High-Performance and Resilient PNT (Position, Navigation & Timing)

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Who Is Satelles?

Satelles Business Overview

Satelles is a U.S. company that provides an alternative to GPS/GNSS for global network time synchronization that is:

Delivered by Low Earth Orbit (LEO) satellites,

Resilient to GPS/GNSS outages,

Works indoors where GPS/GNSS does not, and

Provides a secure backup for critical infrastructure.

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Satelles at a Glance

Satelles provides the only global time and location service available today that augments GPS/GNSS and addresses some of the limitations of these systems

66

LEO satellites

via exclusive partnership with Iridium

40+

patents

70+

employees

World-renowned GPS experts from leading companies and academic institutions:

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What Makes Our STL Technology Unique?

L Band!
(Most mega LEOs are small sats in K Band)

Powerful Signal

STL's high-power signals are 1,000x stronger than GPS, allowing them to penetrate indoors and underground

Proprietary Authentication

An innovative mesh architecture of 66 **cross-linked LEO satellites** forms a global network in space to ensure service everywhere

Impervious to Hacking

Timing solutions **with UTC accuracy of 50 nanoseconds;** 1-sigma with maximum error of less than 200 nanoseconds

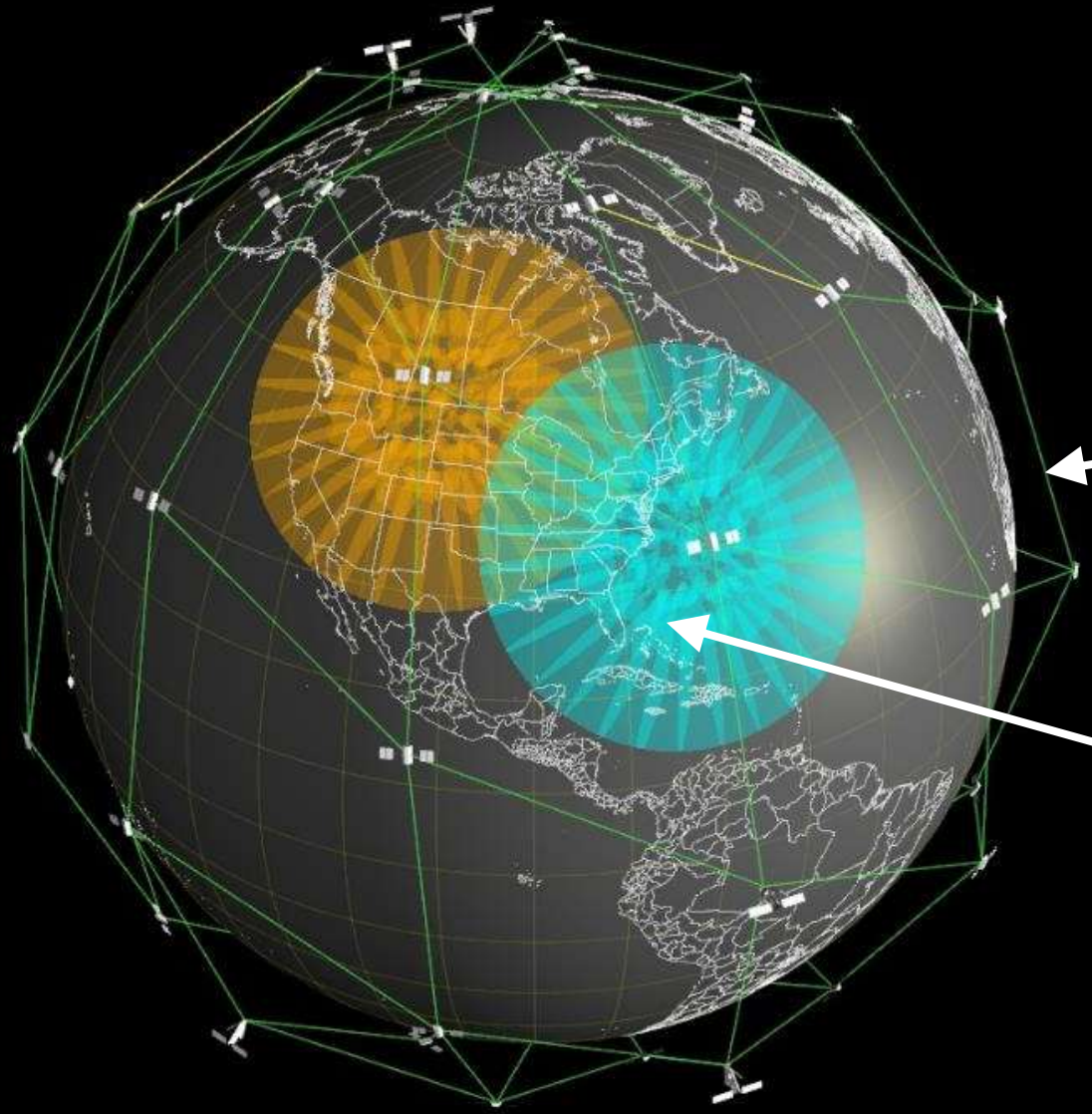
Satelles' LEO orbit benefits, combined with modern cryptographic techniques, allow Satelles to deliver **a trusted time and location service globally**

