ARCHIVED REPORT

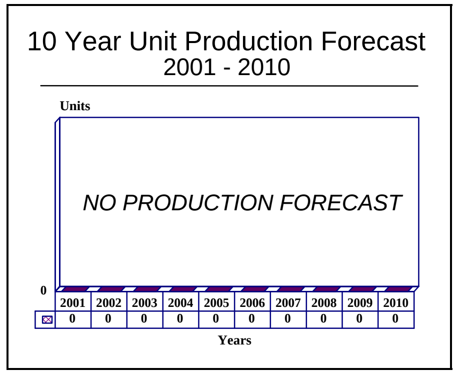
For data and forecasts on current programs please visit

www.forecastinternational.com or call +1 203.426.0800

NAVSTAR GPS Airborne Terminals – Archived 12/2002

Outlook

- Production approval given for the Selective Availability Anti-Spoofing Module (SAASM) and Miniature Precision Lightweight Global Positioning System Receiver Engine (MPE-S)
- NAVSTAR technology is being embedded in various airborne equipment
- Due to the difficulty in identifying equipment solely designated as NAVSTAR GPS airborne terminals, this report will be archived next year



Orientation

Description. Three-dimensional, space-based navigation system. This report covers Global Positioning System (GPS) receivers for military, commercial and civil aircraft applications.

Sponsor

US Space Command
250 South Peterson Boulevard
Suite 116
Peterson AFB, Colorado (CO) 80914
USA
Web site: www.spacecom.af.mil/usspace

US Air Force
Aeronautical Systems Center
Wright-Patterson AFB, Ohio (OH) 45433
USA
Web site: www.af.mil

US Navy
Naval Air Systems Command (NAVAIR)
Air-09C/2.0C Bldg. 441
21983 Bundy Road, Unit #7
Patuxent River, Maryland (MD) 20670-1127
USA
Tel: +1 301 757 9044
Web site: www.navy.mil

US Army
Communications & Electronics Command
Fort Monmouth, New Jersey (NJ) 07703
USA
Tel: +1 732 532 4511
Web site: www.army.mil

Contractors

ARINC Research Inc
2551 Riva Road
Annapolis, Maryland (MD) 21401
USA
Tel: +1 410 266 4000
Fax: +1 410 266 4040
Web site: http://www.arinc.com
E-mail: custserv@arinc.com
(GPS integration/services for KC-10, E-4, C-9 aircraft)

The Boeing Company
(formerly McDonnell Douglas)
PO Box 3707
Seattle, Washington (WA) 98124
USA
Tel: +1 206 655 2121
Fax: +1 206 655 1177
Web site: http://www.boeing.com
E-mail: boeing@pss.boeing.com
(Integration of GPS/INS in F/A-18; GPS for T-1 and F-15 aircraft) (GPS/INS for E-3 and Boeing 767 AWACS, and E-6 aircraft) (GPS upgrades for B-1; Pacer Crag upgrade kits)

Raytheon
(Chrysler Technologies Corp)
1725 Jefferson Davis Highway
Suite 500
Arlington, Virginia (VA) 22202
USA
Tel: +1 703 413 4416
Fax: +1 703 413 4443
Web site: http://www.raytheon.com
(GPS Mod kits for C-141 and C-130)

Harris Corp
Government Communications Systems Division
PO Box 91000
Melbourne, Florida (FL) 32902
USA
Tel: +1 800 442 7747
Fax: +1 407 729 4167
Web site: http://www.harris.com
E-mail: communications@harris.com
(Airborne GPS digital-analog converter program)

Honeywell Inc
Space & Aviation Control
Space Systems Group
13350 US Hwy 19 North
Clearwater, Florida (FL) 34624
Tel: +1 813 539 3447
Web site: http://www.honeywell.com
E-mail: Query form available through Web site
(Embedded GPS/INS for helicopters and fixed-wing aircraft)

Lockheed Martin Aeronautical Systems
86 South Cobb Drive
Marietta, Georgia (GA) 30063
USA
Tel: +1 404 494 4411
Fax: +1 404 494 7518
Web site: http://www.lockheedmartin.com
(INSII/GPS for S-3B and ES-3A navigation upgrade)
(GPS retrofit kits for F-16C/D)

