



Consider Terrestrial-based Alternative Timing Solutions

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Michael Fox, Center for Applied Communications and Networks, Texas A&M

Sam Matheny, National Association of Broadcasters

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Agenda

- Introduction to Time and GPS
- Critical Infrastructure and communication network applications
- Overview of impacts caused by GPS interference
- Alternative terrestrial-based timing solutions
- Action Plan

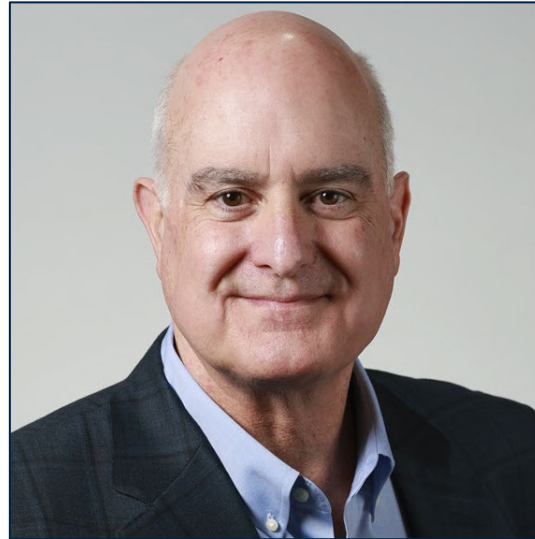
Today's Panelists



Robert Crane

Program Executive,
Public Sector Engagements,
Energy Security, and PNT

Institute for Homeland Security
Sam Houston State University



Michael E Fox

Executive Director,
Center for Applied
Communications and Networks

The Texas A&M University System



Sam Matheny

Executive Vice President,
Broadcast Positioning System

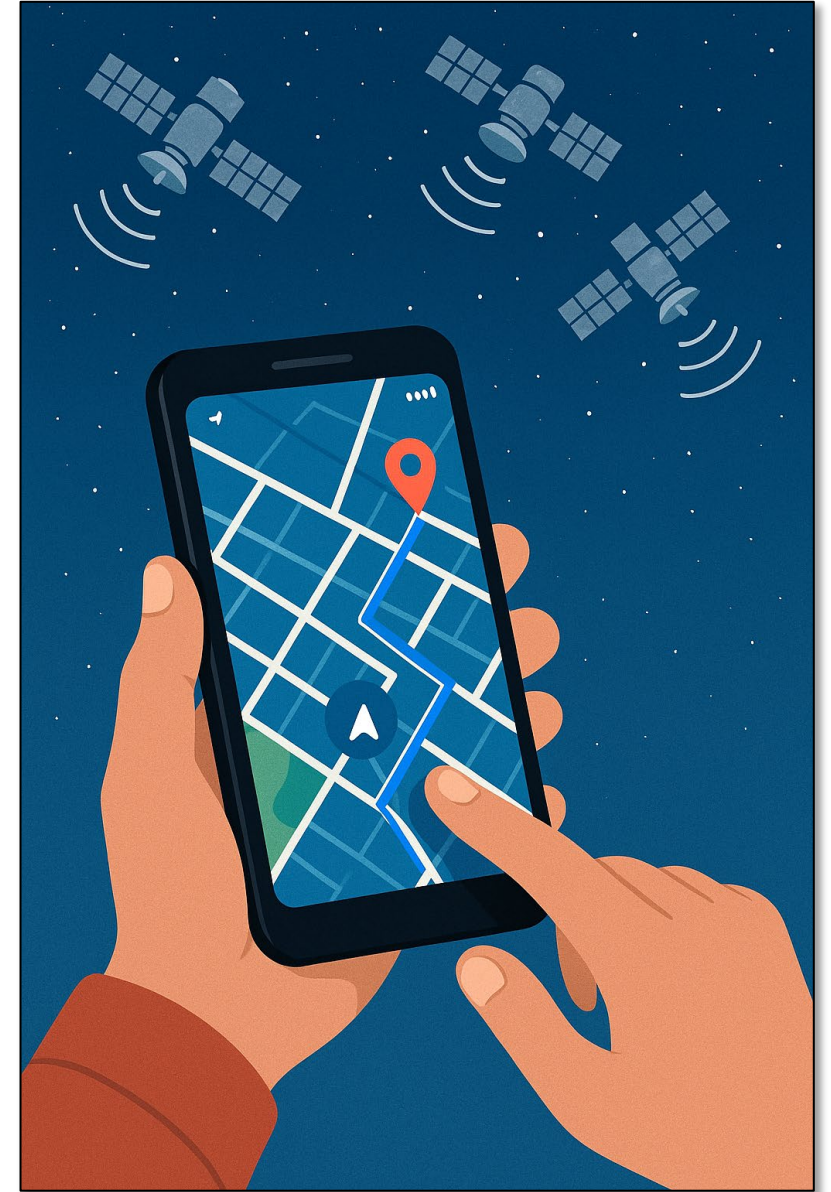
National Association of
Broadcasters



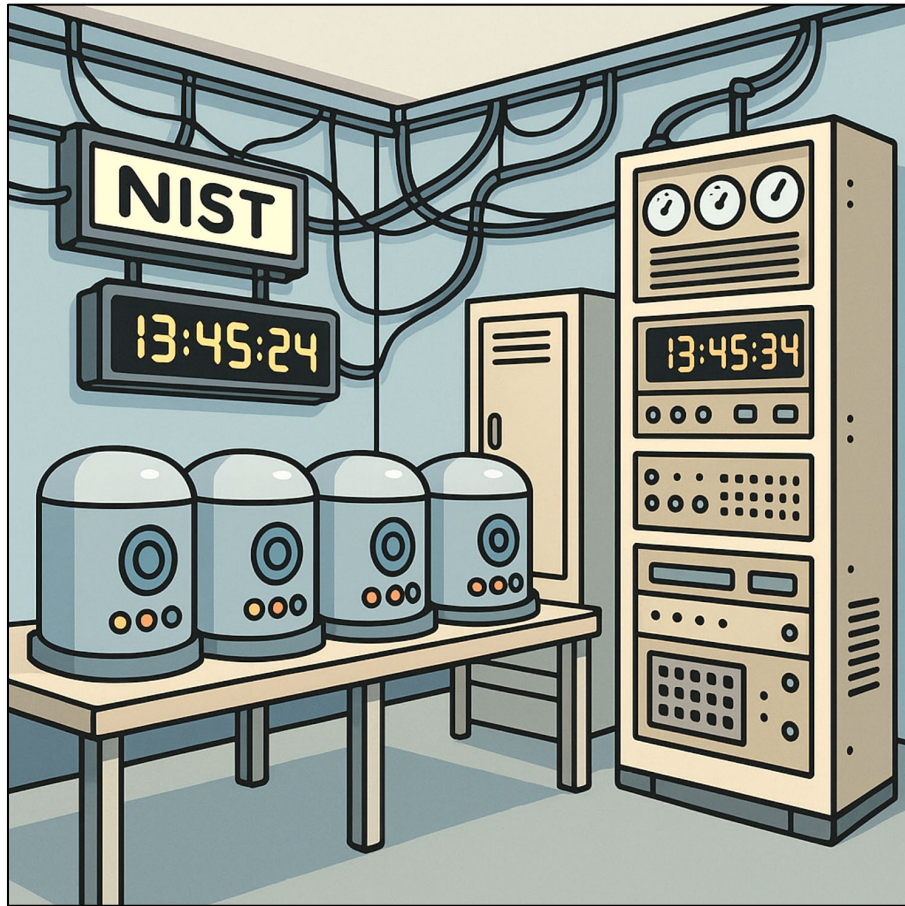
Introduction to GPS and Time

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What Most People Think About When You Mention GPS