STL using
66 Iridium satellites
global coverage
485-mile altitude
1,000x closer

High-power signals from nearby LEO satellites can penetrate indoors and in places where GPS does not reach

24 GPS satellites
global coverage
12,550-mile altitude
25x farther away

Resilient Architecture

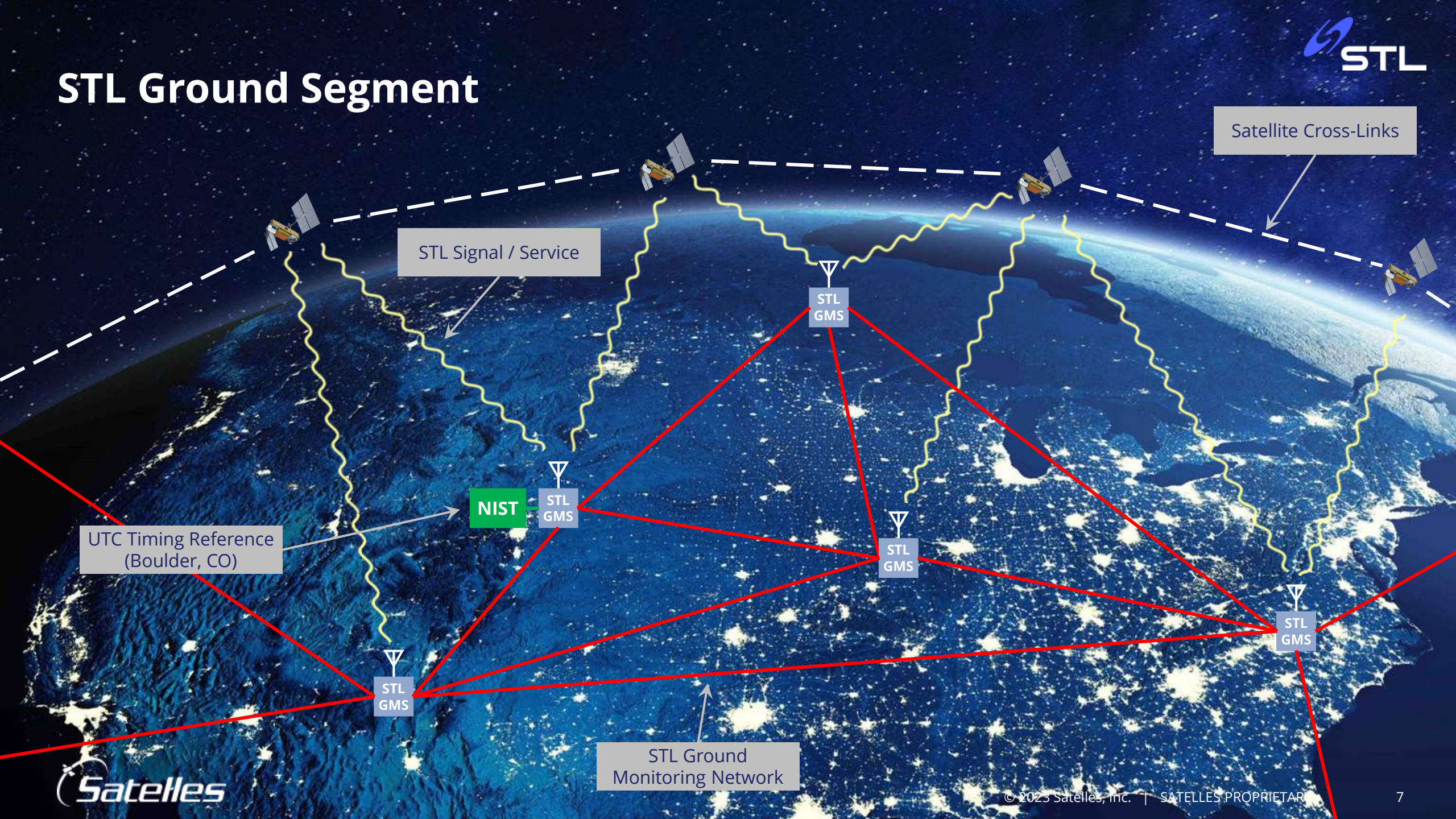


STL is secure because the signal is **unpredictable in advance** — yet it is **easy to validate when received**.

