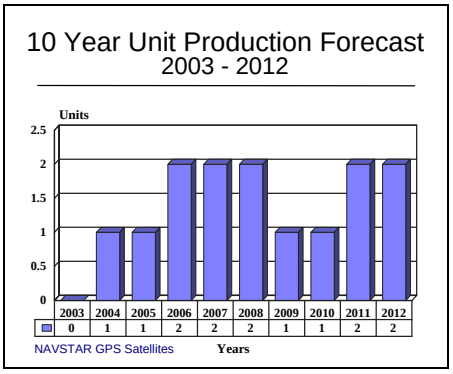
NAVSTAR GPS Satellites - Archived 12/2004

Outlook

- Forecast International projects the U.S. Air Force to purchase some 14 NAVSTAR GPS satellites over the next decade
- In 2004, look for the NAVSTAR GPS program to continue GPS IIF satellite development



Orientation

Description. The Navigation Signal Timing and Ranging (NAVSTAR) Global Positioning System (GPS) is a constellation of orbiting satellites that provides navigation data to military and civilian users all over the world. The system is managed by the United States NAVSTAR GPS Joint Program Office at the Space and Missile Systems Center, Los Angeles Air Force Base, California.

Sponsor

United States Air Force Space Command
Peterson AFB, Colorado (CO) 80914
Tel: +1 719 554 3731
Fax: +1 719 554 6013
Web site: http://www.peterson.af.mil/hqafspc/

United States Air Force
Space and Missile Systems Center
Los Angeles AFB, California (CA) 90245
Tel: +1 310 363 1110
Web site: http://www.losangeles.af.mil

Contractors

Boeing World
100 North Riverside Plaza
Chicago, Illinois (IL) 60606
Tel: +1 312 544 2000
Web site: http://boeing.com
(Block II/IIA/IIF satellites)

Lockheed Martin
6801 Rockledge Drive
Bethesda, Maryland (MD) 20817
Tel: +1 301 897 6000
Fax: +1 301 897 6406
Web site: http://www.lockheedmartin.com
(Block IIR satellites)

Status. Operational, with a constellation of 28 GPS satellites. GPS Block IIR satellites are replacing Block II satellites, while initial Block IIF satellites are slated for delivery in 2004.

Total Produced. Together, some 50 GPS Block II and Block IIR satellites have been produced through 2002.

Application. To provide navigation data to military and civilian users all over the world.

Price Range. Block IIR Navstar satellites cost approximately US$40 million; Block IIF spacecraft cost about US$30 million.

Technical Data

	Metric	U.S.
Dimensions		
(Block IIF)	1.8 x 1.6 x 1.4 m	6.1 x 5.5 x 4.6 ft
Weight		
Block I	524.8 kg	1,157 lb
Block II	843.6 kg	1,860 lb
Block IIR	2,036 kg	4,480 lb
Block IIF	2,136	4,710 lb
Orbit		
All Models	12 hr, 55° circular	
Performance (Block IIF)		
Autonomous operations	Up to 60 d	
Power	1,510 W (EOL)	
Uplink data rate	1 or 2 Kbps	
Downlink data rate	Up to 32 Kbps	
Time accuracy offset	20 ns	
Design life	15 yr	

Design Features. The NAVSTAR GPS is a satellite-based radio navigation system. It permits land, sea, and airborne users to instantly ascertain data regarding three-dimensional position, velocity, and time worldwide, 24 hours a day, in all types of weather. The complete GPS constellation consists of 21 active satellites and three spares placed in 12-hour, 55° inclination angle orbits. These are segregated into six planes with satellites evenly spaced (120° separation) within each of these planes. Rockwell (now Boeing) was prime contractor for the development of the 24 Block II replacement satellite constellation, which was launched from 1989 to 1994.

Transmission Frequencies. The downlink frequency is 1783.74 MHz. The satellites transmit navigation data in spread spectrum format using the L1 band, 1575.42 MHz, and L2 band, 1227.6 MHz.

