

GPS III

Payloads

Briefing

GPS III (*Global Positioning System III*) is the proposed follow-on to the NAVSTAR GPS Block 2R and Block 2F military radio positioning and navigation satellites. The current NAVSTAR GPS constellation consists of 24 (plus three in-orbit spares) second-generation Block 2, third-generation Block 2A, and fourth-generation Block 2R model satellites deployed in six planes of four satellites each.

NAVSTAR GPS provides worldwide passive, all-weather, all-altitude precise three-dimensional position, velocity, and time. Each satellite supports two types of service. For civilian access, a standard positioning service (SPS) signal is broadcast. An encrypted signal, precise positioning service (PPS) is broadcast for military applications.

The GPS III system, which will number 32 satellites, will have about 500 times the transmitter power of the current system and thus provide more secure, jam-resistant military signals and more accurate civilian signals. Plans call for launching GPS III beginning in 2018. The constellation would remain operational through at least 2030.

On August 11, 2000, The US Air Force Space & Missile Systems Center (SMC) issued a Request for Proposals (RFP) for the GPS III program. On November 9, 2000, SMC awarded Boeing Air Force Space Systems and Lockheed Martin Space Systems Co. 12-month contracts worth \$16 million each for System Architecture and Definition (SARD) studies in support of

GPS III development. Boeing and Lockheed Martin completed their architecture studies work in November 2001. The companies received separate contracts from the Air Force on January 5, 2004 to proceed with a comprehensive 24-month Systems Requirement Review (SRR) Phase A study. Each of the contracts was valued at \$20.8 million. On August 2, 2006, the Air Force awarded GPS III contract modifications to Boeing and Lockheed Martin worth \$10 million each. The actions call for additional design work on the satellites, taking into account the Air Force's new acquisition strategy that called for a "low risk incremental approach" to fielding system capabilities.

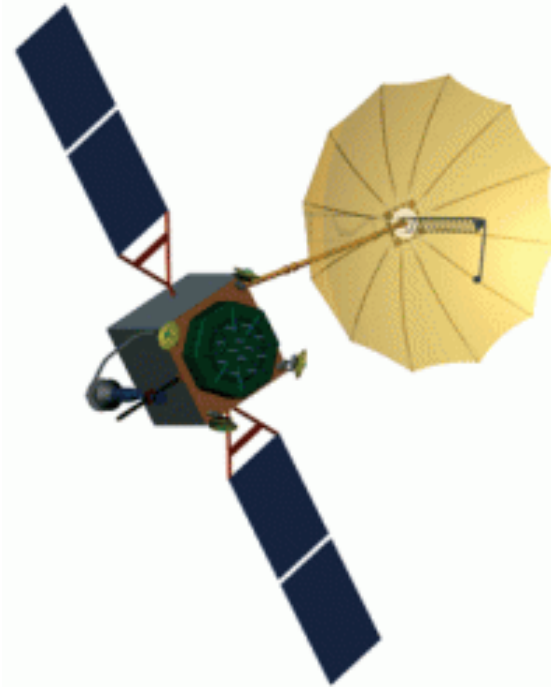
The Air Force awarded Lockheed Martin the prime contract on May 15, 2008 to develop and build the GPS III system. The

action, valued at \$1.5 billion, calls for production of eight GPS III Block A satellites, plus later increments of eight GPS III Block B and 16 GPS III Block C satellites. On February 25, 2010, the Air Force awarded Raytheon Space Systems a six-year \$856 million contract to build the Advanced Control Segment (OCX) for the GPS III system. The contract could ultimately be worth as much as \$1.535 billion, if all options are exercised.

Recent Developments

Falcon 9 Will Launch Third GPS III

On March 14, 2017, SMC awarded Space Exploration Technologies, Inc. (SpaceX) a \$96.5 million contract to launch the GPS III-3 satellite aboard a Falcon 9 v1.2 rocket in 2019. Last year, SpaceX won an \$82.7 million contract to launch the



GPS III-2 on a Falcon 9 v1.2 in 2018.