Cross-links provide continuous orbit and time information on the entire constellation even when most are not in view of ground systems.

Secure, independent signals on each **spot beam** ensure high integrity and resilience (48 spot beams per satellite × 66 satellites = 3,168 spot beams globally).

STL Ground Segment



Satellite Time and Location (STL):
Alternative PNT from Low Earth Orbit

- Powerful signals
- Secure service
- Global availability
- Resilient to the loss or disruption of GPS
- Traceable to UTC(NIST) and UTC(USNO)
- Commercially available since 2016

- Timing accuracy of 20-100ns (oscillator dependent)
- Timing stability comparable to GPS — confirmed via NIST study
- Stratum 0 source for Stratum 1 PTP Grandmaster — Primary Reference Source
- Positioning accuracies of ~10 meters (33 feet)

Satelles Solves Important Problems

PNT for Critical Infrastructure

Positioning **N**avigation **T**iming

- Communication Systems
- Electrical Power Grids
- Financial Networks
- Internet of Things
- Navigation Systems
- Transportation & Logistics
- Autonomous Cars
- Autonomous Drones
- Location-based Authentication
- Location-based Advertising & Marketing

Most of these applications are essential for the proper functioning of our society, and they all use GPS for PNT… **without any back-up**

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The Need for Resilience

GPS and other GNSS are amazing, but they require an operational contingency plan for:

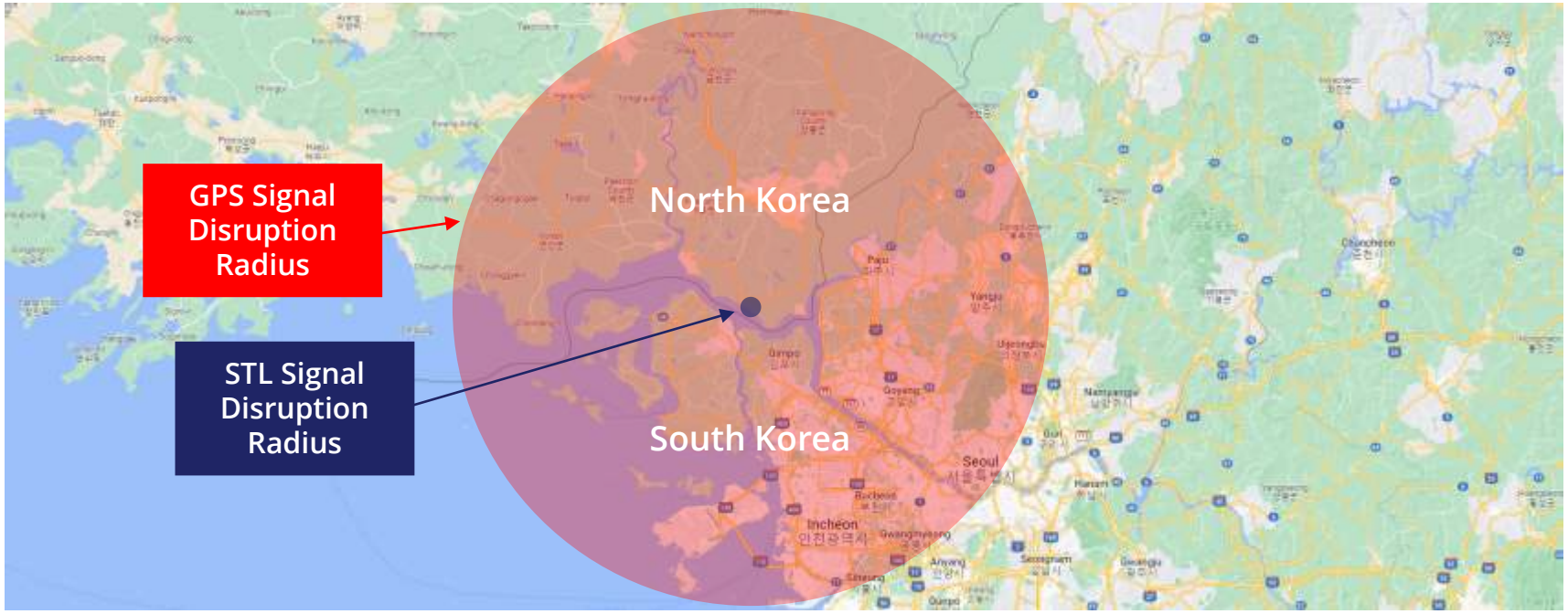
- inadvertent events
- unintended interference (such as jamming)
- deliberate attacks (such as jamming)

