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SAFE SKIES.
SUSTAINABLE FUTURE.

It’s all about Time
Resilient Time—What Why & How

Ken Alexander

Chief Scientist for Satellite Navigation Systems
U.S. Federal Aviation Administration

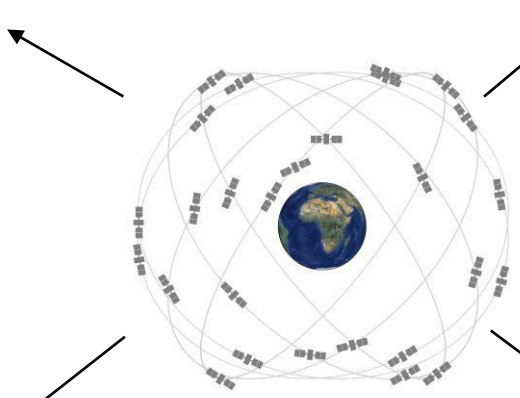
Resilient Time Overview

The Challenge

- Aircraft & ATC Critical Infrastructure (CI) Systems, Applications and Services must be robust and resilient to evolving threats—including spoofed GNSS Time
- Modern society and businesses rely on: Communications, Computers & Information Technology (C&IT), Automation, Hardware and Software defined Networks and Busses
  - Including aviation CI and aviation's supporting CI (dispatch, maintenance, ticketing, etc.)
- Time and Frequency are increasingly intertwined and crucial to our increasingly digital "info-centric" world (as well as for many legacy analog systems)
- Computer applications, communications networks, busses, and avionics need stable, phase-aligned frequency
  - Signals from different sources arrive at the receiver at the same time, preventing interference and enabling coherent signal processing
- Most Applications & Services need Universal Coordinated Time (UTC) or related time std
- Time distribution requires time-domain protection and fault location technologies for accuracy and speed

Today, GPS & GNSS Are The World's Clocks

- GPS/GNSS is an inexpensive and extremely accurate timing distribution source for the user
- Most fielded GPS/GNSS receivers are vulnerable to spoofing
- Resilience & Robustness to threats is critical



"… ability to anticipate, withstand, recover from, and adapt to adverse conditions, stresses, attacks or compromises on system resources …"

NIST SP 800-160

GNSS Dissemination of Coordinated Universal Time (UTC)

Vital information delivery often depends on GNSS

GNSS is the principal "Pacemaker" synchronizing most aviation networks including:

Communications: Ensuring seamless data exchange between aircraft, ground stations, and satellites

Navigation: Calculating aircraft positions & trajectories

Surveillance: Real-time aircraft tracking for safe separation and efficient air traffic management

Spacing & Sequencing: Maintaining safe, optimized flows

Network Synchronization: Keeping aircraft, air to ground, ATC, aviation industry, and supporting infrastructure networks functioning

Weather: Real-time weather for flight planning and safety

NOTAMs: Timely notifications of limitations, hazards, etc.

Flight Plans: Accurate scheduling and routing of aircraft

False GNSS "Heartbeats" can de-synchronize data flows and precipitate failure of some systems

De-Synchronization can result in:

Communication Breakdowns: Loss of contact between aircraft & ground control

Navigation Errors: Aircraft straying off course, increasing the risk of collisions

Surveillance Gaps & Errors: Inability to track aircraft, increasing safety risks

Data may be missing, or incorrect and misleading

Misleading Erroneous Information due to incorrect/fragmented time can lead to:

Compromised flight safety: Pilot and Controllers making decisions based on incorrect information

Disrupted air traffic flows: increased delays, diversions, and workloads

Aircraft and ATC Timing Standards

- ICAO SARPS specify aircraft and ATC:
  - Achieve a local time reference accuracy of within 30 seconds of UTC, and
  - Wherever data link communications are utilized by air traffic services, clocks and other time-recording devices shall be checked to ensure correct time to within 1 second of UTC
  - Aircraft requirements: clock must display hours, minutes, and seconds, either digitally or with a sweep-second pointer
- Resilient Time is critical for civil aircraft and ATC infrastructure systems & aviation interoperability Including Comm, Nav, Surveillance, Automation & Safety systems
- Resilient Time is critical for aircraft systems including internal (e.g., bus & avionics communications) as well as external communications (e.g., CPDLC, SATCOM)
- Currently aircraft, and too often ATC Infrastructure, time and frequency are based upon GNSS without ensuring resilient sources (e.g., oscillators/clock ensembles)
- Aviation timing requirements do not address resiliency
  - Resilience can be achieved via reasonableness checks
  - Reasonableness checks can include consistency checks as well as crosschecks with complementary timing

Aircraft and ATC Timing Standards (continued)

For consideration and discussion:

- How can aircraft and ATC best achieve resilient time and frequency (e.g., oscillator or clock ensembles)?
- ICAO ATC and aircraft requirements do not address current aircraft and ATC “derived” time and frequency performance needs
- Standardize provision of Time for ATC use (Systems challenge—e.g., all ICAO panels have equities)?
- Who should standardize avionics & aircraft use (e.g., aircraft original equipment manufacturers (OEMs) in conjunction with avionics OEMs)?