Northrop Grumman Corp
1840 Century Park East
Los Angeles, California (CA) 90067
USA
Tel: +1 310 553 6262
Fax: +1 310 201 3023
Web site: http://www.northgrum.com
E-mail: Query form available through Web site
(GPS-aided Munitions for B-2 aircraft; Embedded GPS/INS; MAGR) (Embedded GPS/INS for F/A-18 and EA-6B aircraft)

Rockwell Collins Inc
400 Collins Road NE
Cedar Rapids, Iowa (IA) 52498
USA
Tel: +1 319 295 1000
Fax: +1 319 295 5429
Web: http://www.rockwell.com
E-mail: collins@collins.rockwell.com
(MAGR; multimode receivers for commercial aircraft)

Sechan Electronics Inc
525 Furnace Hills
Lititz, Pennsylvania (PA) USA 17543-8954
Web site: http://www.sechan.com
(GPS modification kits for C-5)

Smiths Industries Aerospace & Defense Systems Inc
4141 Eastern Avenue SE
Grand Rapids, Michigan (MI) 49518
USA
Tel: +1 616 241 7000
Fax: +1 616 241 7533
Web site: http://www.smithsind-aerospace.com
(GPS for navigation system aboard 7HC-130P/N aircraft)

Trimble Navigation Ltd

Military Systems
645 North Mary Avenue
Sunnyvale, California (CA) 94086
USA
Tel: +1 408 481 8000
Fax: +1 408 481 2000
Web site: http://www.trimble.com
(CUGR for US Army UH-1 helicopters)

Status. GPS achieved full operational status in July 1995. Various receivers for military and commercial applications are in development and production, with new products frequently entering the market.

Total Produced. Through 1999, an estimated 1,000 CUGR, 1,600 EGI, and 1,400 MAGR systems were produced. These represent only a fraction of the total market.

Application. GPS is designed to provide worldwide navigation coverage at sea, on the ground, in the air or in low-Earth orbit.

Price Range. Based on 1999 contract averages, the price of a JDAM kit for free-falling bombs is estimated to be US$20,150; an Embedded GPS/INS (EGI) combination for military aircraft, US$74,650. These represent two highly visible military applications. The rapid introduction of new products and a highly competitive environment are tending to drive prices down (particularly in the commercial/civil sector).

Technical Data

Satellite Segment Design Features. The NAVSTAR (Navigation System Time and Ranging) GPS (Global Positioning System) program uses 21 active satellites and three spares placed in 12-hour period, 55° inclination-angle orbits. They are longitudinally segregated into six equally spaced planes (60° separation), with satellites evenly spaced (120° separation) in each of these planes. The altitude of each of the orbits is 20,200 kilometers (10,900 nm). The system provides 24-hour positioning data worldwide.

All GPS satellites are controlled over an S-band link: 2227.5 MHz for the uplink, 1783.74 MHz for the downlink. They transmit navigation data in spread-spectrum format using two frequencies: the L1 frequency band (1575.42 MHz) and the L2 frequency band (1227.6 MHz).

User Equipment Design Features. A wide range of NAVSTAR airborne equipment has evolved over the years; hence this section clarifies the equipment features in very general terms. The GPS user segment consists of signal receivers/processors, antennas and control/display units. Receivers calculate pseudo-range and pseudo-range rate. Pseudo-range is the distance from each satellite to the receiver, plus an offset due to clock bias. Because this distance is not perfectly measured, it is called a pseudo-range instead of simply a range. Pseudo-range rate gives the velocity between receiver and satellite – again, with a clock offset.

The basic calculation method is to determine the time lag from each satellite's transmitter to the GPS receiver. Then the ephemeris of each satellite is calculated, giving the position of each satellite when it transmitted each bit of data. From four satellites, the receiver may obtain three-dimensional (position, velocity and time) data.

Operational Characteristics. Based on tests conducted by the US Air Force, using an initial constellation of seven satellites, the GPS demonstrated accuracy in position to within 35 feet for aircraft and ground vehicles. Speeds have been measured to within 0.1 knot, and time transmitted with an accuracy to within millionths of a second. The accuracies indicated were achieved through the use of two satellite channels simultaneously. Accuracy is not dependent on the number of channels. Rather, it is a function of the time it takes to gain a fix and re-acquire it.

Up until May 2000, the US DoD had opted for a selected availability (SA) security capability that allowed the US to intentionally degrade the GPS signals by closing out the P code (Precision Positioning Service) to all except military users. This left the less accurate Standard Positioning Service capability for commercial users. The SPS was designed to provide positional accuracy no better than 100 meters. However, commercial C/A code receivers have demonstrated accuracies in the 20-40-meter range. In May 2000, use of the SA signal was discontinued by order of President Clinton. However, the signal can be utilized in times of national emergency.