> **"Because of the widespread adoption of PNT services, the disruption or manipulation of these services has the potential to adversely affect the national and economic security of the United States."**

Executive Order 13905 – *Strengthening National Resilience Through Responsible Use of Positioning, Navigation, and Timing Services*

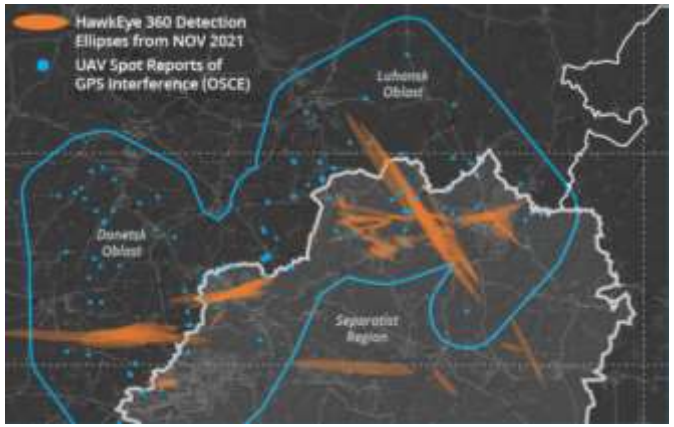
STL is Resistant to Jamming

GPS/GNSS Jamming Radius Compared to STL



Active Jamming in Europe

Ukraine Invasion



Jamming devices must be significantly closer to the desired jamming area or far more powerful to disrupt STL

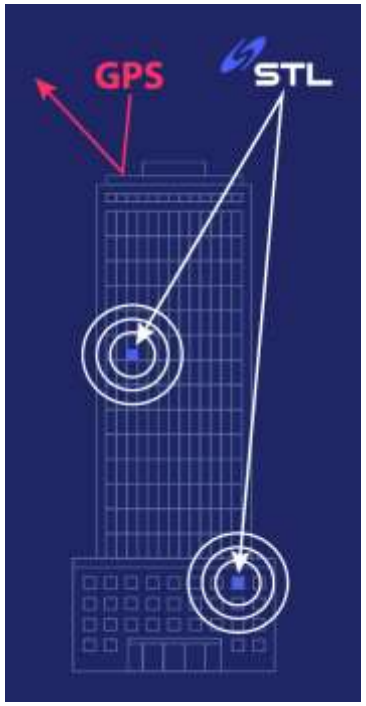
A truck driver used a cigarette lighter GPS jamming device to hide his whereabouts from his employer and caused interference at Newark Airport

Critical Infrastructure – Telecom

The 5G Synchronization Problem

5G is Moving Wireless Communications Indoors

To provide high-speed services directly to users, 5G is moving wireless communication access points (eNBs) from outdoor high power Radio Access Networks (RAN) on towers and buildings to indoor low power RAN, small cells, and femtocells on ceilings and walls



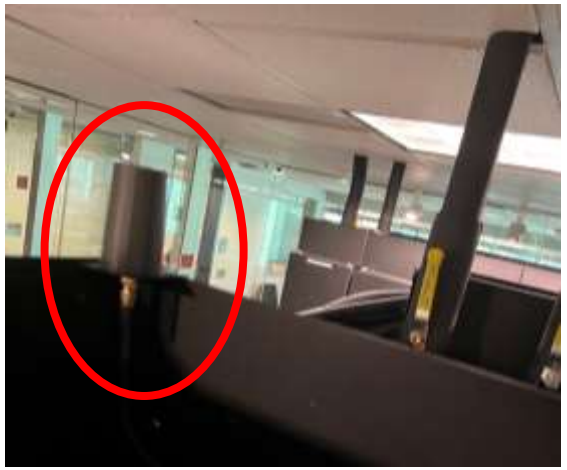
GNSS synchronization **is the most accurate method** to meet 5G timing requirements – **5G deployments are delayed while operators struggle to find alternatives to GPS/GNSS**