Independent Systems Keep Aviation Safe
Multiple Systems' dependence on GNSS Impacts Safety

ATC services & Aircraft systems are intended to complement/supplement

Enables Ops to recover if capability is degraded or disabled (3/4-Legged Stool analogy)

Systems with GNSS dependent capabilities:

- Communications
- Navigation
- Surveillance
- Air Traffic Management
- Safety Systems
- Maps / Displays
- Automation and Networks

Aviation use of GNSS positioning and time is pervasive across more and more aircraft and ATC systems and services

Multiple, concurrent malfunctions + increased workload can upset the "Stool"

Don't let your seat come off the rails!

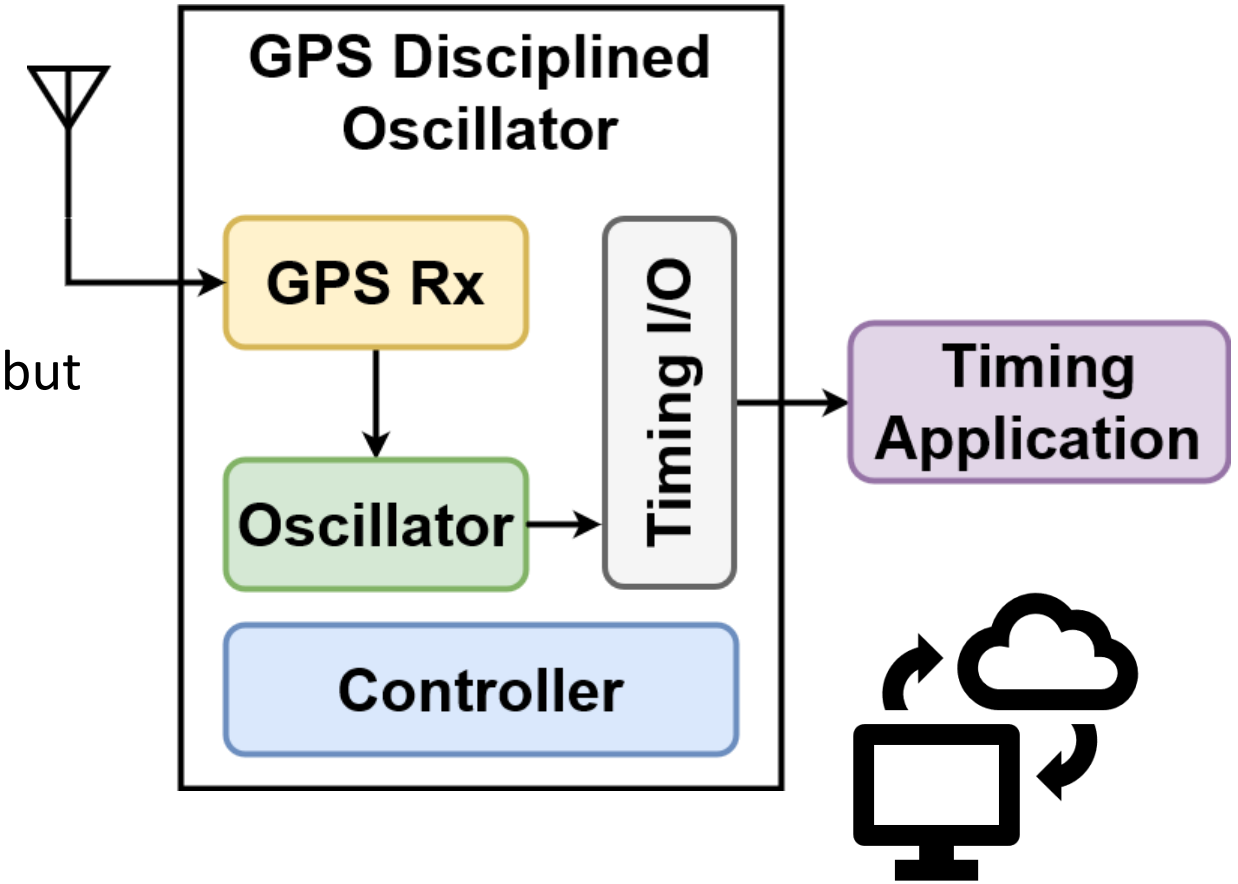
Apply SMS

GNSS Disciplined Oscillator

Homeland Security Systems Engineering and Development Institute (HSSEDI)
POC: Dr. Arthur K. Scholz ascholz@mitre.org