New GPS Production Plant

Construction has begun on a new GPS III production plant (Gateway Center) for Lockheed Martin near Denver, CO. The \$350 million facility, which will also produce other kinds of satellites, is planned for completion by 2020. It will include state-of-

the-art high bay clean room, a large thermal vacuum chamber, an anechoic chamber for testing of sensors and communications systems, and an advanced test operations and analysis center.

Harris Delivers Navigation Payload for Third GPS III

Harris Corp. delivered the navigation payload for the GPS III-3 satellite to Lockheed Martin

on August 9, 2017. The payload will be integrated into the satellite by the end of the summer. Integration of the second navigation payload with the GPS III-2 was completed in May.

Executive

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NAVSTAR GPS Joint Program Office
PO Box 92960
Worldway Postal Center
Los Angeles, CA 90009
USA
tel: +1 (310) 363-3538
(*program manager*)

Manufacturers

Lockheed Martin Missiles & Space Co.
1111 Lockheed Martin Way
Sunnyvale, CA 94089
USA
tel: +1 (408) 742-4321
(*prime contractor*)

Specifications

Mass (at launch):	3,680 kg
Design lifetime:	15 yr
Orbit:	20,200 x 20,200 km, 55° inclined
Deployment:	6 orbital planes
Power:	4,480 W (end of life)
Accuracy (horizontal):	0.5 m
Accuracy (vertical):	1.0 m

Subsystems

Frame

The frame of the satellite is based on Lockheed Martin's A2100A modular bus made of

composite. The composite structures of the bus are built by Orbital ATK, Inc. of San Diego,

CA. Orbital ATK of Commerce, CA also manufactures the propellant tanks.

Launch Systems

The first GPS III satellite will be launched aboard a Boeing Delta IV-M+ rocket, marketed by United Launch Alliance (ULA) of Centennial, CO. The

second and third GPS IIIs are contracted to go up on Falcon 9 v1.2 rockets, produced and marketed by Space Exploration Technologies, Inc. (SpaceX) of

Hawthorne, CA. The remainder of the GPS IIIs will likely be launched by either Falcon 9 v1.2s or ULA Atlas V/411 rockets.

Power

Electrical power for each satellite will be provided by two pairs of aluminum honeycomb solar arrays built by Lockheed Martin Space Systems in Sunnyvale, CA. The arrays employ high-efficiency ultra triple

junction (UTJ) solar cells. The satellites carry rechargeable nickel-hydrogen (NiH₂) batteries.

In the past, Lockheed Martin has contracted with several companies to supply solar cells for its

satellites, including EMCORE Corp. of Alhambra, CA and SolAero Technologies Corp. of Albuquerque, NM. It has also contracted with EaglePicher Technologies, LLC of Joplin, MO to provide NiH₂ batteries.

Guidance & Control

Attitude and Orbit Control

The satellites are designed to be zero-momentum, 3-axis stabilized, and Earth oriented, with Sun-nadir steering capability. They carry static Earth and Sun sensors and have control reaction wheels and magnetic torquers. Inertial measurement units (IMUs) are provided by Honeywell Aerospace Defense of Phoenix, AZ.

Propulsion

Moog-ISP Ltd. of Westcott, Buckinghamshire, UK is supplying LEROS 1 C bipropellant hydrazine-fueled rocket engines.

In recent years, Lockheed Martin has contracted with Aerojet Rocketdyne Corp. of Sacramento, CA to supply AR-5 Hall Effect and MR-510 Arcjet electric propulsion subsystems, as well as monopropellant rocket

engines for the modernized A2100 satellite.

Operational Control System

Raytheon Space Systems Div. of Aurora, CO is the prime contractor on construction of the Operational Control System (OCX). The OCX consists of 20 ground stations and antennas around the world. Raytheon's contractor team members include:

- Boeing Co. of Aurora, CO
- Braxton Technologies LLC of Colorado Springs
- Infinity Systems Engineering LLC of Colorado Springs
- ITT Geospatial Systems of Rochester, NY
- NASA Jet Propulsion Laboratory (JPL) of Pasadena, CA

Satellite Control Software

Overlook Systems Technologies, Inc. of Colorado Springs, CO supplies control segment software development, sustainment and testing, configuration/data management, and engineering drawing and technical order development and maintenance.

