**Satellite Systems - Navigation Systems**

The world's first space-based navigation system was called Transit. It was developed by scientists at Johns Hopkins University's Applied Physics Laboratory in 1958. DOD's Advanced Research Projects Agency (ARPA) initiated the development program in September 1958 and assigned it to the Navy a year later. The Air Force Ballistic Missile Division launched the Navy's first Transit satellite on 13 April 1960. The system achieved initial operational capability in 1964 and full operational capability in October 1968. It used three operational satellites to produce signals whose Doppler effects and known positions allowed receivers—primarily ships and submarines—to calculate their positions in two dimensions. Transit established the principle and some of the technology of navigation by satellite and prepared military users to rely on such a system. However, it was too slow and imprecise for rapidly moving, three-dimensional platforms such as aircraft. Transit's signals were turned off deliberately in December 1996 because DOD had decided to rely on a newer, faster, and more accurate system.

All of DOD's navigation and position-finding missions are now performed by the Global Positioning System (GPS). The system consists of 24 operational satellites that broadcast navigation signals to the earth, a control segment that maintains the accuracy of the signals, and user equipment that receives and processes the signals. By processing signals from four satellites, a user set is able to derive the location of each satellite and its distance from each one. From that information, it rapidly derives its own location in three dimensions.

Besides Transit, GPS had two immediate programmatic ancestors: a technology program called Project 621B, initiated by SAMSO and the Aerospace Corporation in October 1963, and a parallel program called Timation, undertaken by the Naval Research Laboratory in 1964. Project 621B envisioned a constellation of 20 satellites in synchronous inclined orbits providing continuous three-dimensional positioning information. The satellites would broadcast ranging signals using pseudorandom noise, a technique later incorporated in GPS. The project conducted feasibility tests at White Sands Missile Range in 1972, inverting the planned future direction of the signals by using aircraft with prototype user equipment that received signals broadcast by transmitters on the ground and in balloons.

The NRL's Timation Program envisioned a constellation of 21 to 27 satellites in medium altitude orbits providing three-dimensional positioning information. The satellites broadcast passive ranging signals based on highly stable internal clocks, another technique later incorporated in GPS. Experimental Timation satellites 1 and 2, with clocks using quartz-crystal oscillators, were launched in 1967 and 1969. Timation satellites 3 and 4, renamed Navigation Technology Satellites (NTS) 1 and 2, incorporated atomic clocks and were launched in 1974 and 1977 as part of the Phase 1 GPS program.

In 1973, elements of the two programs were combined into the GPS concept, which employed the signal structure and frequencies of 621B with medium altitude orbits and atomic clocks similar to those used for Timation. Deputy Secretary of Defense William P. Clements authorized the start of a program to "test and evaluate the concepts and costs of an advanced navigation system" on 17 April 1973, and he authorized the start of concept validation for the GPS system on 22 December 1973.

GPS was acquired in the classical three phases: validation, development, and production. During the validation phase, Block I navigation satellites and a prototype control segment were built and deployed, and advanced development models of various types of user equipment were built and tested. During the development phase, additional Block I satellites were launched to maintain the initial satellite constellation, a qualification model Block II satellite was built and tested, and manufacture of additional Block II satellites was initiated. In addition, an operational control segment was activated, and prototype user equipment was developed and tested. During the production phase, a full constellation of 24 Block II and IIA (A for advanced) satellites was deployed. User equipment was also produced and put into operation by issuing it to foot soldiers and installing it in ships, submarines, aircraft, and ground vehicles. The full constellation was completed on 9 March 1994, allowing the system to attain full operational capability in April 1995.

GPS supported a wide variety of military operations, including aerial rendezvous and refueling, all-weather air drops, instrument landings, mine laying and mine sweeping, anti-submarine warfare, bombing and shelling, photo mapping, range instrumentation, rescue missions, and satellite navigation. However, GPS was also the focus of a growing civilian market whose users had become far more numerous than military users by the year 2000. Indeed, it was widely used commercially by the time it reached full operational capability, and some commercial applications, such as airline navigation, were both critical and sensitive. At one time, the GPS signal available to civil users contained intentional inaccuracies, a condition known as selective availability, to provide an advantage to authorized military users. At President Clinton’s direction, the intentional inaccuracies were set to zero on 1 May 2000, providing significant improvements in the accuracy available to the system’s civil users.

SMC began launching the next block of GPS satellites, known as IIR (R for replacement), in 1997.The following block of GPS satellites, which incorporated further improvements, was known as Block IIF (F for follow-on). SMC awarded a contract for the development and production of 33 IIF satellites on 22 April 1996, but it reduced the quantity to 12 in 2000 because the operational lifetimes of GPS satellites were turning out to be longer than expected, and it wished to take advantage of the resulting longer intervals between launches to improve the design of the satellites. Four of the IIF satellites had been launched by early 2014, the first on 27 May 2010 using a Delta IV EELV and the fourth on 15 May 2013 using an Atlas V EELV.

SMC also began the development and initial production of a new and more capable generation of GPS space, control, and user segments known as GPS Block III. It issued competitive system definition and risk reduction contracts to Lockheed Martin and Boeing on 5 January 2004, and it awarded a contract for the first increment of Block III satellites (Block IIIA) to Lockheed Martin on 15 May 2008. The contract provided for development and initial production of two satellites with options for up to 10 additional satellites. By early 2014, the active contract provided for production of six satellites, the first two of which were undergoing integrated testing at Lockheed Martin’s facility before delivery.

The Block III satellites would be larger and heavier than the Block IIF satellites, and they would have major enhancements in capability. They would have a design life of 15 years (rather than 12 for IIF) and offer three times greater navigational accuracy and signal power. A stronger military signal (M-code) would have greater resistance to jamming, and a new fourth civil signal (L1C) would be compatible with signals from the European Space Agency's navigation satellite system known as Galileo.