Nuclear Blast Detection. The NAVSTAR GPS Block II satellites feature instruments for detecting above-ground blasts of nuclear weapons. Sandia National Laboratories produces one of these sensors, called a bang meter. It always faces the Earth's surface to monitor surface and atmospheric nuclear explosions. The device can distinguish the bright flash of lightening from the distinct flash a nuclear fireball produces. Other sensors aboard the NAVSTAR GPS satellite are designed to detect X-rays and neutrons from nuclear blasts in space. These sensors are produced by the Los Alamos Laboratory and are mounted on various parts of the satellite to provide a view in all directions.

Major Payload Elements. The major elements of the GPS satellite are the pseudo-random noise assembly, the atomic frequency standard (clock), the processor, and the L-band antenna.

C/A and P Codes. As part of the GPS's selective availability feature, the L1 signal is modulated with a precision (P or P[Y]) and a coarse acquisition (C/A) pseudo-random-code quadraphase modulated with the P code. The C/A code is available to any user at no cost. Military users who can access the P code use the C/A code to acquire an initial estimate of position, which is necessary to decipher the P code. C/A code is transmitted at 1.023 million bits per second.

Both the L1 and L2 signals are modulated by the precision (P) code. It carries 10 times the data of the C/A code, at 10.23 Mbps. Along with carrying the navigation data, it can be used to carry messages or other non-navigation data. Two bands are used for the precision code, and by differentially comparing the two, the receiver compensates for distortions of accuracy due to atmospheric and ionospheric conditions. To "correct" this situation, Block IIR satellites have a provision to intentionally degrade the C/A signal and deny non-paying users the usual C/A accuracy when necessary, such as in time of war.

Specialized users, who can take the time to gather hours of data, use GPS to measure the rate of continental drift, which is measured in centimeters per year.

GPS has turned out to be far more accurate than originally envisioned. It rivaled even very long baseline interferometry (VLBI) using quasars or pulsars as sources of a modulated signal.

Ground Element. Ground stations located in friendly nations act as the control segment of the NAVSTAR system. The launch of the first Block II satellite in February 1989 marked the official transfer of the master control station to the Consolidated Space Operations Center at Falcon Air Force Base, Colorado Springs, Colorado. The master control station maintains the accuracy of the atomic clocks housed within the satellites, making sure all are synchronized.

Operational Characteristics. Each satellite transmits its ephemeris data, within a precisely measured time reference. The location of a GPS receiver can be determined at any given time by processing the data provided by four satellites. The timing data is accurate to within a millionth of a second, and they are now being used as a timing standard for ultra-high-accuracy scientific applications in many parts of the world.

Variants/Upgrades

Block I. This was the early version of the satellites.

Block II/IIA/IIB. These satellites were follow-on versions, launched from 1989 to 1997, to replace Block I satellites.

Block IIR. As Block II satellites aged, the U.S. Air Force planned to replace them with updated Block IIR satellites beginning in 1997. The new satellites were capable of operating autonomously for up to 180 days. Lifetime of the spacecraft was calculated at seven-and-a-half years. Lockheed Martin (formerly Martin Marietta Astro Space Division) was the prime contractor for the 21-satellite Block IIR programs. The final delivery occurred in 1999.

Block IIF. These units, with a design life of 15 years and planned for deployment later in the decade, feature a new payload to increase the accuracy of the system to civilian users. The current GPS system has two accuracy modes: L1, a clear acquisition mode available to all users, and L2, a protected mode for military users who have the key to unscramble the required data. The new L5 frequency payload will improve the accuracy of the non-military GPS signal from 30 meters to 21.2 meters.

Block III. Block III is a dramatically improved version, with launches to begin at the end of the decade. This generation of GPS satellites is expected to provide navigation information until the year 2030. The Air Force Space and Missiles Systems Center awarded two GPS Block III Architecture Studies/Analyses of Alternatives contracts worth US$16 million, in November 2000.

Program Review

The NAVSTAR Global Positioning System began as the U.S. Navy's TIMATION (Time/Navigation) program and U.S. Air Force's Program 621B. The first navigation experiment involving a U.S. Navy Transit satellite occurred in 1960 and provided two-dimensional data. The GPS program entered its concept validation phase in 1974, followed four years later by the launch of the first NAVSTAR satellites.

Four NAVSTAR satellites were launched in 1978, with each satellite designed to test the onboard clock and frequency standard system. Rockwell International developed the network of Block II configuration satellites that replaced the original partial network of Block I experimental satellites. In November of 1990, the first Navstar GPS Block IIA satellite was launched. Also in that month, the first NAVSTAR GPS Block IIB satellite was launched.