The NAVSTAR system is available for use on any kind of aircraft, vehicle, vessel or individual, for both navigation and recreation. The receiver processes the position and time signals produced by the satellites and displays processed data on readout equipment. The various types of receivers installed on military and civilian equipment scan the skies for a satellite signal. The more channels that are scanning, the greater the number of satellites being tracked, allowing a more precise location and velocity value to be obtained. Logistics is the main driver, particularly if there is no aiding source or if alignment from sources such as an

Inertial Navigation System (INS) is available. The higher channel receivers are more robust and have anti-jamming benefits, especially important for more dynamic applications such as fighter aircraft.

Variants/Upgrades

With the increased usage of GPS devices, the number of military and commercial GPS receivers has proliferated. It is expected that GPS devices will continue to evolve at a rapid pace as new uses for GPS are discovered.

Program Review

Background. The origins of GPS can be traced back to the early 1960s, when the US Navy sponsored two navigation programs called Transit and Timation. Transit became operational in 1964 and supplied navigation data to low-dynamic users such as the Navy Fleet. Timation was a developmental program formulated to advance 2D (latitude and longitude) navigation. The Air Force was also working in the same direction, except that its program, called 621B, was a 3D approach (i.e., it added altitude).

The 1973 Joint Chiefs of Staff master navigation plan called for a single, precise satellite-based positioning system to serve a variety of US DoD requirements. As the result of an Office of Secretary of Defense directive in 1973, the Air Force was designated as the executive service to consolidate the various efforts under the NAVSTAR GPS umbrella, with the US Air Force Systems Command Space Division acting as the executive agency.

In 1974, Rockwell received contracts to design, produce, launch and operate three prototype GPS satellites, as well as two flight-acceptance navigation development satellites. The first GPS constellation was created in 1978, when four advanced-development GPS satellites were launched. In 1979, Rockwell received contracts to build two operational GPS satellites, as well as to modify the space shuttle to use GPS for navigation. Due to cost concerns raised in 1980, the scope of the program was somewhat reduced, from 21 satellites in the constellation to 18. By mid-1989, the total had been bumped back up to 21, with three backups. Deployment of the constellation was delayed until 1991.

In 1995, the complete constellation of 21 GPS satellites plus three on-orbit spares became operational. As Block II satellites aged and failed, the Air Force replaced them with updated Block IIR satellites – a process that began in 1997. Lockheed Martin was the prime contractor for the 21-satellite Block IIR replacement program. The final deliveries of these satellites were made in 1999.

The next generation of NAVSTAR satellites is being procured. Three teams led by Hughes, Lockheed Martin and Rockwell International competed in a winner-take-all contest for a 33-satellite package, submitting proposals in October 1995. In 1996, the Air Force selected Rockwell International (now Boeing Space Systems) to build the next generation of NAVSTAR GPS spacecraft. Rockwell received an initial contract worth $382.4 million to build the first six GPS Block IIF satellites. The contract had one option for 15 satellites and a second option for 12 more.

In February 1996, the Air Force reversed course and announced that Boeing would build only 12 Block IIF spacecraft, and not 33 as originally planned. USAF did not fault Boeing performance in altering the contract, but rather said the need for advanced technology in future satellites went beyond the current Block IIF design. In November 2000, Boeing and Lockheed Martin were awarded study contracts worth $16 million each to further develop the design concept for GPS Block III.

Early Military Receivers. Rockwell International Corporation's Collins Government Avionics Division was awarded the original contract for production of GPS user equipment receivers for the US DoD in 1985. The contract, worth approximately US$61 million, called for Collins to produce a complete range of receivers for all of the US military services. This contract covered approximately 4,300 receivers split between ARN-151(V) receivers (for F-16C/D Block 40, A-6E, F-111, B-52, and SH-60B platforms) and ARN-149(V) receivers (for the CH-47D, MH-47, UH-60, and MH-60 helicopters). This contract is believed to have been completed in 1991.

In October 1987, the Navy Avionics Center awarded Canadian Marconi and SCI second-source production contracts for US$7.5 and US$7.1 million, respectively. Both three-year contracts called for each company to produce a total of 150 systems for evaluation, in order compete against Collins for receiver procurement starting in FY90. The systems were Rockwell-designed, likely based on the user equipment developed under the Phase III effort.