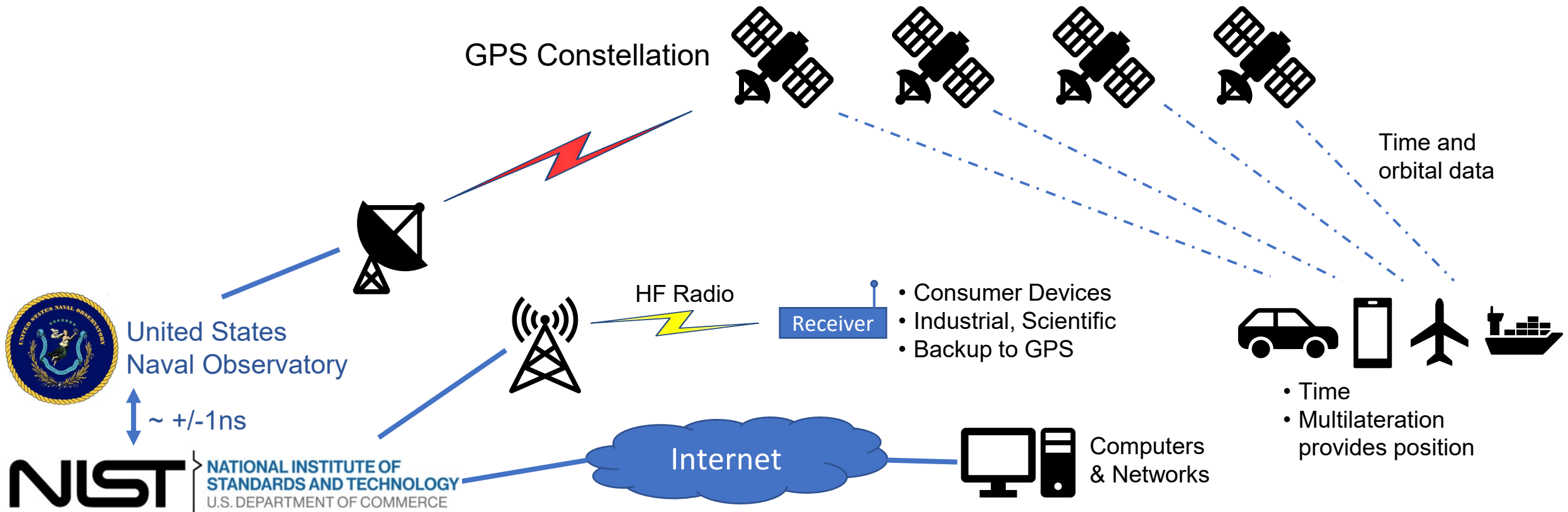
Time



- UTC – Coordinated Universal Time
 - The world’s primary time standard
 - Maintained by international network of timing labs including NIST (civil) and USNO (military and GPS)
- Clock “Ensemble”
 - NIST and USNO use a network of ultra-stable atomic clocks
 - Weighted average produces free-running atomic time scale
 - Small adjustments are made to align with UTC, producing UTC(NIST) and UTC(USNO)
 - NIST and USNO make regular comparisons
- UTC(NIST) – official U.S. civilian realization of UTC
 - Precise, legally recognized time
- UTC(USNO) – official US military and GPS time

GPS is One Method for Distributing Time

Time is distributed worldwide via the Internet, radio, and satellite (GPS)





Critical Infrastructure and Communication Network Applications

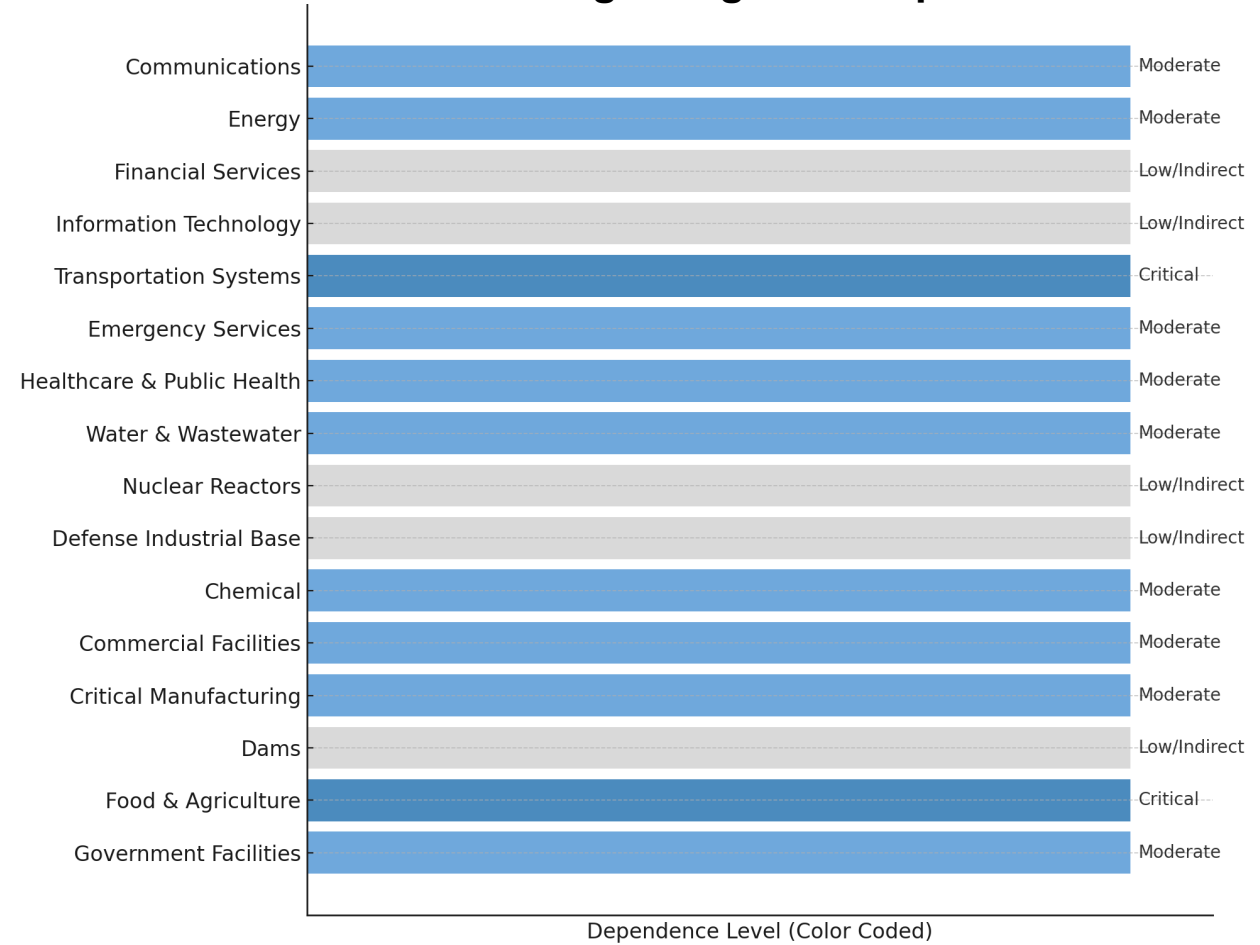
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DHS Critical Infrastructure Dependent on GPS

