AEROSPACE

POSITIONING, NAVIGATION AND TIMING

The Global Positioning System (GPS) touches almost every aspect of the world economy; services reliant on GPS are forecast to be a $146.4B industry by 2025.[1] Currently, GPS is utilized by more than 4.5 billion users, including most U.S. military systems and several U.S. critical infrastructure sectors. GPS is also one of a handful of global navigation satellite systems (GNSS). For more than six decades The Aerospace Corporation has led the conceptualization, development, implementation, modernization, and continued innovation of GPS and broader positioning, navigation and timing (PNT) capabilities. GPS is a central element of PNT, but alternative and complementary sources of PNT provide a greater availability of signals, help ensure the integrity of GPS signals, and assure a PNT solution when access to GPS is limited or denied, such as signals over challenging terrain or in contested environments.

Advancing Defense, Civil, and Commercial Applications

PNT applications are growing exponentially in privately and publicly owned and operated critical infrastructure. These applications have enabled precision farming and minimized the use of pesticides, as well as the accurate tracking of ships and shipping containers (essentially revolutionizing the shipping industry), and made air travel safer and more efficient. Additionally, PNT functions sustain the financial operations of multinational corporations by providing precise timekeeping for transactions and enabling many location-based services (LBS).

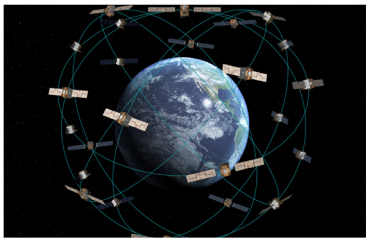
Designing a More Resilient PNT Architecture

A growing reliance on PNT applications brings increased vulnerabilities. GPS is continually threatened by signal jamming, spoofing, and techniques that can impede military operations and have dire disruptive impacts on civilian infrastructure. Aerospace is a leading contributor to U.S. efforts to define a more resilient national PNT architecture. Internationally, Aerospace works with the allied GNSS community to ensure compatibility and interoperability of foreign GNSS with GPS. Multi-GNSS solutions are a key element of alternative and ensured PNT.

The availability of PNT services, with GPS as their core component, must be secured for all users, including the LBS market and current nascent technologies that depend on PNT. Large-scale, machine-controlled operations in industry, robotics, next-generation communication networks, air traffic control systems, and autonomous vehicles will require integration with the modernized space and ground architectures that enable resilient PNT.

Aerospace Resilient PNT Capabilities

- Requirements analysis
- Architecture design and engineering
- Technology development and integration
- Availability, integrity, and reliability analysis
- Testing and evaluation, simulation and testbeds
- Tracking and security
- Standards and protocols
- Implementation of new signals in user equipment



The U.S. military relies on GPS for everything from mounted and dismounted missions to missile systems, while globally, civilian life relies on multi-GNSS PNT. Dependence on these space systems puts them at risk for becoming a single point of failure—robust technical and policy solutions are necessary to ensure their continued success and maintain GPS as the "gold standard" in GNSS.

[1]Mike Griffin, former Under Secretary of Defense for Research and Engineering, Testimony to the Senate Armed Services Committee Spectrum Hearing, May 6, 2020.

Collaborating to Meet New National Mitigation Responsibilities

At no time has there been a greater need for bridging policy with technology to make the national space enterprise more resilient. Recent guidance indicates an increasing expectation for end users to be responsible for both mitigating temporary GPS disruptions and establishing prudent risk management procedures to minimize negative impacts. Aerospace can help meet this challenge, bringing decades of experience to design-in security and resilience features, identifying anomalous PNT signals, and ensuring system operation even through interference.

Aerospace fosters relationships in the R&D domain with academic institutions, federal laboratories, and industry to help integrate, test and evaluate new technologies and systems used by the government. This collaborative approach supports common research goals, accelerates transition to operations, and reduces time to market for diverse applications.

Precision farming GPS-based applications are vital to farm planning, field mapping, soil sampling, tractor guidance, crop scouting, variable rate applications, and yield mapping. Additionally, GPS enables farms to operate during low-visibility field conditions such as rain, dust, fog, and darkness.

Current PNT Initiatives

Monitoring signals of opportunity, including developing modular open architectures for sensor fusion and using software-defined radios to track signals across radio frequency (RF) bands, provides many flexible options for alternative or diversified PNT applications. Examples of PNT initiatives Aerospace is exploring include:

Anti-jamming research and development. Threats to GPS access from signal interference, including accidental or adversarial signal jamming, can affect military operations as well as civilian infrastructure in ways that can drastically disrupt daily life. An outage of space-based systems has the potential to cripple multiple interdependent networks and systems. Blind interference signal suppression (BLISS) is a pioneering new anti-jamming technology that uses machine learning to counter signals that would interfere with GPS reception. BLISS is a low size/weight/power module that can be inserted behind the antenna in a receiver to enable the removal of high-powered jamming signals.

Anti-spoofing and signal integrity research and development. Threats to GPS integrity, including malicious spoofing of GPS military and civil signals and the manipulation of positioning and timing information, can be catastrophic. An error in timing or positioning can send a ship into a danger zone or cause a financial transaction to be late, thereby putting the users' safety at risk or resulting in major losses. Aerospace has deep expertise in advanced antenna systems, cryptographic authentication algorithms, machine learning techniques, and approaches that integrate several technologies to mitigate the different spoofing threats. Aerospace expertise is relied upon by the U.S. Space Force who acquires and operates GPS. The FAA also relies on Aerospace to ensure safe use of GPS for aviation.

Rethinking space-based PNT. An advanced, proliferated low Earth orbit (LEO) constellation could serve as an augmentation, backup or as a GPS threat deterrent, capable of operating independently of GPS through the use of crosslinks and other enabling technologies. Currently a maturing concept, once developed, the Very Inexpensive Navigation Enhancement Layer (VINEL) would be deployed with frequent launches to enable continuous innovation. The design itself can be used as a reference architecture for demonstrations and experiments, or as a baseline for future designs by government agencies, academia, laboratories, or industry groups.

For more information, please contact Dr. David Tralli, PNT Hub Lead, Science and Technology Strategy and Development, Office of the Chief Technology Officer (OCTO).

Power companies and utilities have fundamental requirements for time and frequency to enable efficient power transmission and distribution. For example, GPS-based time synchronization devices in power plants and substations can trace the exact location of power line breaks to reduce or avoid electrical anomalies and blackouts.

The Aerospace Corporation

The Aerospace Corporation is a national nonprofit corporation that operates a federally funded research and development center and has approximately 4,000 employees. With major locations in El Segundo, Calif., Albuquerque, N.M., Colorado Springs, Colo., and Washington, D.C., Aerospace addresses complex problems with agility, innovation, and objective technical leadership across the space enterprise and other areas of national significance. For more information, visit www.aerospace.org.