Additionally, several companies have been involved in research and development on software and technology options for the advanced satellite control segment, including:

- General Dynamics C4 Systems of Scottsdale, AZ
- Integral Systems, Inc. of Lanham, MD
- Northrop Grumman Space Technology of Redondo Beach, CA

- Raytheon Space and Airborne Systems of El Segundo, CA

Data Handling/Transmission

General Dynamics Advanced Information Systems of Gilbert, AZ provides the Network Communications Element (NCE) for the satellites, including the ground-to-space command and control channel, the space-to-space inter-satellite channel, and

the command and telemetry communication channels.

M-Code Signals

At least three companies have been involved in developing technology to enable user terminals to receive and process M-

Code encrypted military signals, including:

- L3/Interstate Electronics Corp. of Anaheim, CA
- Raytheon Space and Airborne Systems of El Segundo, CA
- Rockwell Collins Government Systems Div. of Cedar Rapids, IA

Thermal Control

The satellites have a passive thermal control system that in-

cludes heat pipes, control blankets, thermal coatings, radiators,

and electrically controlled heaters.

Payload

- Department of National Defence in Ottawa, Ontario, Canada
- navigation payload element (NPE)*; development of the Mission Data Unit (MDU)

- ada: Search and Rescue/GPS (SAR/GPS)
- Naval Research Laboratory (NRL) in Washington, DC: Laser Retroreflector Array (LRA)

- IIT Exelis, Inc. of Clifton, NJ: advanced
- PerkinElmer, Inc. of Waltham, MA: Rubidium clocks

* The NPE includes the radiation-hardened payload computer (known as the Mission Data Unit), four L-band transmitters (L1, L2, L3, L5), three atomic frequency standards (Rubidium clocks), and signal filters.

Other Subsystems & Services

Engineering and design services for construction of Lockheed Martin’s new production plant near Denver, CO for GPS III and other satellites include:

- ETS-Lindgren, LP Cedar Park, TX: anechoic chamber design and construction
- Dynavac Corp., Hingham, MA: thermal vacuum chamber design and construction
- Hensel Phelps Construction Co., Greeley, CO: general contractor
- Matrix PDM Engineering, Inc., Sewickley, PA: construction engineering

Contract Briefs

Date	Contract Number	Source	Value	Details
<i>Boeing, Air Force Space Systems</i>				
08/02/06	FA8807-04-C-0002	SMC	\$10,000,000	CPFF contract modification to accomplish a Delta System Requirements Review (SRR) on the Global Positioning System III program in October 2006. Work scheduled for completion in December 2006.
<i>Boeing Integrated Defense Systems</i>				
11/09/00	F04701-01-C-0010	SMC	\$16,000,000	FFP contract to provide for architecture studies in support of the Global Positioning System III program. Work scheduled for completion by 11/02/01. PE involvement: 0305165F. Program involvement: GPS.
01/05/01	FA8807-04-C-0002	SMC	\$10,330,000	Increment as part of a \$20,800,000 CPFF contract for the GPS III Phase A acquisition to select up to

two contractors to competitively mature GPS III requirements for a successful system requirements review. Work scheduled for completion by 12/31/05. Program involvement: GPS III.