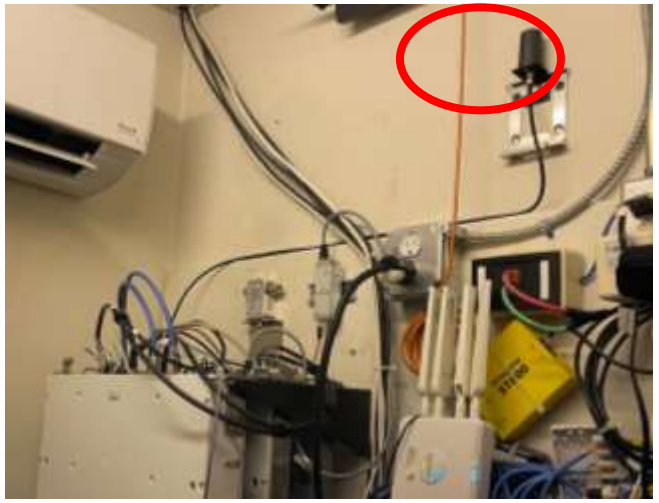
However, it works poorly or not at all in:

- **Urban canyons (limited sky view)**
- **High multipath environments (signal shredding)**
- **Indoors (excessive attenuation)**

STL: Small Antennas – Operate Indoors

STL antennas not only install and operate indoors but are significantly smaller than GPS antennas





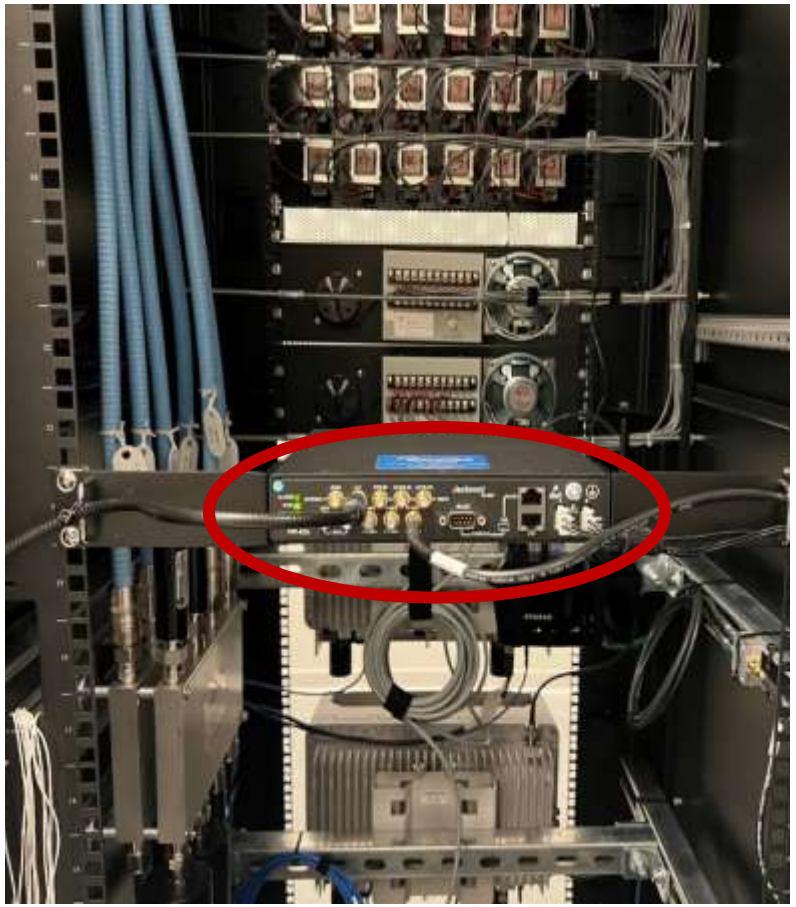
STL Equipment Form Factor — Stand Alone Receivers

Standalone receivers are small and can be rack mounted to integrate easily with 4G and 5G RAN gear.

Recent Installation Examples for 5G Operators Using Indoor Antennas

STL EXAMPLE: Urban High-Rise Building

STL receiver used to synchronize Nokia 5G Micro BTS RANs on 40th floor of office building