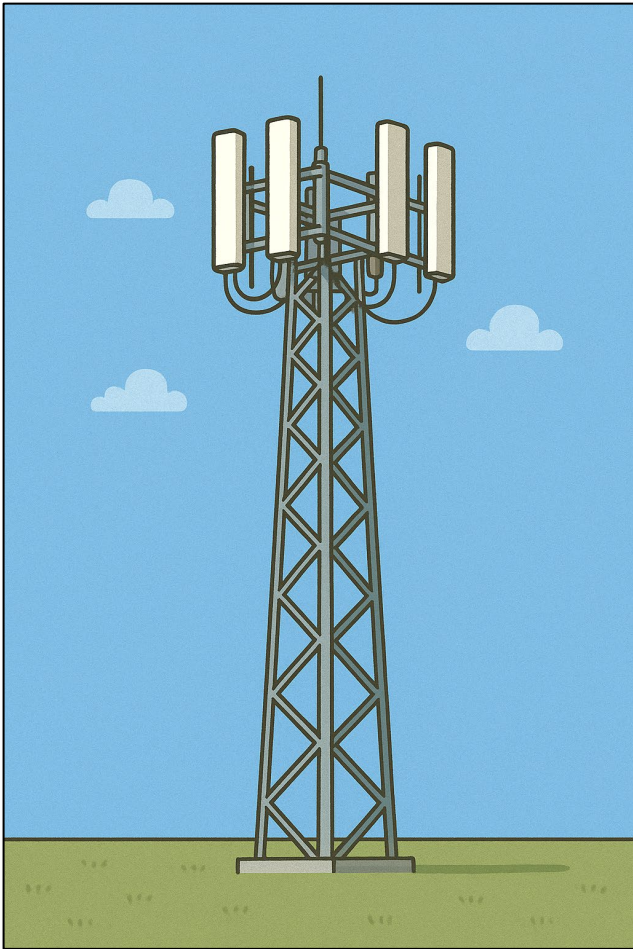
Timing Dependence



Positioning/Navigation Dependence



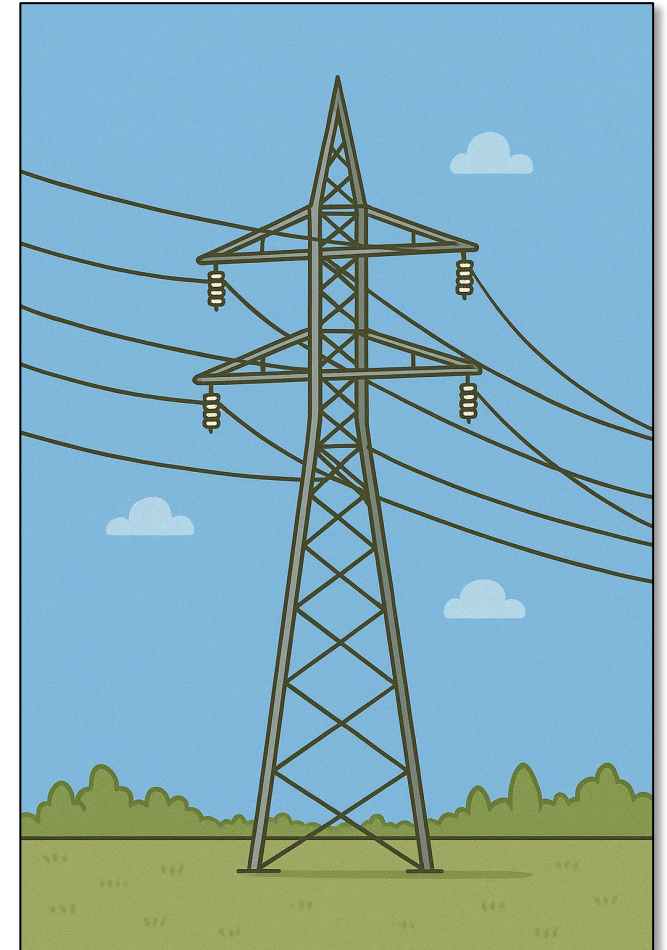
Communications Use Cases



- Core Network Synchronization
 - Modern networks require timing accuracy within nanoseconds
- Cellular Networks
 - Align transmission slots to eliminate interference
 - Support handover between cells
 - Massive MIMO beamforming accuracy
- Internet Backbone
 - Packet ordering, traffic management, fault detection
- Public Safety & Emergency Communications
 - 9-1-1 call routing and dispatch systems
 - P25 radio simulcast synchronization

Energy Use Cases

- Grid monitoring and control
 - Phasor Measurement Units (PMUs) measure voltage, current, and phase angle across the grid
 - GPS provides common, accurate time reference across wide area (possibly hundreds of miles apart)
- Synchrophasor Systems
 - Use time-synchronized phasor measurement data used to monitor grid oscillations
- Fault detection and location
 - Triangulation of faults by comparing arrival times of electrical disturbances
- Substation automation
 - Automated protection relays and breakers require exact timing to coordinate fault isolation and load shedding



Financial Services Use Cases



- Transaction Timestamping
 - Timestamps required by regulators
 - Trade sequence reconstruction for audits, detecting market abuse, resolving disputes
- High-Frequency Trading
 - Algorithms execute trades in microseconds or less
- Global Market Synchronization
 - Fair order matching across geographically distributed data centers

Information Technology Use Cases

- Network Time Synchronization
 - Servers, routers, and switches in data centers, cloud services, enterprise networks
- Data Integrity and Logging
 - Financial, legal, regulatory compliance, forensic analysis
- Cybersecurity
 - Authentication systems, encryption protocols, detecting replay attacks or mismatched transactions
- Distributed Systems and Cloud Computing
 - Applications running across multiple locations
- Telecommunications Backbone
 - Overlap with telecom; sync edge servers



Transportation System Use Cases



- Precise Time
 - Traffic Signals & Control Systems
 - Synchronization of traffic lights and highway sensors
 - Railway Signaling
 - Track-side and onboard control systems
 - Air Traffic and Port Operations
 - Radar, communications, data system synchronization between control towers, ground stations and vehicles
- Positioning and Navigation
 - Aviation: en-route nav, approaches, landings, ...
 - Road: turn-by-turn directions, fleet tracking, ...
 - Rail: Positive Train Control (PTC)
 - Maritime: Automatic Identification Systems (AIS), nav

Emergency Services Use Cases

- Precision Time
 - 9-1-1 call routing
 - Infrastructure for routing 9-1-1 calls to the correct PSAP
 - Radio Networks
 - Trunked, simulcast digital radio systems require microsecond-level time synchronization
 - Data & Video Feeds
 - Sync mobile data terminals, body cams, vehicle dash cams
 - Interagency Coordination
 - Synchronized applications and logs for event timelines
- Positioning and Navigation
 - Dispatch and Routing
 - Search and Rescue
 - Incident Tracking and Situational Awareness



DHS Critical Infrastructure Dependent on GPS

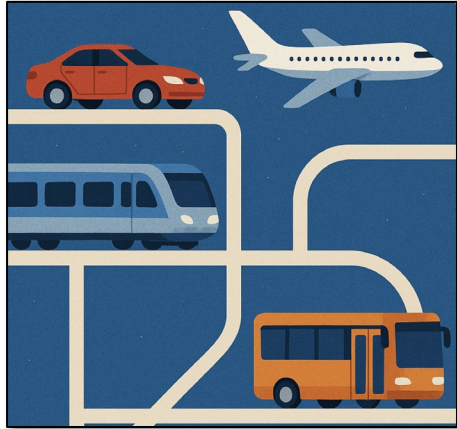
Timing Dependence



Positioning/Navigation Dependence



Position & Navigation Use Cases



Transportation Systems

- Aviation: en-route navigation, approaches, landings, ...
- Road: turn-by-turn directions, fleet tracking, ...
- Rail: Positive Train Control (PTC), ...
- Maritime: Automatic Identification Systems (AIS), navigation, ...