The GPS Joint Program Office announced in early 1988 that plans to open GPS receiver procurement to competition would emphasize non-developmental items or off-the-shelf receivers, taking advantage of the growing number of GPS receivers, in addition to Rockwell Collins hardware, to reduce acquisition costs.

In September 1990, SCI Technology won the US$17 million, Phase IV, low-rate production contract, with options for 1,200 ARN-149(V) and 4,100 ARN-151(V) sets over five years starting in 1992. A follow-on award was made to SCI in July 1992 for additional receivers.

Desert Storm. The Persian Gulf War gave GPS applications a major boost. Because of the lack of terrain features, GPS receivers became a critical navigation aid. Available receivers were rushed over, even though some were still only developmental models. The urgency was such that the US Air Force stopped encoding GPS signals so that US forces could use commercial systems and still achieve military accuracy.

The opening battle for Kuwait saw the satellite system providing navigation for US Air Force Special Operations Forces (SOF) MH-53J helicopters escorting US Army AH-64 Apache attack helicopters into Iraq. The Apaches were instrumental in knocking out several Iraqi radar installations, which threatened the first wave of allied aircraft heading for Baghdad. Equipped with NAVSTAR GPS satellites, the MH-53Js led the helicopter attack force at low altitude in the early morning hours.

Overall, it is believed that US forces deployed approximately 15,000 GPS receivers, ranging from hand-held units such as Trimpak and Magellan to the Collins family of airborne receivers.

<u>Embedded GPS/Inertial Navigation Systems</u>. Technological advancements dramatically reduced the size of the GPS receivers and inertial-grade ring laser gyros. These packaging enhancements consequently led to the development of hybrid systems known as Embedded GPS/Inertial Navigation Systems, or EGIs. An EGI eliminates the need for the special secure databus and other security requirements, allowing the GPS pseudo-range and range-rate data to be directly combined with inertial data.

The US Air Force initially tested two EGI designs, the Honeywell H-764G and the Litton/Rockwell LN-100G (GINA – GPS Inertial Assembly) ring laser gyro-based INS, in order to demonstrate the concept. Litton/Rockwell provided the LN-100G embedded GINA system to the US Navy for the T-45 Goshawk trainer and the Army's AH-64 Apache attack helicopter, while the Marines carried out test flights of the Honeywell H-764G on board the AH-1W SuperCobra attack helicopter.

In pursuit of this technology, the Defense Advanced Research Projects Agency (DARPA) has sponsored development of the GPS Guidance Package (GGP), a compact, lightweight GPS/Inertial Navigation System for aircraft, missile and unmanned air vehicle (UAV) applications. In August 1992, DARPA selected the team of Texas Instruments (now Raytheon Systems Company) and Honeywell to develop the GGP. TI was to supply the multi-channel GPS receiver, mated to a Honeywell inertial measurement unit. DARPA investigated the possible application of GGP to existing and future missile systems to correct for navigation errors during missile flight, with GPS signals permitting the missiles to explode within 3 meters of the intended target without pilot assistance.

In early 1997, the US DoD announced the completion of a successful demonstration of GPS and INS used together in an advanced navigation set aboard an F/A-18 aircraft. DARPA and the Navy conducted the test. Many contracts for Embedded GPS/INS were already in place at the time the test occurred.

<u>COMSEC</u>. The US DoD, through the National Security Agency, developed the means to protect the integrity of the signal and prevent jamming or degradation to military users. To this end, the US DoD has encrypted the P code signals into Y code, which requires a COMSEC decryption module to be embedded within the GPS receiver. The NSA reportedly worked with Rockwell Collins, Magnavox (now Hughes) and Motorola to develop the PPS-SM (Precision Positioning Service-Security Module) for insertion into new military receivers.

<u>Civil Aviation</u>. Interest in GPS has exploded within the entire civil aviation community, from general aviation operators to commercial air carriers, as an aid for – or replacement of – instrument landings. Preliminary concept demonstration trials were carried out by the Federal Aviation Administration (FAA) in 1991 to demonstrate the feasibility of GPS for Category 1 (CAT-I) approaches. FAA Cat 1 regulations require a 730-meter runway visual range and a 200-foot (60-meter) above-ground-level decision height. The FAA conducted flight tests out of its Atlantic City (New Jersey) test facility using GPS without selective availability. The test aircraft was an FAA-operated Gulfstream IV outfitted with a Honeywell GPS receiver. Results were sufficient to move tests into a second phase that evaluated differential GPS (DGPS) with selective availability engaged.

