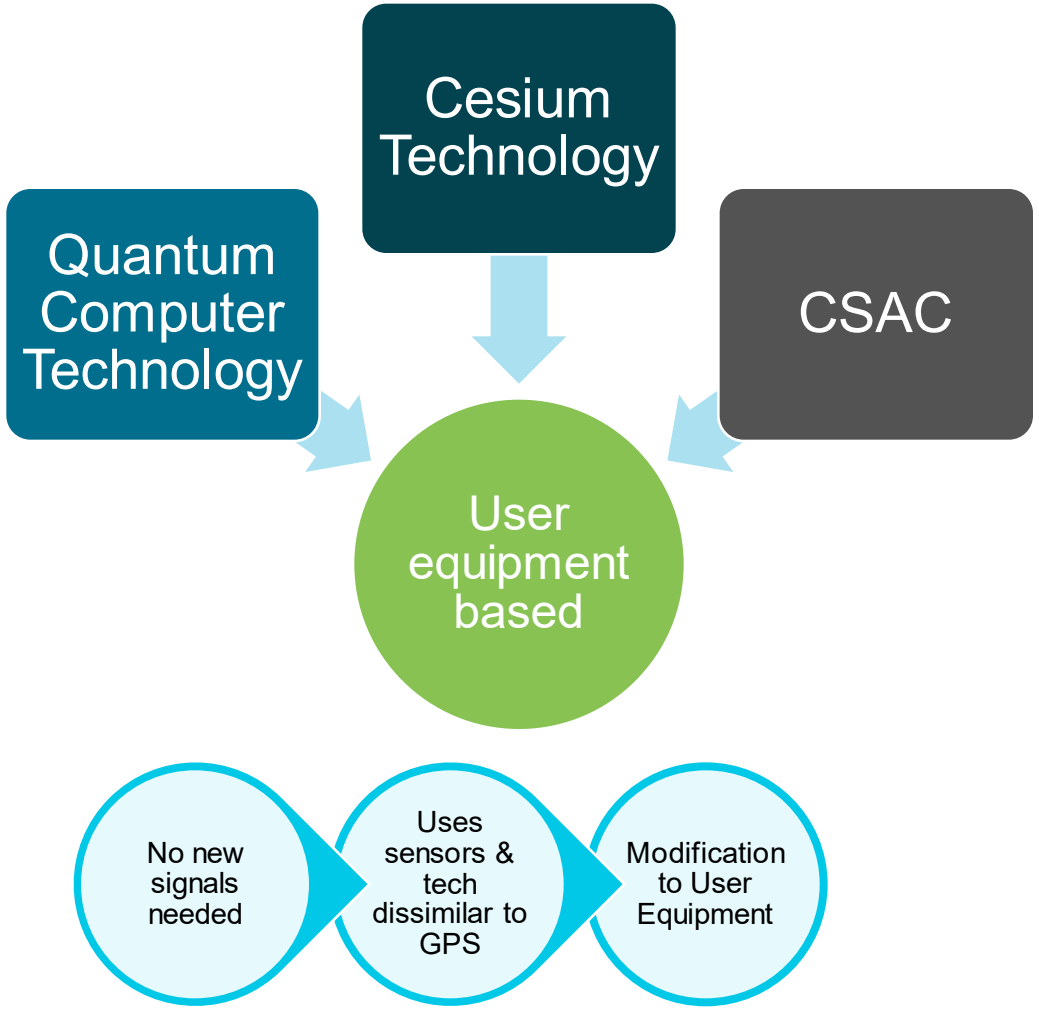
Ingredients of a terrestrial APNT timing network