Food and Agriculture

- Precision Agriculture
 - Field mapping, variable rate application, harvest optimization
- Livestock Management
 - Animal tracking, fence mapping
- Supply Chain & Logistics
 - Fleet tracking, cold chain monitoring
- Environmental monitoring, Disaster Response, Food Security



GPS Interference and Impacts

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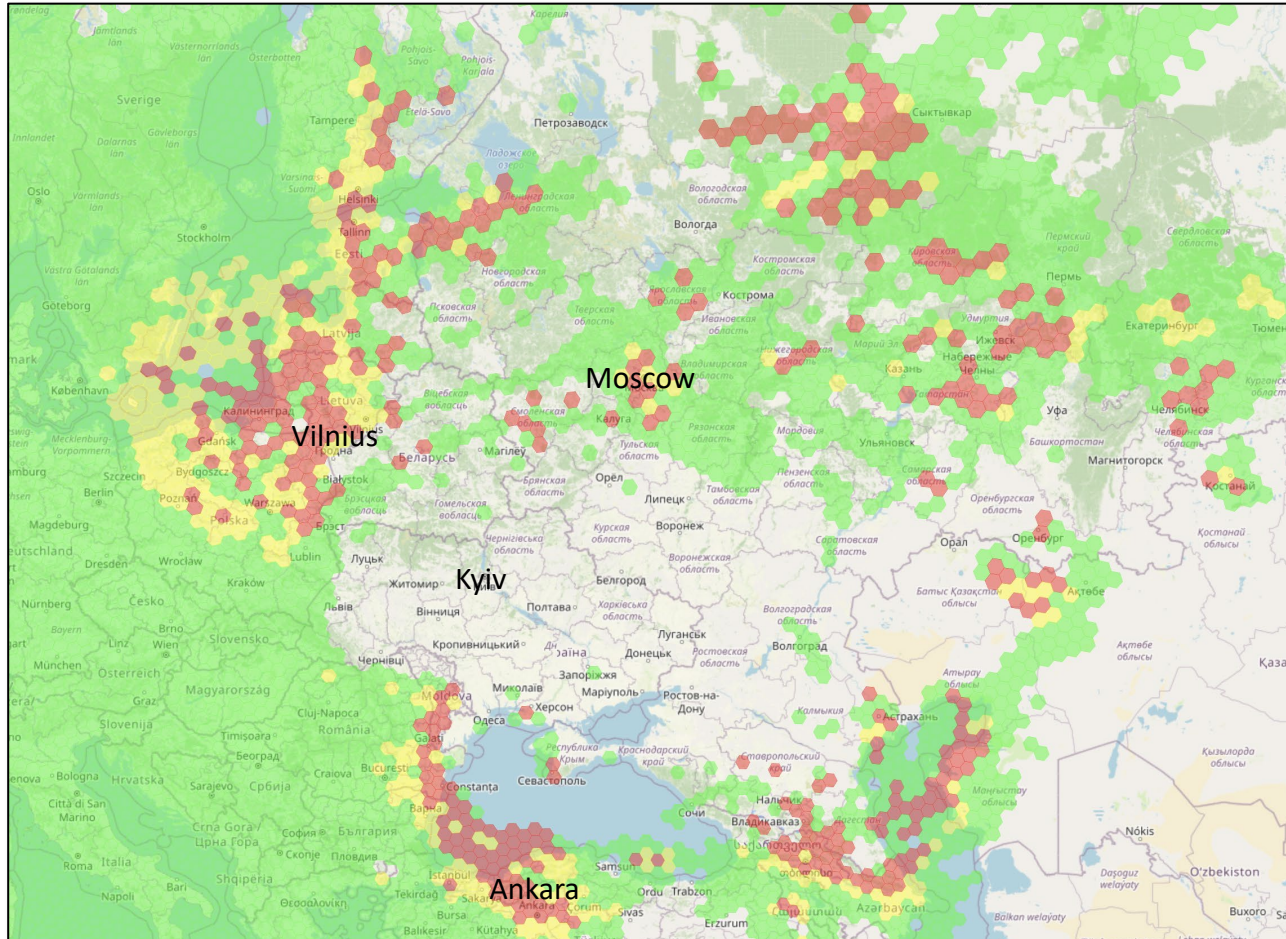
Threats to GPS are Numerous!

- Cyber
 - Break defense and contractor networks
- Directed Energy
 - High power microwave, radio frequency and laser weapons
- Electronic – Jamming/Spoofing
 - Block transmissions or spoof to manipulate data
- Direct-Ascent Kinetic Anti-Satellite
 - Ground, sea, or air-launch missiles
- Orbital Attack
 - Kinetic kill vehicles, jammers, chemical
- High Altitude Nuclear / EMP
 - Massive radiation pulse to disable electronics
- Kessler
 - Satellites collide with each other or debris from other collisions

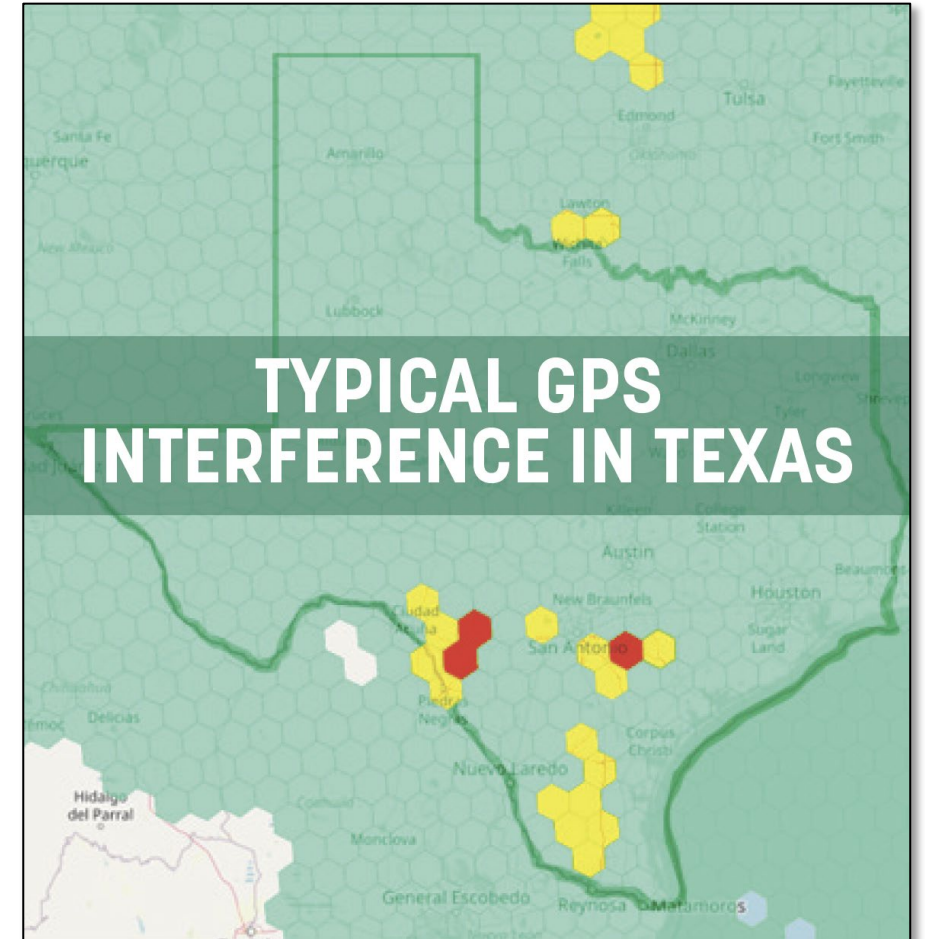


Localized GPS Interference

Expected



Unexpected?



Results of a GPS outage:

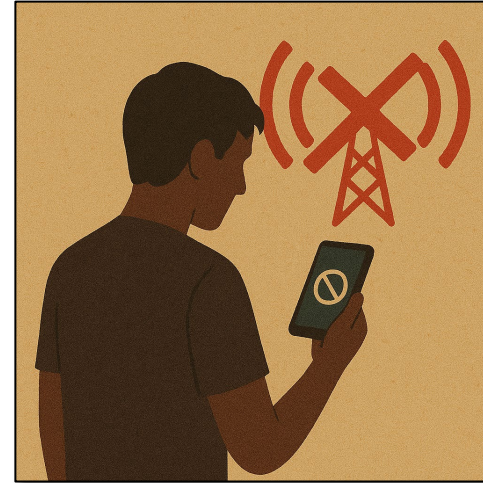
Power Grids, Financial Systems, Cellular Networks, Public Safety Communications, Computer Networks, Traffic Control, and Air Traffic would fail or severely degrade

\$1B to \$1.6B Per Day!