DGPS incorporates ground-based reference equipment at known locations to measure accuracy errors and transmit corrections to aircraft receivers (and other GPS remote units) via data link. DGPS overcomes the effects of selective availability and lapses associated with the satellite's orbital data and local atmospheric conditions. The second phase was completed by mid-1992 and showed that DGPS demonstrated near-CAT-I instrument landing system capabilities.

In June 1993, the FAA approved the supplemental use of GPS for both en route navigation and non-precision approaches to airports. Implementation would occur in three phases. Under Phase 1, GPS would be employed as the primary navigation aid if traditional navigation systems were on board to monitor and assure the accuracy of the GPS guidance. This would allow GPS-equipped aircraft to be used in more than 5,000 published non-precision approaches at 2,500 US airports, many of which lack precision landing systems.

Phase 2 would allow use of GPS as the sole means of navigation, including non-precision approach, without active monitoring of other onboard navigation systems. The onboard GPS equipment had to meet the new FAA certification TSO C-129, including Receiver Autonomous Integrity Monitoring (RAIM). In September 1993, as part of its campaign to publicize the benefits of GPS to commercial aviation, the FAA demonstrated GPS's ability to guide a Gulfstream IV on a flight path along the Potomac River and return it for a landing at National Airport in Washington, DC.

Under Phase 3 guidelines, GPS could be employed for all phases of IFR flight. By 1995, the FAA had approved the use of GPS as the primary means of en route navigation over oceanic and remote areas.

In a decision having major commercial aviation impact, the FAA gave the official nod in June 1994 for the development of a GPS-based Category II and III landing approach system, as it had abandoned its beleaguered Microwave Landing System (MLS) in a sweeping ATC reform. Despite its developmental status, this move was intended to clear the way for GPS's inevitable domination of the ATC system in the 21st century.

The emphasis was on demonstrating the accuracy, availability and security of GPS in implementing Category II and III landings. The FAA chose then-E-Systems and Wilcox Electric Inc (a Thomson subsidiary) to perform these demonstrations, which required accuracy augmentation to satisfy the requirement of Category III 1.3-meter vertical accuracy at a 50-foot altitude. Initial tests were performed by the FAA in October 1994 using a United Airlines 737-300 at NASA's Crows Landing airfield in California and a UPS 757-200PF aircraft at Atlantic City, New Jersey.

To provide further insurance of meeting CAT-II/ CAT-III requirements, however, the FAA sponsored research efforts to develop kinematic carrier-phase tracking technology at Stanford University and the NASA Ames Research Center. Advances made during 1994 at Stanford in the area of Differential GPS increased accuracy beyond the one-foot requirement set by the International Civil Aviation Organization.

In August 1997, the world's first civil Differential GPS satellite landing system – the Honeywell-Pelorus SLS-2000 – achieved FAA Special Category 1 (SCAT-I) approval. In this system, designed to replace the instrument landing system (ILS), a ground reference station utilizes three Remote Satellite Measurement Units (RSMUs) to determine differential position error. The correction is sent through a data link to approaching aircraft, which can use the information to make the most accurate approaches possible within a 55 kilometer (30 nautical mile) radius of the ground station. In addition to SCAT-I approval, the system will be both CAT-I- and CAT-II-capable, with growth potential to CAT-III as well. Ground stations were installed at Minneapolis/ St. Paul and Newark international airports, with one Boeing MD-80 operated by Continental Airlines earmarked as the first user aircraft.

In a move that pleased the Aircraft Owners and Pilots Association (AOPA), the FAA gave notice in July 1998 that it would approve GPS for non-precision approaches, in place of distance-measuring equipment and automatic direction finders. Although the substitution would entail some restrictions, it would result in increased safety and reduced costs for aircraft owners, and would benefit regional airlines, commuter airlines and general aviation within the US.

A major milestone in the civilian use of GPS was reached in May 2000 when activation of the selective availability (SA) signal by the US DoD was discontinued. The order came from President Clinton and made it possible, for the first time, for civil GPS users to get the same signal accuracy as the military. The White House has, however, given the DoD approval to reapply degradation in cases of national emergency.

