



**BORROWED TIME:** Why Precision  
Timing Became the Most Critical  
Element of PNT

**BORROWED TIME:**

Why Precision Timing Became the Most Critical Element of PNT

Position, Navigation, and Timing (PNT) form the operational foundation of advanced defense systems. Engineers designing PNT architectures typically focus on Global Navigation Satellite Systems (GNSS) receivers, inertial navigation systems, sensor fusion, and anti-jam antennas. Timing rarely receives the same attention because many architectures assume GNSS already provides the timing reference.

This assumption highlights an often-overlooked vulnerability in defense platform design. Borrowed from GNSS, program architects historically did not engineer timing as an independent capability. Decades of reliable satellite signals normalized this reliance, and the “T” in PNT became a background function rather than a defined requirement.

GNSS denial, degradation, and spoofing now occur routinely across contested operational theaters. Platforms that depend on GNSS as their primary timing reference therefore inherit a systemic single point of failure. When that reference disappears, the consequences extend far beyond navigation.

**KEY INSIGHT**

Timing was not engineered into most PNT architectures. Instead, it was borrowed from GNSS. When the signal disappears, many systems lose their timing reference.

## Timing Is the Operational Backbone

Precision timing enables advanced defense systems to operate as coordinated networks rather than isolated components. Communications systems depend on synchronization to maintain encrypted waveforms, frequency hopping patterns, and low probability of intercept/low probability of detection (LPI/LPD) signals. Radar platforms rely on precise pulse timing and coherent processing to maintain range resolution and target discrimination, while electronic warfare systems synchronize sensing and emissions within tightly controlled timing windows.

Navigation systems also depend on a stable time reference. Inertial navigation systems require precision timing to bound accumulated drift when

GNSS updates are unavailable. Distributed sensor networks must timestamp observations accurately to correlate data across platforms. Multi-domain operations across air, ground, maritime, space, and cyber domains rely on shared time to coordinate operations across the force.

When the reference disappears, effects cascade across the architecture. Communications links lose synchronization, while radar and electronic warfare systems forfeit coherent processing advantages. Inertial navigation drift grows without correction, sensor timestamps diverge (degrading data fusion), and multi-domain operations lose temporal coordination.

**BORROWED TIME:**

Why Precision Timing Became the Most Critical Element of PNT

## GNSS Denial Is Now Routine



GNSS interference is no longer rare. Low-cost jammers and spoofing systems are widely available, enabling both state and non-state actors to disrupt GNSS signals.

In March 2024, jamming near Russia's Kaliningrad region disrupted more than 1,600 aircraft across Eastern Europe. Since 2023, tens of thousands of interference events have affected aviation and maritime operations in the Baltic region. Large-scale spoofing campaigns in the Eastern Mediterranean have displaced hundreds of vessels by falsifying GNSS position and timing data. Along the Black Sea, military and civilian operators report interference on a weekly basis.

**KEY INSIGHT** GNSS denial is no longer a theoretical threat. Jamming and spoofing now occur routinely across contested operational theaters.

## Assured PNT Is Now a Strategic Priority

Assured Position, Navigation, and Timing (PNT) is now a priority across national defense strategies. The United States Department of Defense (DoD) emphasizes PNT resilience in new programs and modernization efforts, and allied nations pursue similar initiatives.

The United Kingdom maintains a national PNT resilience framework and a dedicated National PNT Office. European institutions are evaluating complementary PNT infrastructure, while Indo-Pacific allies invest in sovereign and regional alternatives. The policy signal is clear: defense platforms must maintain operational capability in GNSS-degraded and GNSS-denied environments.



## Engineering Timing Resilience

---

Addressing GNSS vulnerability requires a resilient local timing architecture that maintains synchronization during signal loss. The key performance parameter is holdover, which defines how accurately a local oscillator maintains time after losing its reference source.

All oscillators drift over time. The rate of that drift determines how long a system can maintain acceptable performance without external correction. High-quality oscillators maintain accurate timing long enough to bridge outages or acquire

alternative references, while lower-quality devices accumulate timing error rapidly, degrading communications, navigation, and sensor coordination.

For this reason, holdover must be defined at the system architecture level rather than specified solely at the component level. Engineers evaluate timing performance under the vibration, shock, and temperature conditions platforms encounter in operational environments.

## Why Quartz Timing Creates Operational Risk

---

Quartz oscillators have long provided the timing foundation for defense electronics. However, their physical characteristics introduce limitations in environments where timing resilience matters most. Quartz resonators are sensitive to acceleration. Shock and vibration produce measurable frequency deviations in aircraft, rotorcraft, ground vehicles, and munitions. Thermal transitions introduce additional instability as devices move through temperature extremes during operation. Precision quartz solutions that mitigate these effects often require larger packages and higher power consumption.

Global supply chain fragility introduces additional risk. A 2020 factory fire at Asahi Kasei Microdevices in Japan, which produces more than 80 percent of the ICs used in global temperature-compensated crystal oscillator (TCXO) production, disrupted quartz oscillator supply worldwide, with shortages persisting into 2022. Ongoing geopolitical tensions further highlight the vulnerability of concentrated component supply chains. Programs with multi-decade lifecycles must therefore consider supply chain resilience alongside performance.

## MEMS Precision Timing for Assured PNT

Silicon MEMS timing technology addresses these limitations through a fundamentally different architecture. MEMS resonators are fabricated using standard semiconductor processes that provide improved mechanical stability and scalable manufacturing. Manufacturing across multiple semiconductor foundries diversifies supply, reducing the geographic and supply chain concentration associated with quartz timing. MEMS oscillators exhibit g-sensitivity orders of magnitude lower than that of quartz devices, maintaining stable output under the shock and vibration profiles of tactical aircraft, rotorcraft, ground vehicles, and munitions. Integrated temperature sensing and compensation maintain frequency stability across the full military temperature range, while compact semiconductor construction enables precision timing in packages that meet strict size, weight, and power (SWaP) constraints.

These devices achieve mean time before failure (MTBF) of up to 2 billion hours, compared to roughly 30 million hours for quartz. At a production scale of 10,000 units per year, that difference equates to roughly three quartz failures annually versus fewer than one for MEMS, with direct implications for platform downtime, maintenance cost, and mission risk.

### KEY INSIGHT

Assured PNT requires resilient local timing. Systems must maintain synchronization even when GNSS signals are degraded or unavailable.

## Conclusion

The “T” in PNT was historically invisible because GNSS delivered precision timing reliably and continuously. GNSS denial, degradation, and spoofing now occur routinely in contested environments, creating a critical vulnerability for defense systems that depend on GNSS timing. PNT architectures must incorporate resilient local timing capable of maintaining synchronization during GNSS outages.





**Si**Time®

**BORROWED TIME:** Why Precision Timing Became the Most Critical Element of PNT

[WWW.SITIME.COM](http://WWW.SITIME.COM)