01/05/04	FA8807-04-C-0002	SMC	\$20,800,000	CPFF contract to competitively mature GPS III requirements for a successful system requirements review in support of key decision Point B acquisition milestone. Work scheduled for completion by December 2005.
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General Dynamics Advanced Information Systems

03/21/14	—	Lockheed Martin	\$26,000,000	Contract to provide the Network Communications Element (NCE) for Space Vehicles 5 and 6, including the ground-to-space command and control channel, the space-to-space inter-satellite channel, and the command and telemetry communication channels within each satellite.
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09/29/14	—	Lockheed Martin	\$25,400,000	Contract to provide the Network Communications Element (NCE) for Space Vehicles 7 and 8, including the ground-to-space command and control channel, the space-to-space inter-satellite channel, and the command and telemetry communication channels within each satellite.
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General Dynamics C4 Systems

07/11/05	—	SMC	\$1,200,000	Six-month research and development contract to study hardware, software and technology options that will deliver an advanced Global Positioning System (GPS) satellite control segment architecture. The GPS Operation Control Segment (OCX) program will focus on military transformational and civil needs across the globe, including advanced anti-jam capabilities, improved system security, accuracy and reliability.
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Harris, ITT Exelis

03/20/12	—	Lockheed Martin	\$32,000,000	Contract to manufacture the navigation payloads for the GPS III Space Vehicles 3 and 4.
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Honeywell

04/10/10	—	Lockheed Martin	\$45,000,000	Contract to supply supply Inertial Measurement Units (IMU) for the first two GPS III satellites, with options for up to 10 additional satellites.
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Integral Systems

07/11/05	—	SMC	\$1,200,000	Six-month research and development contract to study hardware, software and technology options that will deliver an advanced Global Positioning System (GPS) satellite control segment architecture. The GPS Operation Control Segment (OCX) program will focus on military transformational and civil needs across the globe, including advanced anti-jam capabilities, improved system security, accuracy and reliability.
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L-3/Interstate Electronics

05/28/03	—	SMC	\$630,000	Increment as part of an \$10,425,619 contract to reduce risk and advance technology required for the future development of modernized military Global Positioning System User Equipment
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(MUE). Work scheduled for completion by 02/28/05. PE involvement: 0305164F. Program involvement: GPS.

Lockheed Martin Space Systems

11/09/00	F04701-01-C-0008	SMC	\$16,000,000	FFP contract to provide for architecture studies in support of the Global Positioning System III program. Work scheduled for completion by 11/02/01. PE involvement: 0305165F. Program involvement: GPS.
01/05/01	FA8807-04-C-0001	SMC	\$10,330,000	Increment as part of a \$20,800,000 CPFF contract for the GPS III Phase A acquisition to select up to two contractors to competitively mature GPS III requirements for a successful system requirements review. Work scheduled for completion by 12/31/05. Program involvement: GPS III.
01/05/04	FA8807-04-C-0002	SMC	\$20,785,675	CPFF contract to competitively mature GPS III requirements for a successful system requirements review in support of key decision Point B acquisition milestone. Work scheduled for completion by December 2005.
08/02/06	FA8807-04-C-0001	SMC	\$10,000,000	CPFF contract modification to accomplish a Delta System Requirements Review (SRR) on the Global Positioning System III program in October 2006. Work scheduled for completion in December 2006.
11/01/06	FA8807-04-C-0001	SMC	\$24,950,000	Increment as part of a \$49,900,000 CPFF contract to accomplish a system design review in March 2007 and Key Decision Point B in June 2007. Work scheduled for completion by 6/30/07. PE involvement: 0305165F.
05/04/12	FA8807-08-C-010	SMC	\$67,961,418	CPFF contract to provide on-orbit operations engineering support research and development of GPS III space vehicles One and Two. Work is scheduled to be completed by 5/17/2014. Program involvement: GPS III.
02/08/13	FA8807-13-C-0002	SMC	\$62,000,000	FFP contract for Global Positioning System III Space Vehicles 5 and 6. Work is scheduled to be completed by 6/30/2017. Program involvement: GPS III.
02/03/14	FA8807-13-C-0002	SMC	\$14,430,612	FPIF contract for GPS III long lead material for Space Vehicles 7 and 8. The work will be performed in Clifton, NJ. Work is scheduled to be completed by 6/30/2015. Program involvement: GPS III.
03/31/14	FA8807-08-C-0010	SMC	\$245,778,905	Modification to a CPIF contract for additional Global Positioning System III Space Vehicles 7 and 8. The work will be performed in Littleton, CO. Work is scheduled to be completed by 4/1/2018. Program involvement: GPS III.
05/21/15	FA8807-08-C-0010	SMC	\$12,454,485	Modification to a previously awarded contract for the alternate payload processing facility. Work is scheduled to be completed by 12/31/2017. PE involvement: 0603423F
02/04/16	FA8807-08-C-0010	SMC	\$6,000,000	Increment as part of a \$96,040,000 undefinitized contract to provide Global Positioning System (GPS) III contingency operations services and supplies to modify the current GPS control segment to operate all GPS III satellites that are