In recent years, several contracts and production approvals have been issued for various GPS systems such as the MAGR 2000 GPS receivers and Rockwell Collins' Miniature Precision Lightweight Global Positioning System Receiver Engine (MPE-S). These smaller and lighter GPS components are being integrated into other systems like Traffic Collision Avoidance Systems (TCAS) and the Joint Precision Approach and Landing System (JPALS). As GPS systems are being increasingly embedded in a wide array of devices, it is becoming more difficult to identify systems that can be considered solely as a NAVSTAR terminal.

Funding

US FUNDING[a]

	FY01		FY02		FY03		FY04	
	QTY	AMT	QTY	AMT	QTY	AMT	QTY	AMT
RDT&E (US Air Force) PE#0305164F Project 3028 NAVSTAR GPS User Equipment Space	-	60.3	-	53.0	-	87.0	-	61.0

	FY05		FY06		FY07	
	QTY	AMT	QTY	AMT	QTY	AMT
RDT&E (US Air Force) PE#0305164F Project 3028 NAVSTAR GPS User Equipment Space	-	62.0	-	64.4	-	70.1

	FY01		FY02		FY03		FY04	
	QTY	AMT	QTY	AMT	QTY	AMT	QTY	AMT
RDT&E (US Navy) PE#0604777N Project X0921 NAVSTAR GPS Equipment	-	12.8	-	13.6	-	19.1	-	22.7

	FY05		FY06		FY07	
	QTY	AMT	QTY	AMT	QTY	AMT
RDT&E (US Navy) PE#0604777N Project 3028 NAVSTAR GPS Equipment	-	15.4	-	22.5	-	23.0

	FY01		FY02		FY03	
	QTY	AMT	QTY	AMT	QTY	AMT
Procurement (US Air Force) NAVSTAR GPS User Equipment	-	36.9	-	26.3	-	17.6

	FY01 QTY	FY01 AMT	FY02 QTY	FY02 AMT	FY03 QTY	FY03 AMT	FY04 QTY	FY04 AMT
Procurement (US Navy) NAVSTAR GPS BLI 2657	-	12.0	-	13.9	-	11.4	-	16.8

	FY05 QTY	FY05 AMT	FY06 QTY	FY06 AMT	FY07 QTY	FY07 AMT
Procurement (US Navy) NAVSTAR GPS BLI 2657	-	13.0	-	14.3	-	13.6

Source: FY03 US Air Force and Navy Budget Estimates

All US$ are in millions.

[a]The programs presented here are specific programs pertaining to GPS equipment funding under the respective services. More funds are allocated to the RDT&E and procurement of GPS systems under a variety of other programs such as JPALS.

Recent Contracts

Contractor	Award ($ millions)	Date/Description
Sextant	Unknown	Mar 2000 – From French Air Force to replace current GPS on 65 Transall C160R tactical transport aircraft. Deliveries will start in 2001. Replacement system is Sextant’s Topstar 100-2 GPS satellite receiver.
Honeywell	7.1	Apr 2000 – Option to an FFP contract to provide for 91 Embedded GPS Inertial Navigation System (EGI) units applicable to the F-16 aircraft and 91 lots of recurring Delta hardware. Expected completion date is March 29, 2002. Aeronautical Systems Center, Wright-Patterson AFB, is the contracting authority. (F33657-99-C2040-P00020)
Rockwell Collins	8.1	Jul 2000 – Option to an FFP contract to provide 269 Miniaturized Airborne GPS receivers applicable to various aircraft. Expected completion date is July 2001. Space and Missile Systems Center, Los Angeles AFB, California, is the contracting authority. (F04701-99-C-0051-P0003)
Boeing	34.5	Jul 2000 – Modification to an FFP contract to adjust the GPS Block IIF Satellite Operational Control Segment (OCS) development to align it with developmental changes in the GPS OCS support contract. Expected completion date is September 30, 2001. Space and Missile System Center, Los Angeles AFB, California, is the contracting authority. (F04701-96-C-0025-P00089)
Boeing	123.3	Aug 2000 – Modification to cost-plus-incentive-fee contract to design and develop modifications in order to incorporate new military and civil signals into GPS Block IIF satellites. Expected completion date is March 1, 2003. Space and Missile Systems Center, Los Angeles AFB, California, is the contracting authority. (F04701-96-C0025-P00080)
Gnostech Inc	5.7	Aug 2000 – ID/IQ CPFF for engineering and technical services for GPS support. Contains options which, if exercised, would bring total cumulative value to US$9.6 million. Work is expected to be completed by