- **Notional GPS/GNSS Disciplined Oscillator:**
  - High quality oscillator stable over hours; drifts over days
  - GPS receiver time accurate on average, fluctuates over short time scales
  - Disciplining leverages the short-term local oscillator stability with the high average accuracy of GPS/GNSS time transfer

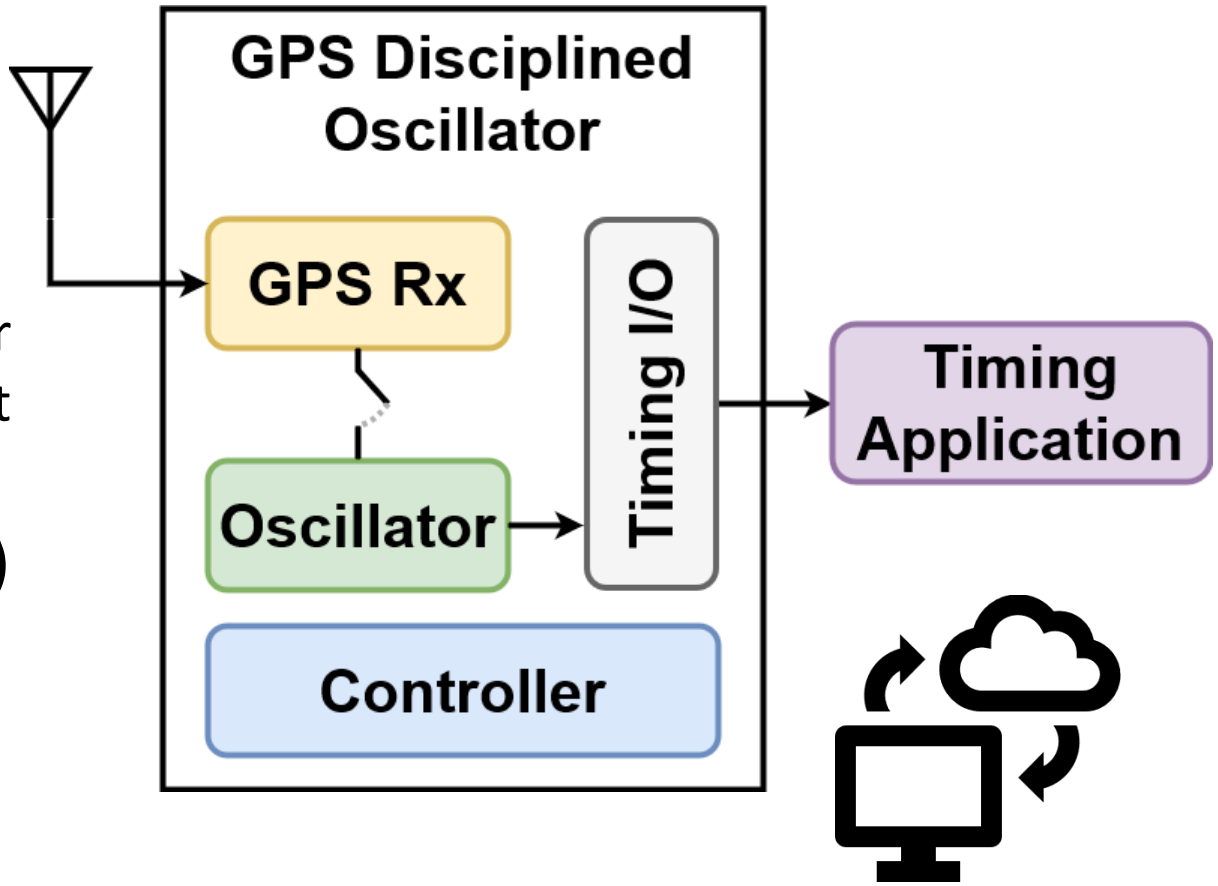
but



When GPS/GNSS receiver is exposed to spoofing, continuous disciplining makes the Oscillator (or Atomic Clock) vulnerable as well

Flip The Concept

- **Trust the oscillator**
  - Oscillator can free run for a long time (hours to days) while still meeting the needs of many applications
  - During free run, the GPS/GNSS receiver can be powered down and thus is not vulnerable to attacks
- **Discipline intermittently (and irregularly)**
  - Oscillator will wander while free running
  - Intermittent GPS/GNSS disciplining only as required to prevent time errors from exceeding applications' tolerance(s)



