6. Positioning, Navigation, and Timing

Area Description

Space-based navigation systems provide three-dimensional positioning data and a standard timing source to military, civil and commercial users worldwide, 24 hours a day. Precision navigation and timing provide targeting and geolocation information critical to coordinated and accurate force application by any platform in any medium. Today, the Global Positioning System (GPS) provides nearly worldwide coverage and constitutes a national asset.

The growing importance of space-based navigation systems to the national economy, as well as to a variety of non-military needs (civil aviation, emergency management, highway transportation, etc.), has created the need for significant upgrades and modifications to this space constellation. Additional civil signals that are separate from the military signals are one example. Meanwhile, on the military side there is a standing requirement for a "military-only" frequency. Thus, military interest in encrypted signals that are more easily denied to, and less easily denied by, an adversary during hostilities is another factor driving potential changes to the system.

Precise location and timing information, available in real-time, will be a prerequisite for effective force application in future military operations. As "sensor-to-shooter" capabilities mature, thereby accelerating ops tempo and the weapons-delivery cycle, updated targeting data will ensure the "precision" in precision-guided munitions (PGMs) and smaller target acquisition and launch errors for interceptors under ever-shortening information distribution cycles. These tactical advantages will, in turn, add confidence to the planning process, efficiency of force/weapons allocation, and effectiveness in overall operations.

Current plans call for modifying the last 12 of the third-generation GPS satellites, Block IIR, by adding more power, a second civil signal and a new, more robust military signal. The fourth-generation satellite, Block IIF, is under development. This spacecraft will have many improvements over its predecessors to include longer life, improved reliability, more power, and a third civil signal capable of satisfying safety-of-life requirements for civil aviation. Plans are being formulated to conduct an architecture study for the next-generation satellite navigation system, GPS III, capable of meeting military and civil needs through 2030.

Mission Area Objectives

• Continuous global coverage in all environments	• Operation in a navigation warfare environment (robustness)
• Continuous coverage of space (to GEO x 2)	• Denial of unauthorized third-party use
• Improved positional and timing accuracy	• Timely warning of bad data or failures

Supporting Capabilities

On-orbit reconfigurability/upgrades to accommodate changes in GPS requirements

Satellite RF interference/vulnerability mitigation

Software to provide continuous status reporting

Encryption and on-board software functions

Current Technology Initiatives *(Highlights of Current FYDP)*

Near-term activities seek to upgrade the GPS to a jam-resistant military waveform and to develop navigation warfare technologies. This will include work to ensure that the new waveform is resistant to electronic attack without interfering with the operation of current dual-use equipment.

System performance of new-technology spaceborne atomic clocks for ranging and timing synchronization will be demonstrated by non-interference introduction on the spacecraft.

Selected project detail is tabulated in "Projected Applications," below.

Enabling Technologies *(Unconstrained)*

- Technology to achieve increased location accuracy
- Improved precision time sources (10-ps timing accuracy) (atomic/laser clocks)
  - Network-centric communication synchronization techniques
- Technologies for receivers, waveforms and antennas to enable:
  - Penetration of clouds, obscurants, foliage, and terrestrial structures
  - Control/adjustment of signals, power, and frequencies to enable better signal penetration and jam-resistance
- Radiation hardening and shielding of components
  - Lightweight radiation-hardened materials
- Reprogrammable radios and other electronics system components
  - Field programmable gate array (FPGA) technologies
- More efficient solar cells and batteries (chemically or thermally generated electricity, such as thermionic power generation and thermoelectric conversion)
  - E.g., lithium ion/polymer hybrid batteries
  - Affordable solar cell materials and manufacturing
- Algorithms and coding techniques for software and hardware
  - Waveform error correction
  - Encipherment techniques
  - Navigation algorithms
- Inertial guidance techniques
- Pointing and tracking (e.g., laser pointing)
- Software technologies, programming environments
- Simulation modeling tools.


GPS Block IIR


GPS Block IIF

Projected Applications

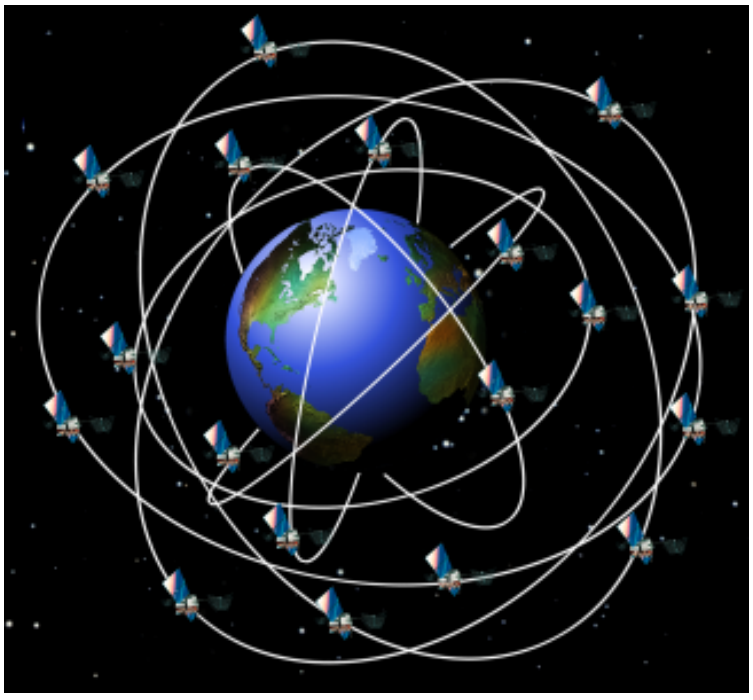
Category	Activities	Status	Agencies
Advanced waveform technologies with anti-jam capabilities	• ***Military waveform studies/assessments***	Technology concepts	Air Force
	– Initial assessments have been conducted and preliminary results delivered		
	– Other studies are ongoing, with future studies planned		
	• ***Current and future military waveform user equipment with anti-jam capabilities***	Technology development and delivery	All Services
	– Ongoing, with deliveries (to all Services)		
Application of geolocation technologies to all DoD systems	• ***Advanced GPS Inertial Navigation Technology***	Development program	Air Force
	– Brassboard delivery ~ FY02		
	• ***Joint Precision Aircraft Landing System***	Dev't pgm	Air Force
	• ***New technology spaceborne atomic clocks***	Technology concept	GPS JPO and Navy
	– To maintain/increase system performance and operability		

Opportunities for Partnering

As a national resource, GPS is managed by the Interagency GPS Executive Board (IGEB), co-chaired by the DoD and Department of Transportation (DOT). IGEB members include NASA and the JCS, as well as other Federal agencies.

As a joint program, the Army, Navy and Air Force have been working together to develop and improve GPS system and user equipment since its inception. GPS has also been adopted by a growing number of civil, commercial and scientific users throughout the world. A large number of equipment vendors are offering literally hundreds of types and models of GPS receivers for sale on the commercial market. The vulnerability of commercial receivers to jamming makes it impossible to use them as-is for military operations. Nevertheless, the highly competitive commercial marketplace has introduced forward-leaning receiver technologies that have found their way into latest generation of military GPS user equipment.

In addition, there is an opportunity for certain military aircraft operating in the National Airspace System to use off-the-shelf (OTS) equipment to be compatible with civilian air traffic control systems that use GPS. The DOT's Federal Aviation Administration (FAA) is lead agency for the development and implementation of those applications.



GPS Constellation