Estimated cost of GPS outage

Secondary Effects of Sustained Loss of GPS

- Can't communicate
 - Cell networks lose power and time sync
 - No power, time sync for land lines, business phone systems
 - Public safety radio systems lose power & time sync, ...
- Can't travel
 - No electricity to charge your EV, or to run gas pumps
- Can't get money
 - No power or networks for banks, ATMs, ...
- Can't get food and supplies
 - No electricity for refrigeration
 - No fuel for planes, trains, trucks to transport food, goods
- Can't get water
 - Water pumps down; sewage systems stop functioning
- Can't get help
 - Police, fire, EMS, hospitals, have no power, fuel, comms, ...
- ...



What Will a Sustained Outage Look Like?

Some Say This ...



... or this



Maybe some of both! Or something in between.



Alternative Terrestrial-based Timing Solutions

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Recent Terrestrial Alternatives to GPS

- Point-to-point Fiber
 - PTP (Precision Time Protocol – IEEE 1588) + SyncE (Synchronous Ethernet)
 - PTP: time and phase; SyncE: frequency
 - Telecom profile + SyncE can achieve <50ns accuracy
 - High accuracy profile “White Rabbit” can achieve < 1ns accuracy
- Wireless
 - 5G Positioning Signals
 - Downlink: Positioning Reference Signal; Uplink: Sounding Reference Signal
 - BPS (Broadcast Positioning System)
 - Digital television broadcast standard ATSC 3.0 that includes time and TX location



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Broadcast Positioning System™ (BPS™)

Sam Matheny

EVP Broadcast Positioning System



What is Broadcast Positioning System (BPS)?



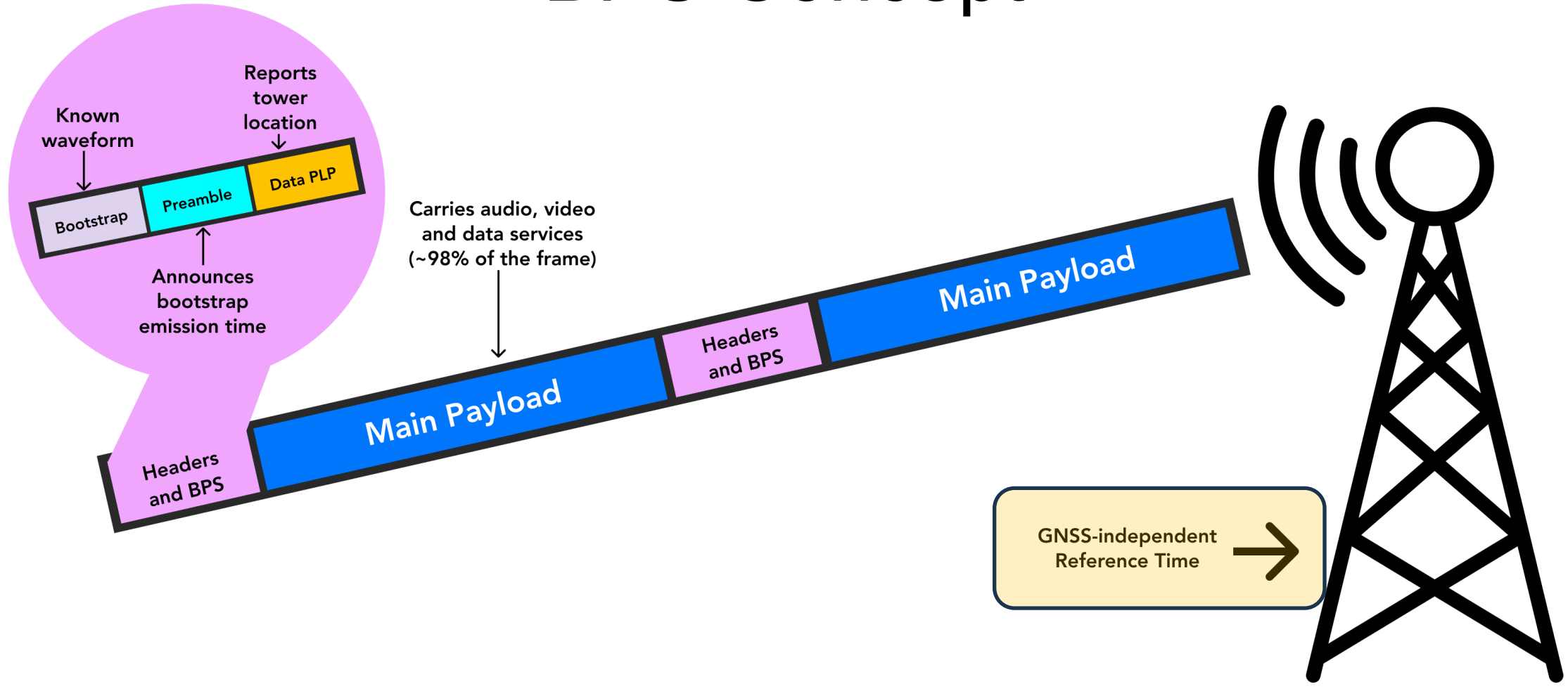
Time and position using ATSC 3.0 signal



Works without GPS, Internet, and cellular connectivity



BPS Concept





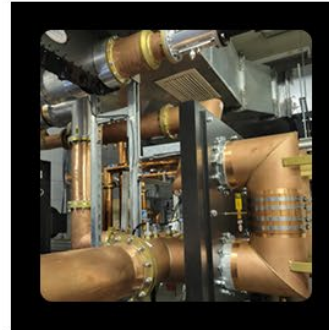
Building Blocks of BPS Infrastructure (Sample from WHUT, Washington, D.C.)

- Existing TV Station Infrastructure
- Equipment Needed for BPS Implementation

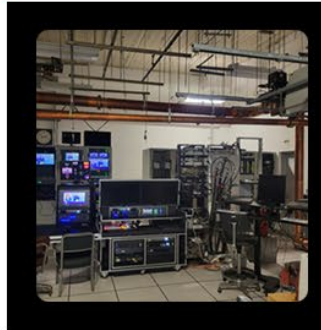
GNSS-independent Reference Time
BPS Synchronizer