launched prior to the transition to the Next Generation Operational Control System. Furthermore, this action will buy GPS III satellite vehicle simulation modules, GPS Simulator, and updates to the GPS Positional Training Emulator. Work will be performed in Littleton, CO and Gaithersburg, MD. The contract is scheduled to be completed by 12/31/2019. Program involvement: GPS. RDT&E involvement: 0603423F.

07/22/16	FA8823-13-C-0002 SMC	\$8,615,667	Modification (P00079) to a previously awarded contract action for the Global Positioning System (GPS) control segment to include the master control station, the alternate master control station, a telecommunications simulator test station, a consolidated test environment, four ground antennas and six monitor stations. The master control station and the alternate master control station consists of the following software systems: architecture evolution plan and the GPS information network. Additionally, there is a training system for the architecture evolution plan called the Positional Training Emulator as well as system simulators. The contract is scheduled to be completed by 7/31/2017. Program involvement: GPS.
09/21/16	FA8807-08-C-0010 SMC	\$373,450,000	Increment as part of a \$395,000,000 modification (P00386) to exercise an option on a previously awarded contract action for GPS III Space Vehicles 9 and 10. The contract is scheduled to be completed by 8/8/2022. Program involvement: GPS III.

Lockheed Martin Information Systems & Global Services

12/14/12	FA8823-13-C-0002 SMC	\$104,205,172	FFP contract for Global Positioning System control segment sustainment. Work is scheduled to be completed by 6/30/2019.
01/31/13	FA8823-13-C-0001 SMC	\$68,856,746	FPIF contract for Global Positioning System on-orbit support. The work will be performed in Colorado Springs, CO. Work is scheduled to be completed by 7/31/2018.
08/01/16	FA8823-13-C-0002 SMC	\$8,504,148	Modification (P00080) to a previously awarded contract action to provide sustainment functions as required for the Global Positioning System (GPS) control segment to include modernized-monitor station technology improvement and capability receiver, test and deploy upgrades to the GPS monitor station receiver elements. The contract is scheduled to be completed by 10/31/2018. Program involvement: GPS.

Northrop Grumman Space Technology

07/11/05	—	SMC	\$1,200,000	Six-month research and development contract to study hardware, software and technology options that will deliver an advanced Global Positioning System (GPS) satellite control segment architecture. The GPS Operation Control Segment (OCX) program will focus on military transformational and civil needs across the globe, including advanced anti-jam capabilities, improved system security, accuracy and reliability.
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PerkinElmer

09/10/09	—	ITT	\$15,000,000	Contract to design and implement several engineering advances into its heritage GPS Block IIR and Block IIF Rubidium Atomic Frequency Standards (RAFS), as well as qualify and deliver flight units for the first two satellite vehicles by March 2012,
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Raytheon Space and Airborne Systems

05/28/03	—	SMC	\$810,000	Increment as part of an \$11,298,869 contract to reduce risk and advance technology required for the future development of modernized military Global Positioning System User Equipment (MUE). Work scheduled for completion by 02/28/05. PE involvement: 0305164F. Program involvement: GPS.
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07/11/05	—	SMC	\$1,200,000	Six-month research and development contract to study hardware, software and technology options that will deliver an advanced Global Positioning System (GPS) satellite control segment architecture. The GPS Operation Control Segment (OCX) program will focus on military transformational and civil needs across the globe, including advanced anti-jam capabilities, improved system security, accuracy and reliability.
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Rockwell International, Collins Government Systems Div.