Remote attackers can't spoof or jam a free running oscillator

Aviation Time and Frequency Recommendations

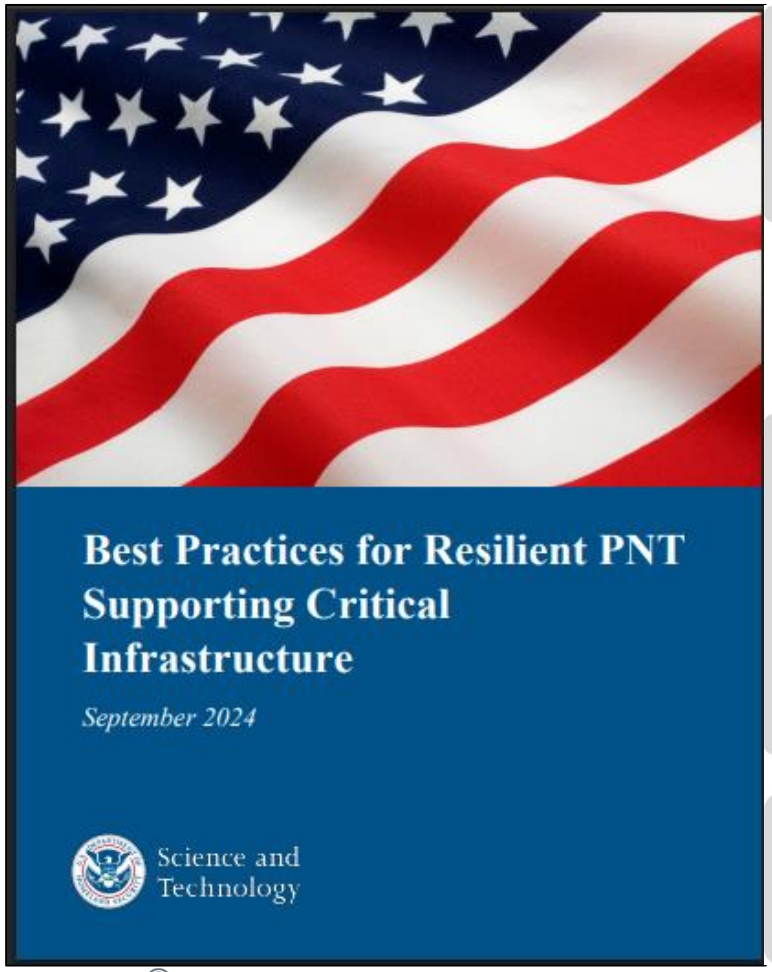
States' Civil Aviation Administrations, Air Navigation Service Providers, and all other civil aviation Critical Infrastructure (CI) owners and operators, manufacturers, and integrators (including ATC CI & aircraft/avionics) should implement resilient time and frequency capabilities as a priority, apply best practices to maintain aviation CI resilient use of time, monitor evolving threats and update technology solutions and PNT services as required.

To maintain aviation safety and security, aviation critical, essential, and supporting systems, applications, and services should secure and maintain resilient time and frequency using independent clocks or oscillators (using an ensemble configuration when appropriate) as the primary source.

Independent clocks or oscillators should be synchronized via direct connections to a resilient Coordinated Universal Time (UTC) source.

For Additional Information: See the following Link

Best Practices for Resilient PNT Supporting Critical Infrastructure September 2024



Directive

PPD21 – Critical Infrastructure Security and Resilience

EO 13905 Responsible Use of PNT Services

Risk Mitigation via Organizational Processes, Policies, and Procedures (OP)

Risk Mitigation via Acquisition of PNT Technology Solutions (AS)

Risk Mitigation via Deployment, Operations & Maintenance (DO)

Best Practices for Resilient PNT Supporting Critical Infrastructure

OP Best Practices | **AS Best Practices** | **DO Best Practices**

Technology Solutions

NIST TN 2189 – An Evaluation of Dependencies of CI Timing Systems on GPS

RPNT Conformance Framework

RPNT Reference Architecture

- **PNT Integrity Library**
- **Epsilon Algorithms**
- **Allowlist Dev Guide**

Best Practices for Improved Robustness of Time and Frequency Sources in Fixed Locations

NIST TN 2187 – A Resilient Architecture for the Realization & Distribution of Coordinated Universal Time to CI Systems in the US

Guidance for Organizations

NIST IR 8323r1 Foundational PNT Profile

Identify, Protect, Detect, Respond, Recover Functions

Resilient PNT Capability Maturity Model

See Also

NIST Technical Note 2187 *November 2021*

A Resilient Architecture for the Realization and Distribution of Coordinated Universal Time to Critical Infrastructure Systems in the United States

Thank You

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