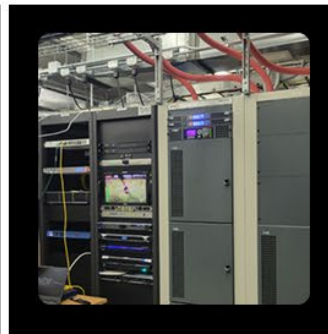
Mask Filter



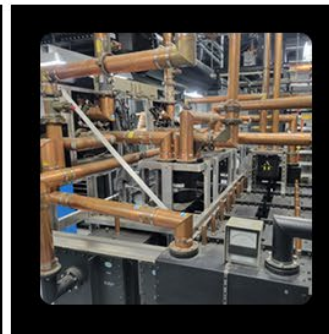
Control Room



Tower and Antenna



TX Chain and Power Amp



Transmission Lines



RF Combiner

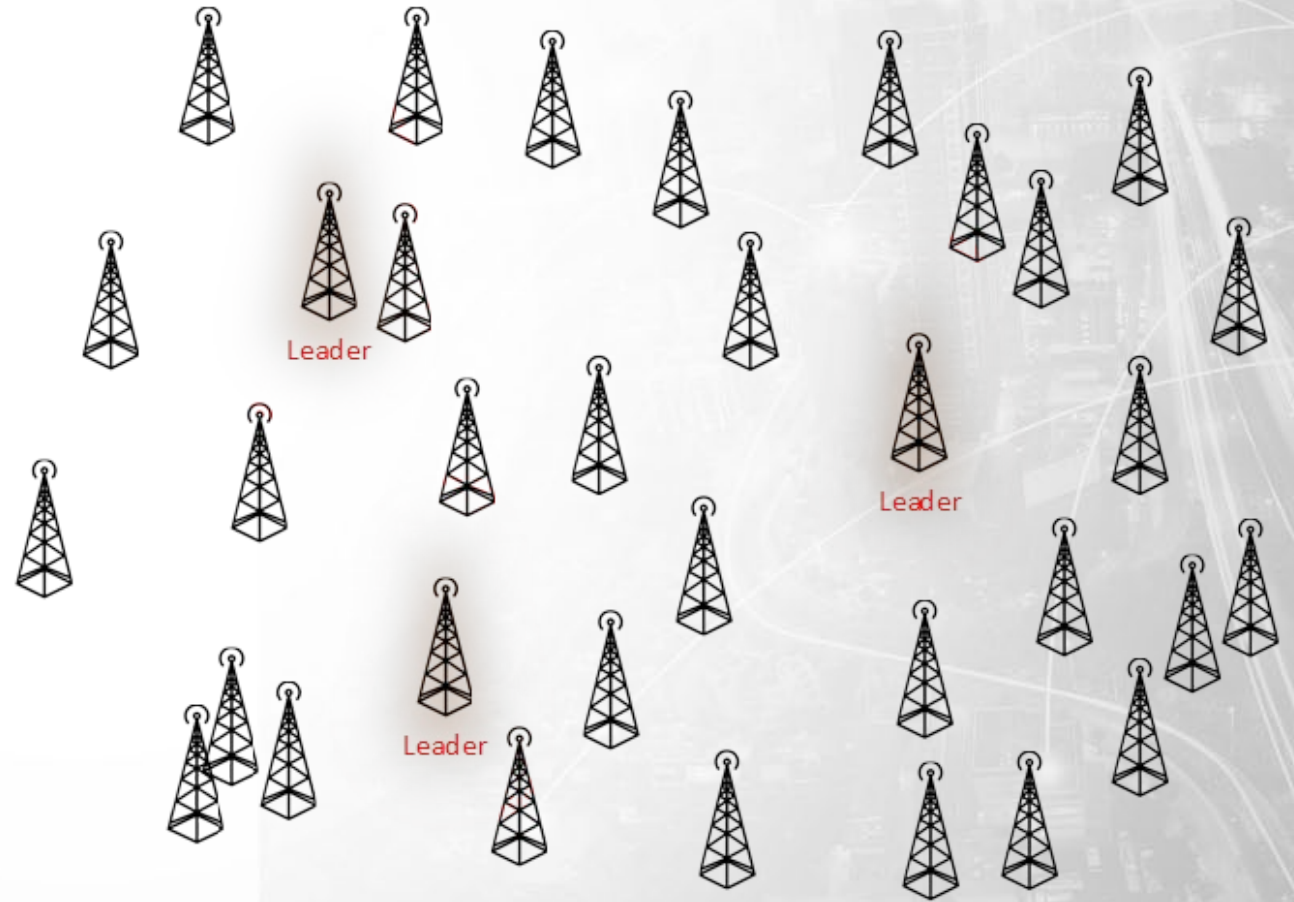
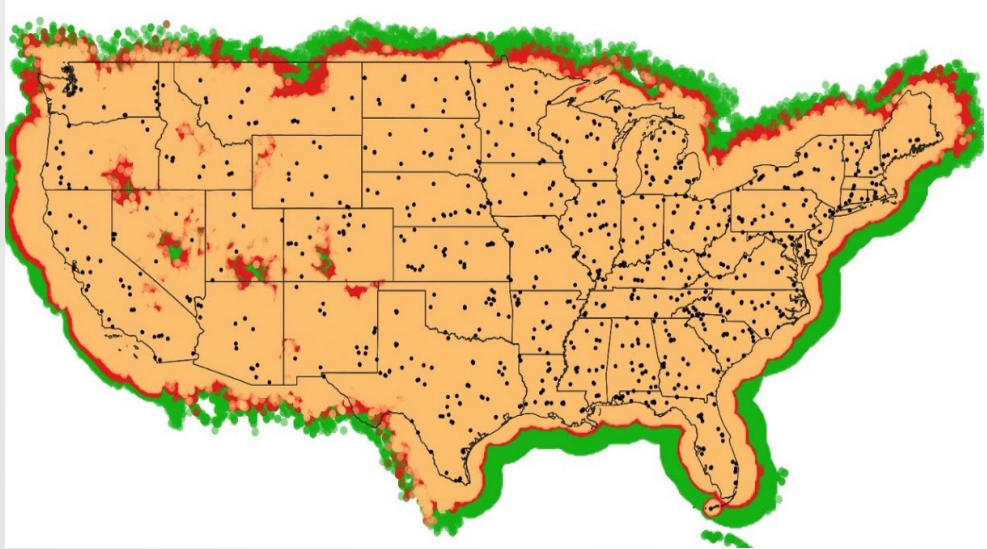




Single Synchronized Network

BPS is the terrestrial equivalent of GPS.

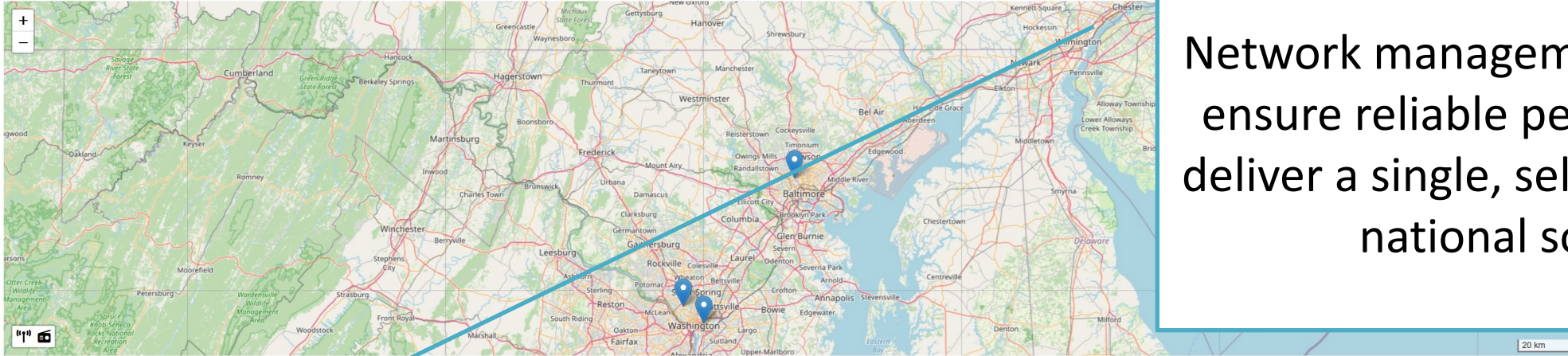
BPS is a single national mesh network that operates as a managed service.





BPS NOC

Transmitters



Network management software to ensure reliable performance and deliver a single, self-synchronizing, national solution.

Transmitter

Name	Call Letters	VPN	Delta	Last Ping	Data
IM Lab	IM	10.8.0.22		03/10/2025 13:45:22	● <input checked="" type="checkbox"/>
Triveni Lab	TD	10.8.0.62		03/10/2025 13:45:28	● <input checked="" type="checkbox"/>
WNUV-TV	WNUV			03/10/2025 13:45:22	● <input checked="" type="checkbox"/>
WHUT-TV	WHUT	10.8.0.66		03/10/2025 13:45:23	● <input checked="" type="checkbox"/>
KWGN-TV	KWGN				● <input checked="" type="checkbox"/>

Details

name WNUV-TV
 transmitter ID 256
 facility ID 7933
 callsign WNUV
 frequency 506 MHz
 latitude 39° 20' 10.4" N (39.336222°)
 longitude 76° 38' 57.9" W (-76.649417°)
 altitude (m) 372.77 m
 power 750 kW
 max gain direction 1
 VPN
 transmitter data
 relative field strengths

Synchronizer Data



TOA Variation - Avateq WNUV RX





PNT Capabilities of BPS

One TV tower can provide accurate time at a known position

Four TV towers can provide both time and position estimation

Can detect GPS spoofing

Can enable GPS-BPS hybrid location



Cooperative Research And Development Agreement

Time Transfer Performance of the Broadcast Positioning System™ (BPST™)

Tariq I. Mondal, *National Association of Broadcasters*
Dr. Jeffrey A. Sherman, *National Institute of Standards and Technology*
David A. Howe, *University of Colorado and National Institute of Standards and Technology*

“BPS time transfer is **comparable to or better** than GNSS (GPS), making BPS a **viable complementary PNT solution** when GNSS is unavailable.”