In March 1991, an 11-year-old NAVSTAR GPS satellite was deactivated by ground controllers after it lost its ability to generate electrical power. It had exceeded its design life by six years. Launched in April 1980, the ailing satellite was part of the original experimental NAVSTAR GPS system.

In January 1996, the U.S. Air Force selected Boeing Space Systems to build the first six GPS Block IIF satellites. The contract had one option for 15 satellites and a second option for 12 more. One month later, the Air Force reversed course and announced that Boeing would build only 12 Block IIF spacecraft (not 33 as originally planned). In 1997, the Air Force began replacing aging and failing Block II satellites with updated Block IIR satellites.

In November 2000, Boeing and Lockheed Martin were awarded study contracts worth US$16 million each to further develop the design concept for GPS Block III. Although Spectrum Astro lost out during this phase of the competition, it continues to develop a GPS concept using its own funding.

In March of 2001, the U.S. Air Force Space and Missile Systems Center awarded Lockheed Martin a US$110 million contract to implement modernization changes for up to 12 Navstar GPS Block IIR satellites. Modernization changes will include incorporating a second civil signal and a new military signal into the system.

Latest Information. In November 2002, Boeing announced it received approval from the U.S. Air Force to begin space vehicle production for the first three satellites of the NAVSTAR GPS Satellite IIF Modernization program. The added capabilities of the IIF satellites include a new signal for civilian users and critical, secure operational M-codes for the warfighter.

In March of 2003, Boeing announced the successful launch of its GPS IIR-9 satellite from Cape Canaveral Air Force Station in Florida. Its deployment brought the GPS constellation to 28 satellites, four more than the required minimum. In 2004, look for the U.S. Air Force NAVSTAR GPS program to continue GPS IIF satellite development.

Funding

U.S. FUNDING

	FY03		FY04		FY05(Req)	
	QTY	AMT	QTY	AMT	QTY	AMT
RDT&E (USAF)						
PE 0305165F Project 3030	-	285.42	-	146.47	-	129.93
PE 0603421F Project 4993	-	55.58	-	0.00	-	40.67

	FY06(Req)		FY07(Req)		FY08(Req)		FY09(Req)	
	QTY	AMT	QTY	AMT	QTY	AMT	QTY	AMT
RDT&E (USAF)								
PE 0305165F Project 3030	-	107.13	-	84.75	-	46.38	-	39.70
PE 0603421F Project 4993	-	180.51	-	291.63	-	779.85	-	792.80

	FY03		FY04		FY05(Req)	
	QTY	AMT	QTY	AMT	QTY	AMT
Procurement (USAF) Global Positioning System (Space)	-	226.34	-	258.85	-	334.88

	FY06(Req)		FY07(Req)		FY08(Req)		FY09(Req)	
	QTY	AMT	QTY	AMT	QTY	AMT	QTY	AMT
Procurement (USAF) Global Positioning System (Space)	-	342.19	-	266.24	-	131.96	-	82.15

All US$ are in millions.

Sources: US Department of the Air Force FY 2004/2005 RDT&E Descriptive Summaries and Procurement Document

Recent Contracts

Contractor	Award ($ millions)	Date/Description
Lockheed Martin	53.0	Aug 2000 – CPIF contract for modernization changes, incorporating a second civil signal and a new military signal, for 12 NAVSTAR GPS Block IIR satellites. (F04701-00-C-0006)
Boeing	9.4	Aug 2000 – Contract modification for engineering efforts in support of a crosslink transponder data unit upgrade development on the GPS IIF satellite. (F04701-96-C-0025-P00096)

Contractor	Award ($ millions)	Date/Description
Lockheed Martin	12.4	Dec 2000 – Lockheed Martin Missiles and Space Company was awarded a contract to provide for advanced long-lead parts in support of the modernization development effort for up to 12 NAVSTAR GPS Block IIR satellites. Space and Missile Systems Center, Los Angeles Air Force Base, CA, is the contracting agency. (F04701-00-C-0006-P00001)
Lockheed Martin	110.2	Mar 2001 – Lockheed Martin Missiles and Space Company was awarded a contract to provide for implementation of modernization changes for up to 12 Navstar GPS Block IIR satellites. At this time, US$37,000,000 of the contract funds has been obligated. Space and Missile Systems Center, Los Angeles Air Force Base, CA, is the contracting agency. (F04701-00-C-0006, P00006)