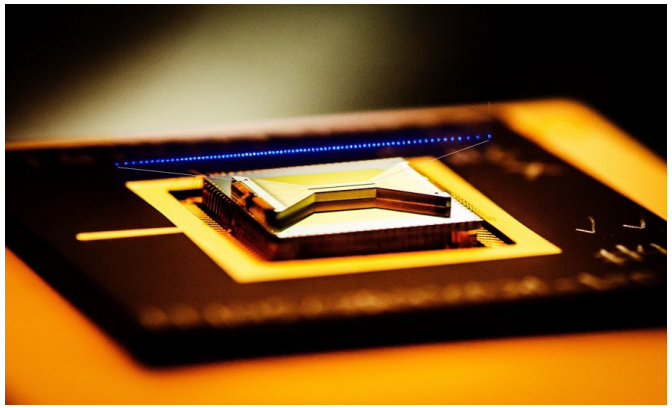
- Highly accurate and stable Cesium Atomic Clocks for higher performance and longer protection
- Optical transport infrastructure to disseminate Time & Frequency securely
- Resiliency by operating multiple instances of ePRTC with Autonomous Atomic clocks
- Management Systems to monitor the network and service layer
- Enabling the mobile edge, datacenters and 5G radio for aPNT



PNT service from multiple sources

Non-Space Based User Equipment Alternatives for Resilient PNT





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Optically Pumped Cesium Atomic Clock

75 YEARS TIMING EXCELLENCE

GPS/ Mcode

GNSS antenna

Optical Cesium clock

PTP Grandmaster

aPNT+™

GNSS/M-code receiver ●

Optical Cesium clock backup

Zero-Trust multisource validator + combiner ●

Other backup sources

PTP / NIST/ eLoran / LEO PNT

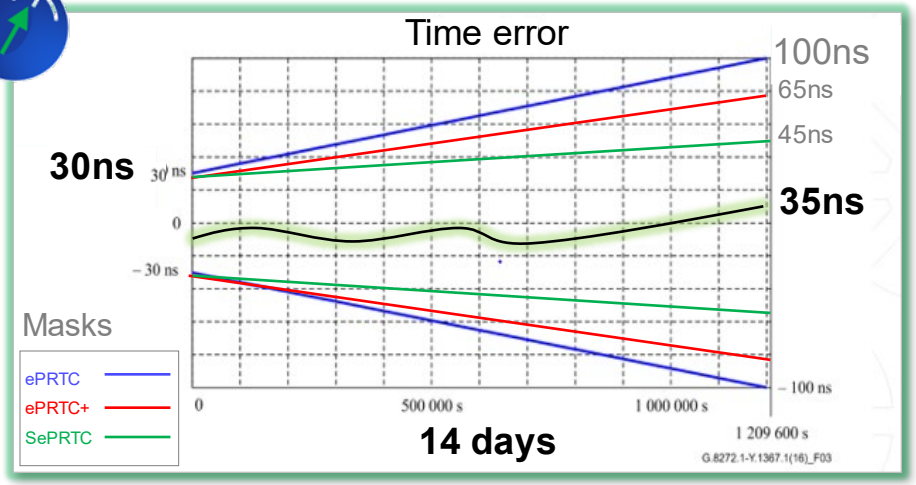
Grandmaster time server

BITS
10 MHz
SyncE
PTP/NTP
IRIG
PPS
PPS+TOD

ePRTC (G.8272.1)
(functional diagram)

● GPS receiver and Zero-trust multisource validator + combiner are integrated into the Grandmaster

Short-term GNSS backup holdover performance



Long-term GNSS backup holdover performance

Time/Phase holdover if GPS goes down

SePRTC*: 100ns over typ. 55 days
1µs over typ. 4 months
SePRTC+:100nsec over typ. 100 days

ePRTC Cesium solution

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Signals of Opportunity (SoOPs)

- Can use mix of signals space based or ground based (TV broadcast stations, radio, WiFi (no time transfer), 5G, communication satellites). These signals are there for other reasons than navigation and time transfer
- Signals can penetrate indoors 10-to-100-meter accuracy is possible. BPS (Broadcast Positioning Service) is capable of 100ns 95% of the time & 100m average accuracy
- Existing RF signals not intended primarily for navigation, may or may not get time. Navsys created software algorythm with signal fusion using SoOPs
- Coverage might not exist everywhere, rollout is expensive
- Cyber issues will persist, challenging reliability and accuracy req-s as signals were not designed for PNT

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Conclusions

Alternative PNT Solutions depend on each application: technologies and sources will vary

Awareness is key!

Reliability and Accuracy will also matter

Availability and Cost will have impact

“RESILIENCE” means to withstand and adjust to challenges

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Thank you

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