**Dominion
Energy**[®]

Energy Sector

- Power substation is physical site
- Precision time is needed to align the phase of the power for transmission.
- Fault Detection Systems require precision time.



PILOT[®]

NAVIGATING BROADCASTING'S FUTURE

BPS BROADCAST POSITIONING SYSTEM



Action Plan

How Do We Move Forward?

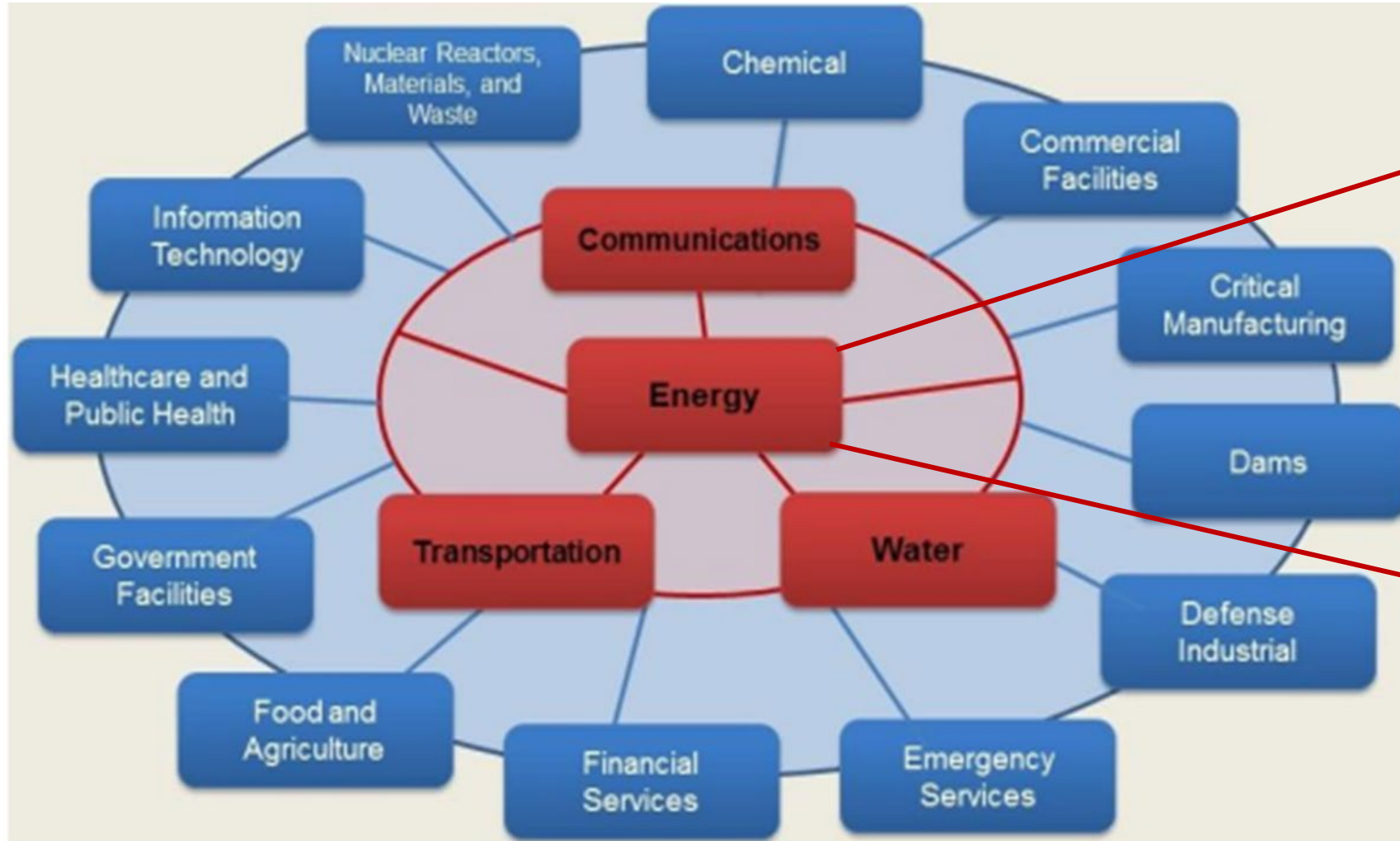
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BLUF

Bottomline Up Front

- U.S. GPS signal is invisible lifeline of the modern economy.
- Our goal must be clear:
 - Uninterrupted Availability of critical lifelines and supply chains.
 - Economic Continuity in the face of GPS disruption
(or any disruption of any critical lifeline, supply chain, and service).
- This is the frontier of National Security and Operational Resilience.
- Intent and Capabilities to disrupt networks exist by various means.
- In today's digitally interdependent and globally competitive environment, Business Continuity must evolve to become Economic Continuity:
 - defined by our ability to keep our **economic engines running**
 - **seamlessly, securely, and without interruption**
 - even in the face of **complex and emerging threats and disruptions.**

Lifelines

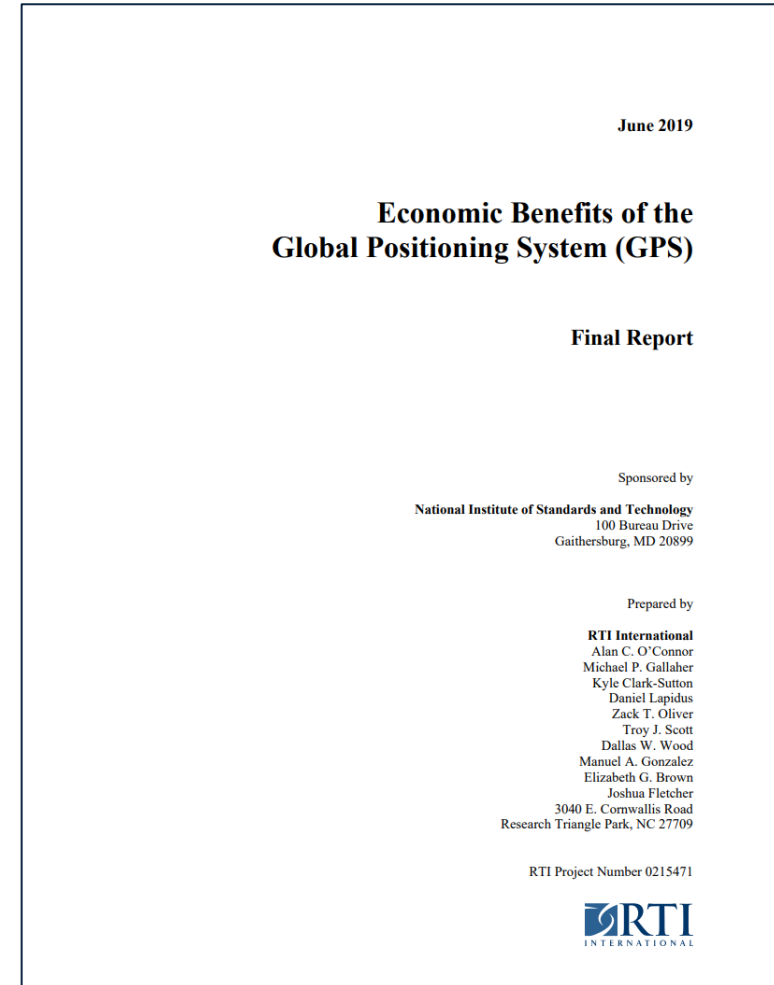


Precise Time and Time Distribution

Public Safety and Security
Law Enforcement/Security, Fire Service, Search and Rescue, Government Service, Community Safety

US Dept of Commerce – Economic Benefits of GPS

- A 2019 study, by the Commerce Department’s National Institute of Standards and Technology (NIST), estimates that GPS generated **\$1.4 trillion in U.S. economic benefits** since the system became available in the 1980s.
- The study also presents an additional analysis of the **potential economic damages from a 30-day GPS outage**.
- Though uncommon (current less than a day), a GPS outage could potentially have an **economic impact of \$1 billion a day**.
- For example, if a 30-day outage occurred during **critical planting seasons for farmers, the impact could be as high as \$45 billion**.