Timetable

Year	Major Development
1960	First satellite navigation experiment (Navy Transit)
1974	Concept validation phase begins
1978	First of initial four NAVSTAR satellites launched
1979	System validation phase begins
1980-85	Satellites 5 through 10 launched
1986	Production phase for Block II GPS satellites begun
1987	Delivery of 1st Block II satellite; first delivery of military GPS receivers
1988	RFP for study of Block IIR NAVSTAR satellites
1989	Launch of 2nd through 5th NAVSTAR GPS
1990	Launch of 6th through 10th NAVSTAR GPS
1990	NAVSTAR GPS Block IIR contract; NAVSTAR GPS declared operational
1991	Launch of 11th NAVSTAR GPS
1992	Launch of 12th through 17th NAVSTAR GPS
1992	Final delivery of Block II NAVSTAR satellites
1993	Launch of 18th through 23rd NAVSTAR GPS
1994	Launch of 24th NAVSTAR GPS
1995	24 satellites achieve Full Operational Capability
1996	Initial Block IIR deliveries
1996	Contract awarded for Block IIF satellites
1996	Third replacement GPS satellite launched
1997	Block IIR-1 lost in Delta vehicle explosion
1997	Block IIR-2 launched on Delta II (7925)
1997	Launch of 4th (and final) Block IIA replenishment satellite, or 28th Block II
1999	Block IIR-3 launched on Delta II (7925)
2000	Block IIR-4 launched on Delta II (7925)
2000	Block IIR-5 launched on Delta II (7925)
2000	Block IIR-6 launched on Delta II (7925)
2001	Block IIR-7 launched on Delta II (7925)
2002	Boeing receives approval from U.S. Air Force to begin space vehicle production for the first three satellites of the NAVSTAR GPS IIF Modernization program
2003	GPS IIR-9 satellite is launched from Cape Canaveral Air Force Station in Florida
2004	Look for the NAVSTAR GPS program to continue GPS IIF satellite development

Worldwide Distribution

This is a **United States Department of Defense** program only, although commercial receivers are used worldwide.

Forecast Rationale

The Navigation Signal Timing and Ranging (NAVSTAR) Global Positioning System (GPS) is a constellation of orbiting satellites that provides navigation data to military and civilian users all over the world. The United States NAVSTAR GPS Joint Program Office at the Space and Missile Systems Center, Los Angeles Air Force Base, California manages the system.

As indicated by the **Ten-Year Outlook** chart, Forecast International projects the U.S. Air Force to purchase approximately 14 NAVSTAR GPS satellites over the next decade. The increase in civilian and military use of the NAVSTAR GPS is driving satellite purchases.

The NAVSTAR GPS IIF satellite will ensure the United States possesses the capabilities it needs to support the infrastructure for Homeland Security and National Defense. Designed for flexibility and growth, the GPS IIF system architecture can accommodate hardware and software changes via incremental technology upgrades to improve efficiency and introduce new military capabilities. In turn, this incremental upgrade approach to the GPS IIF program will reduce the technical risks inherent in developing GPS III, the next generation satellite system.

Ten-Year Outlook

ESTIMATED CALENDAR YEAR PRODUCTION

			High Confidence Level			Good Confidence Level				Speculative			
Designation	System	Thru 02	03	04	05	06	07	08	09	10	11	12	Total 03-12
NAVSTAR GPS SATELLITES	BLOCK IIF SATELLITE-LOT 1 (USAF)	0	0	1	1	1	0	0	0	0	0	0	3
NAVSTAR GPS SATELLITES	BLOCK IIF SATELLITE-LOT 2 (USAF)	0	0	0	0	1	2	2	1	1	0	0	7
NAVSTAR GPS SATELLITES	BLOCK III SATELLITE (USAF)	0	0	0	0	0	0	0	0	0	2	2	4
NAVSTAR GPS SATELLITES	Prior Prod'n:	50	0	0	0	0	0	0	0	0	0	0	0
Total Production		50	0	1	1	2	2	2	1	1	2	2	14