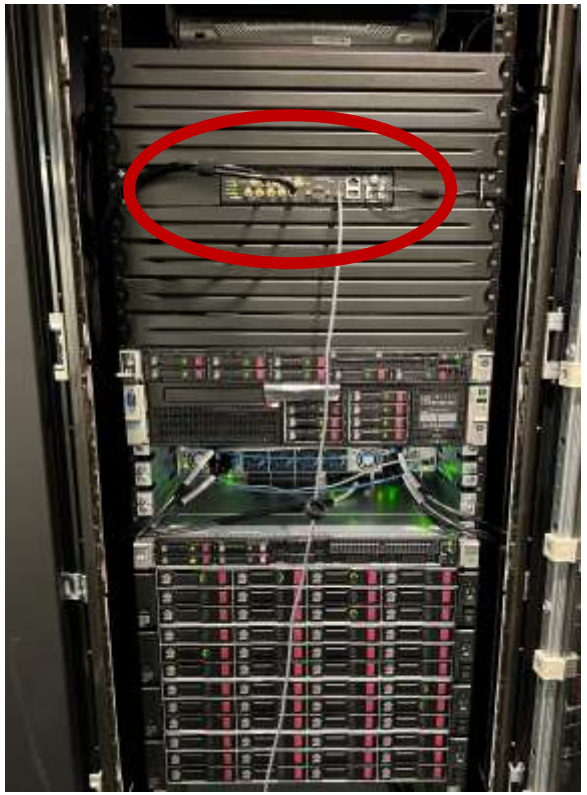


STL antenna mounted in office area ceiling

STL EXAMPLE: Data Center

Proper synchronization of cloud servers increases throughput by >10x

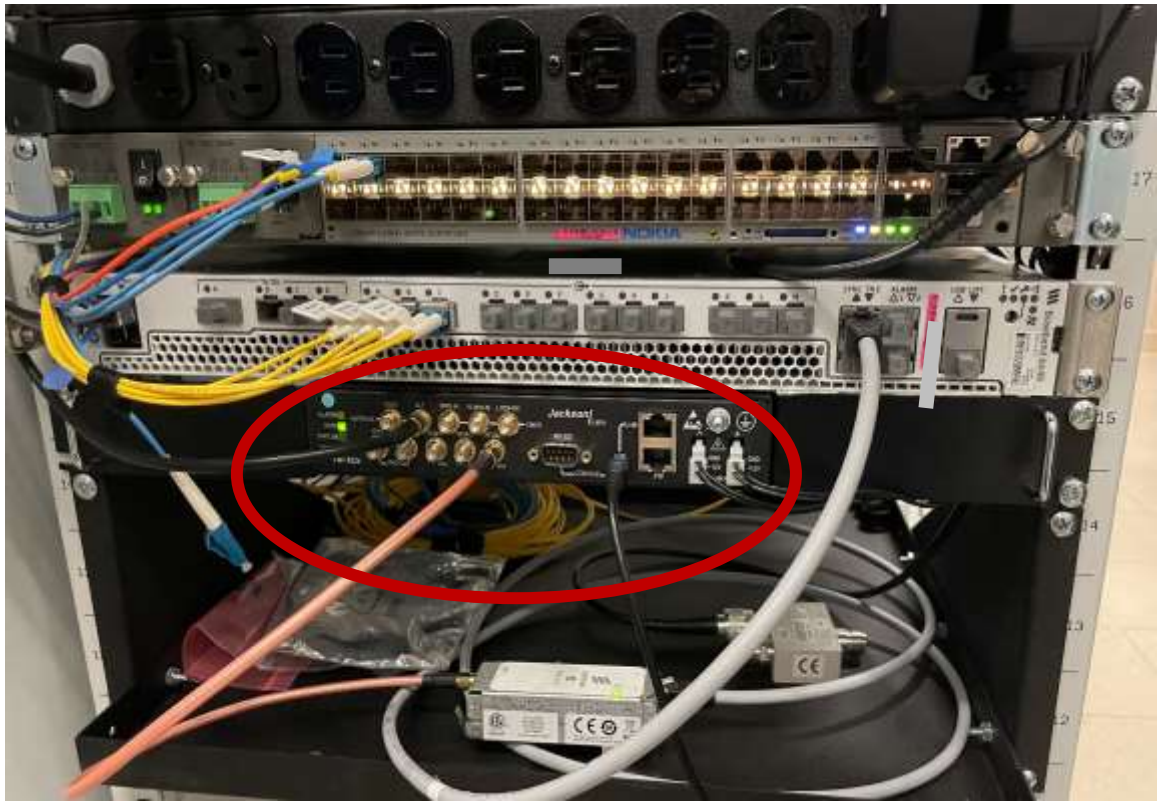
STL receiver used to synchronize data center servers