Continuity of the Economy

S.3928 Continuity of the Economy Act of 2020

This bill requires the President to develop a plan to maintain and restore the U.S. economy in response to a cyberattack or other significant event that is natural or human-caused that results in severe degradation to economic activity. Among other requirements, this plan shall (1) examine the distribution of goods and services across the United States necessary for the reliable functioning of the country during such an event; (2) identify the economic functions of relevant actors whose disruption, corruption, or dysfunction would have a debilitating effect on security, defense readiness, or public health or safety; and (3) identify the critical distribution mechanisms for each economic sector that should be prioritized for operation during such an event.

Source: <https://www.congress.gov/bill/116th-congress/senate-bill/3928>



**INSTITUTE FOR
HOMELAND SECURITY**



**Sam Houston
State University**

**RATIONALE AND PROCESS FOR
CONTINUITY OF THE ECONOMY**

Institute for Homeland Security

Sam Houston State University

Benjamin L. Ruddell

Evolving Mindset – Action Plan for Operational Continuity

We must therefore evolve our posture—from protecting Precise Time and GPS as a critical asset, to ensuring the resilience of the *economic functions that depend on it*.

This means:

- **Identifying mission-critical applications of Precise Time and GPS, especially if a single-point failure.**
- **Deploying and integrating complementary capabilities such as inertial navigation, terrestrial timing systems, or alternate PNT (Positioning, Navigation, and Timing) technologies.**
- **Stress-testing mission-critical operations, "timing" equipment, systems and networks, and operational technology, under degraded GPS scenarios.**
- **Promoting private-public-academic coordination to ensure continuity of lifelines and interdependences between GPS, energy systems, transportation, logistics, financial markets, and public safety/emergency services in the face of loss or degradation of GPS signals.**

Mitigation Options for Civil Users

<https://www.gps.gov>

<https://www.gps.gov>

<https://www.nist.gov/pnt>

<https://www.nist.gov/pnt>



Best Practices for Resilient PNT Supporting Critical Infrastructure
September 2024

U.S. DEPARTMENT OF SCIENCE AND TECHNOLOGY

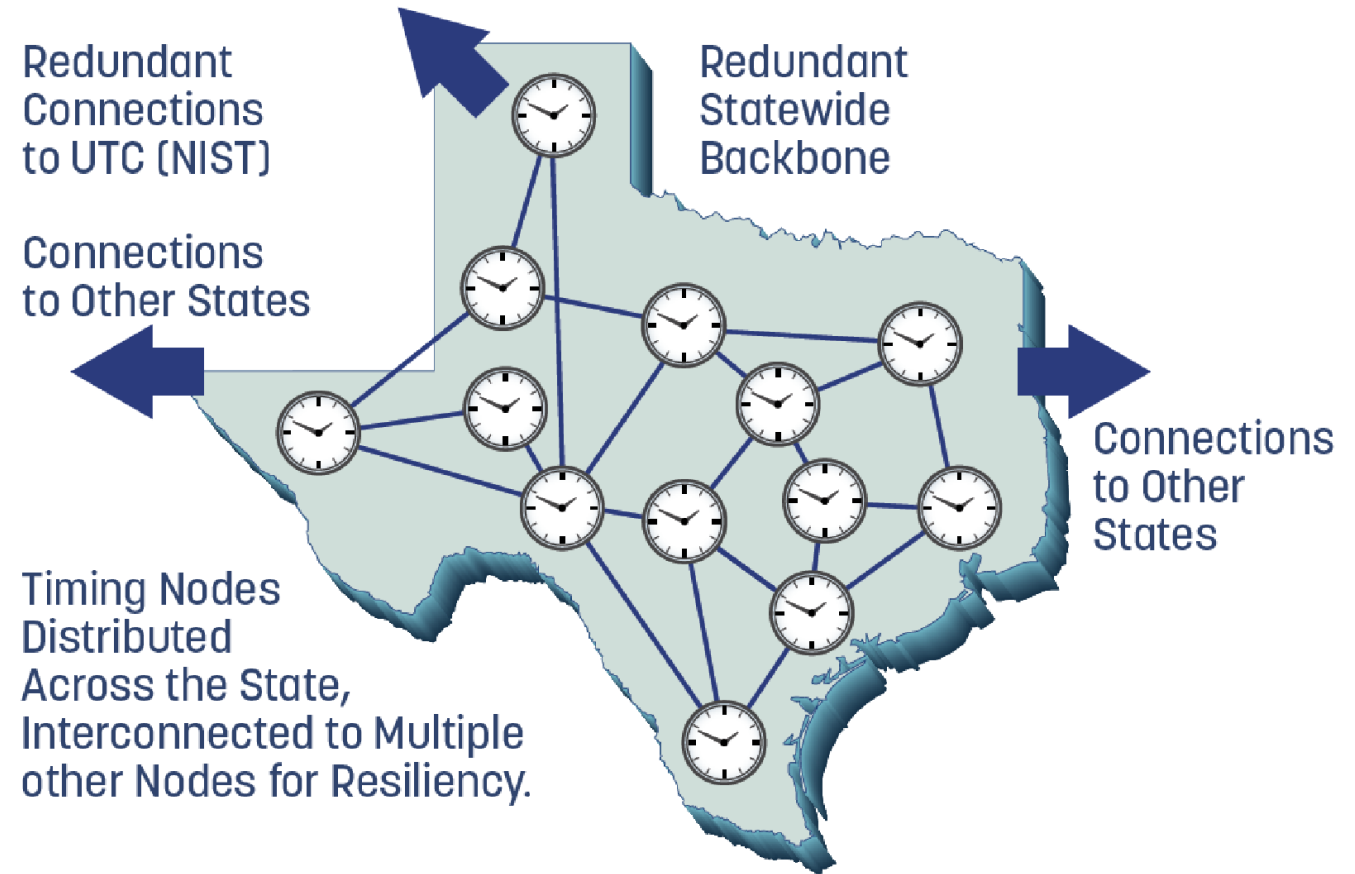
<https://www.cisa.gov/topics/risk-management/positioning-navigation-and-timing>

<https://www.cisa.gov/topics/risk-management/positioning-navigation-and-timing>

<https://www.dhs.gov/science-and-technology/pnt-program>

State or Regional Efforts

- Large critical infrastructure networks maintain atomic clocks as backup to GPS
- If GPS is lost, each network's time will drift with respect to the others
- Statewide or regional networks can maintain synch between all critical infrastructure





For More Information:

DHS Resilient PNT Framework

<https://www.dhs.gov/publication/st-resilient-pnt-conformance-framework>

Precision Time Protocol (PTP) - IEEE 1588-2019 and SyncE

<https://ieeexplore.ieee.org/document/9120376>

<https://www.itu.int/rec/T-REC-G.8262>

Broadcast Positioning System (BPS)

<https://www.nab.org/bps/>

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