05/28/03	—	SMC	\$777,000	Increment as part of an \$11,351,483 contract to reduce risk and advance technology required for the future development of modernized military Global Positioning System User Equipment (MUE). Work scheduled for completion by 02/28/05. PE involvement: 0305164F. Program involvement: GPS.
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Space Exploration Technologies

04/29/16	—	SMC	\$82,700,000	National Security Space (NSS) launch services contract for Falcon 9 v1.2 launch vehicle production, mission integration, and launch operations for the GPS III-2 satellite.
03/14/17	—	SMC	\$96,500,490	National Security Space (NSS) launch services contract for Falcon 9 v1.2 launch vehicle production, mission integration, and launch operations for the GPS III-3 satellite.

Funding

<i>RDT&E (\$ Millions)</i>	FY09	FY10	FY11	FY12	FY13	FY14	FY15	FY16	FY17*
Air Force									
PE 0305265F									
GPS III Space Segment	379.0	423.5	430.1	444.8	281.9	201.0	212.6	180.9	179.2
<i>Procurement (\$ Millions)</i>	FY13	FY14	FY15	FY16**	FY17*				
Space Procurement, Air Force									
GPS III Space Segment	491.2 (2)	480.6 (2)	287.6 (1)	179.6	34.1				

* Request

** Estimate

Costs

Estimated cost of the GPS III program is more than \$8 billion, which includes about \$6.3 for research and development, plus \$1.8 billion for procurement of hardware.

The price of the first GPS III satellite is estimated at just over \$500 million. The average unit cost for the satellites, however, is expected to drop over time to about \$200 mil-

lion. The cost of the Operational Control System (OCX) is estimated at nearly \$5.5 billion. The OCX was originally priced at \$3.5 billion.

Teal Group Evaluation

The GPS III program is progressing much slower than planned. The original target launch date for the first of the satellites was 2014, and now the soonest the GPS III-1 is likely to go up will be next year. There have been some serious technical issues and delays with major elements of the system, notably the ground segment (Raytheon) and the power system for the satellites (Harris).

The network of ground stations is not expected to be completed now until 2022, due largely to an inability to resolve software engineering and encryption problems, thus creating what has been referred to by US military officials as a “cyber security disaster.” It has generally believed that the Air Force vastly underestimated the sophistication and amount of cyber attacks against which the OCX system would need to protect.

As to the power issue, it has mostly involved improper testing

of the ceramic capacitors designed to manage voltage power. The capacitors, as it turns out, were not subjected to the proper qualification tests. And so the first GPS III satellite has been built with potentially flawed capacitors. The second and third satellites will have the capacitors replaced, but that will add more costs to the program and delay it even further.

While the ground segment problems have been more technically complex and perhaps more excusable, the capacitors issue has been more about negligence and poor management.

It was never envisioned that GPS III would be so problematic—as has been the case for so many other US military satellite programs. There was never a great sense of urgency for GPS III because the current constellation of GPS satellites (the Block 2s, Block 2As, and Block 2Rs) has been performing extremely well, and so the development

milestones for the program were always viewed to be more than reasonable.

Full deployment of GPS III will now not be completed until the middle part of the next decade. In order for this to happen, the Air Force will need to get into a regular and fast launch rhythm before the end of this decade. We anticipate at least two GPS IIIs being launched in 2018, followed by at least six more satellites by 2020.

What is certain is that GPS III, despite its delays, will remain a high priority program for the Pentagon. Accurate navigation and targeting are key aspects of US defense and warfighting capabilities. Of course, maintaining a modern and secure GPS system is also vastly important for civilian purposes such as air and ground travel. Our growing personal and commercial reliance on navigation and tracking via satellite is something we take for granted.

Launch Forecast

<i>(payload units)</i>	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026
GPS III	—	2	3	3	3	3	4	4	4	4