STL antenna mounted inside server room at the top of the server rack

STL EXAMPLE: Smart Hospital Installation

STL receiver used to synchronize Ericsson 5G Micro BTS RANs in smart hospital

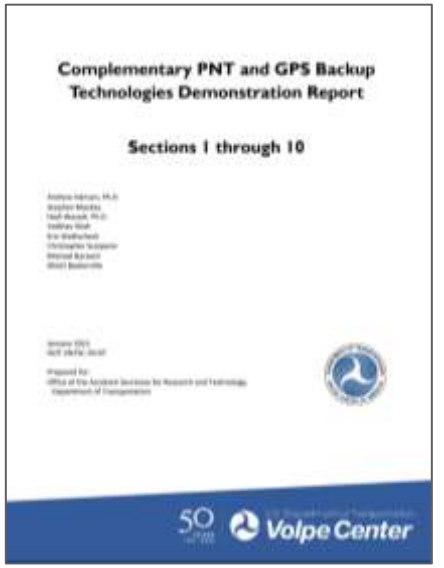


Satelles is Commercially Available Worldwide Today

Validated by Independent Authorities

STL Evaluated by U.S. Dept of Transportation

In January 2021, the DOT published a report summarizing the performance, availability, and readiness of 11 alternative PNT technologies.



Report Summary of (STL) LEO PNT Technology:

- **Technical Readiness Level:** 9 (Ready now)
- **Spectrum Protection:** Protected Spectrum
- **Service Deployment Effort:** Low (no new infrastructure needed)
- **Service Coverage:** 66 LEO satellites provide worldwide PNT service
- **Service Synchronization:** UTC
- **PNT Signal Robustness:** Strong (available indoors and is authenticated)
- **Service Resilience:** Fail-Over (STL promptly reports loss of service)
- **PNT Distribution Mode:** Orbital RF (Iridium Constellation)
- **Service Interoperability:** High (STL is significantly compatible with GPS)
- **PNT Information Security:** High (uses signal authentication for maximum security)
- **Time to Service Implementation:** Short (STL service is available now)
- **PNT System/Service Longevity:** Medium (projected satellite life of 15 to 30 years)

Of the 11 providers evaluated, STL from Satelles is the ONLY alternative PNT technology that is nationally and globally scalable and is available today.

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STL Evaluation by European Commission (DEFIS)

A technical demonstration was conducted Dec 2021 as part of an evaluation of STL and other technologies by the European Commission's Directorate-General for Defence Industry and Space (DEFIS) in a study conducted by the EC's Joint Research Centre (JRC) in Ispra, Italy.

Satelles was the only SOURCE OF TIME, all others were time transfer.

Tested for 1 day, 14 days and 100 days

Timing Accuracy to UTC
Timing Stability (Allan Deviation)
Availability (%)
Continuity (per hour)
Horizontal accuracy (95%)
Vertical accuracy (95%)
First time to provide continuous services upon cold start-up (including system and receiver contributions)

Rigorous testing conducted by EC evaluators confirmed the STL LEO PNT service performed well in all categories verifying that it can provide the accuracy and reliability needed for critical infrastructure operations

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STL Validated by NIST

NIST has concluded that (STL) LEO PNT is a reliable source of UTC timing and available today.

In November 2021, NIST published Technical Note 2189,
An Evaluation of Dependencies of Critical Infrastructure Timing Systems on the Global Positioning System (GPS)

In this report NIST…

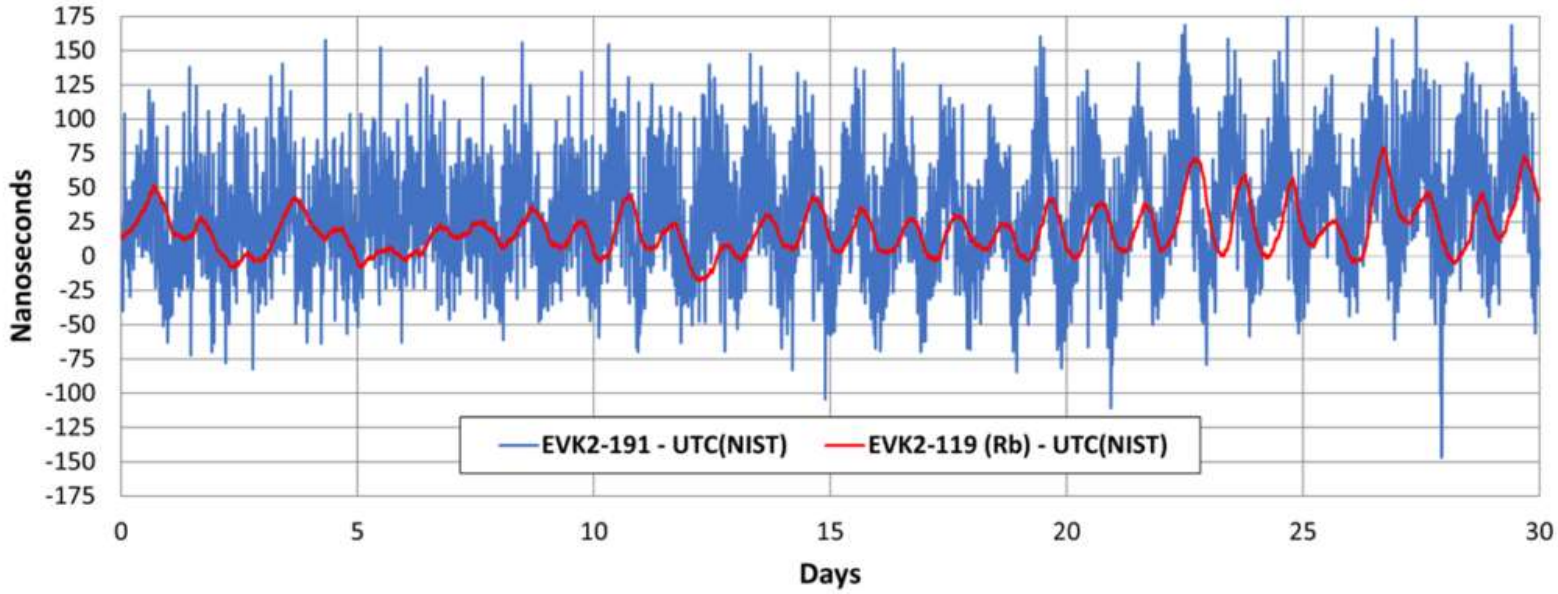
- concluded that STL is a reliable source of timing that is highly consistent with Coordinated Universal Time (UTC)
- categorized STL as an indirect distribution source for UTC(NIST)
- attested that STL is a commercial alternative that exists today
- verified that the timing accuracy specification for STL is ±500 ns (0.5 µs) which meets critical infrastructure requirements, and they acknowledged that published measurements indicate an accuracy better than 200 ns
- confirmed STL's long-term stability of better than 25 nanoseconds with short-term time deviation of 50 ns

☞ **Satelles has an STL ground monitoring station directly connected to NIST's main clock ensemble — the source of UTC(NIST)**

NIST: Timing Accuracy of STL

- Time experts at **Satelles and NIST co-wrote a paper**[1] that was presented at the Institute of Navigation (ION) Precise Time and Time Interval Systems and Applications (PTTI) meeting in January 2023.
- The underlying research of the paper demonstrated that a calibrated STL receiver can achieve an **average time offset better than 18 ns** with respect to UTC(NIST) with a peak-to-peak variation of 325 ns for a typical OCXO receiver and better than 80 ns with a rubidium-based receiver.

*This chart visualizes the comparison of STL to UTC(NIST) for a 30-day period. The **blue line depicts the time offset between UTC(NIST) and an STL receiver with an OCXO oscillator**, and the **red line** represents the same measurement for an STL receiver with a **rubidium oscillator.***



[1] "Measuring the Timing Accuracy of Satellite Time and Location (STL) Receivers"; Johnson, Novick, and Lombardi; https://www.nist.gov/publications/measuring-timing-accuracy-satellite-time-and-location-stl-receivers

5G Wireless Market Recognition for STL as an Innovative Commercially Available Timing Sync Solution

Fierce Telecom Awards

December 2022

Small Cell Forum Industry Awards

May 2023

How Can Governments Promote Resilience?

Critical Infrastructure Requirements Need Multiple Options

- **Multiple forms of alternative PNT deliver a range of operational and performance characteristics that:**
  - meet the diverse needs of applications across all industry sectors
  - are better adaptable to future threats than a single technology with its inherent vulnerabilities
- **Governments should not "pick winners"** by selecting a single technology or architecture as a national backup to GPS. This would stifle the ingenuity of the private sector that is otherwise spurred by competition and investment that:
  - drives the development of multiple GPS alternatives
  - proactively responds to technological innovations and market dynamics
  - addresses new and still evolving use cases not supported by GPS

A multi-technology approach to PNT resilience not only meets a more diverse set of critical infrastructure needs but also ensures a more robust approach to security by providing multilayer resilience. Delivering alternative PNT capabilities on an equal footing with GPS will require government policies and funding that ensure these solutions are cost-effective for critical infrastructure providers and sustainable over the long term.

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What Can Governments Do NOW to Ensure National Resilience?

Continue to study the problems and potential solutions — but don't stop there

Encourage and support innovation by the private sector — incentivize private sector owner operators to adopt resilient altPNT

Lead by example — invest in projects and programs that put multiple forms of PNT into actual operational use to protect critical infrastructure

Thank you!
QUESTIONS?