Contractor	Award ($ millions)	Date/Description
		August 2003. Space and Naval Warfare Systems Center, San Diego, California, is the contracting authority. (N660001-00-D-5083)
Lockheed Martin	53.0	Aug 2000 – CPIF to modernize 12 NAVSTAR GPS Block IIR satellites. A second civil signal and new military signal will be incorporated into the system. Expected completion date is September 2001. Space and Missile Systems Center, El Segundo, California, is the contracting authority. (F04701-00-C-0006)
Boeing	35.0	Jan 2001 – Modification to contract number F04701-96-C-0025 to provide for modernization of the operational control segment supporting the GPS to allow interaction with new capabilities on the GPS IIR and IIF Satellites. Contract is expected to be completed by January 2002.
Trimble	2.7	May 2001 – Contract from Boeing for the US Air Force KC-10A Aircraft Global Air Traffic Management (GATM) upgrade program. Trimble will incorporate its SAASM capability in its TASMAN ARINC-12 (TA-12) GPS receiver.

Timetable

Month	Year	Major Development
Dec	1973	Milestone I – concept validation
Jun	1974	Initial space segment contract issued to Rockwell
Oct	1974	General Dynamics receives control user contract (Phase 2)
Feb-Dec	1978	NAVSTAR 1, 2, 3, 4 launched
Jul	1979	Phase 2 user set development contract awarded; Milestone II – full-scale development achieved
Oct	1979	Block 1 replenishment satellite contract awarded
Jan	1980	First Minuteman 3 with NAVSTAR receiver launched
Feb	1980	NAVSTAR 5 and 6 launched
Dec	1981	NAVSTAR 7 launched, destroyed in booster failure accident
Sep	1982	Rockwell awarded long-lead parts contract for Block 2 satellite production
Mar	1983	Rockwell receives Block 2 NAVSTAR satellite contract
May	1983	First transatlantic flight using NAVSTAR made, using a Rockwell Sabreliner 65
Jul	1983	NAVSTAR 8 launched with nuclear-detonation detection system payload
Nov	1983	Congress asks for civilian use of NAVSTAR
Jun	1984	NAVSTAR 9 launched via an Atlas-E
Sep	1984	NAVSTAR 10 launched
Jan	1985	McDonnell Douglas awarded contract for 28 PAM-D11 upper stages
Apr	1985	Rockwell Collins awarded initial user equipment contract
	1985	First NAVSTAR launch via the Space Shuttle
Oct	1985	NAVSTAR 11 launched
Jun	1986	Program delayed due to the failure of Delta and Titan 34D rockets; EURONAV consortium announced; Milestone IIIA (limited-rate initial production) achieved
Sep	1987	First Collins GPS user equipment delivered for integration by the US Air Force
Dec	1987	First-production 3S user equipment five-channel receiver delivered by Collins to US Navy
	1987	US Air Force completes development of GPS standard interface
Oct	1988	Texas Instruments M/V and five-channel receivers scheduled to begin testing
Feb	1989	First Block II GPS satellite launched
Jun	1989	Canadian Marconi and SCI receivers begin testing
	1990	Full-rate production scheduled for GPS user equipment; negotiations announced to

Month	Year	Major Development
		merge GPS with GLONASS
Sep	1990	SCI Technology awarded FY90 GPS user equipment buy
Fall	1990	GPS systems deployed to Persian Gulf for Desert Shield/Desert Storm
Late	1991	FAA conducts preliminary flight tests of GPS as a Category 1 landing aid
Jun	1993	FAA announces approval of supplemental use of GPS for en route navigation and non-precision approaches to airports
Nov	1993	Phase II for CAT-I GPS landings; Embedded GPS/INS hybrid development increases
	FY93/4	Initial low-rate production of MAGR begins
Mar	1994	Launch of 24th NAVSTAR GPS satellite
Apr	1994	FAA formally declares GPS ready for implementation under IOC
Jun	1994	FAA approves development of GPS-based CAT-II and CAT-III approach/landing system
Jul	1995	Full operational capability of GPS satellite constellation achieved
Aug	1995	First WAAS contract awarded
	1996	Inmarsat 3 begins to transmit DGPS correction signals
Dec	1996	Boeing announces that a modified AGM-86C Conventional Air-Launched Cruise Missile was launched from a B-52 bomber and guided successfully to a target entirely by GPS
Jan	1997	Successful demonstration of Embedded GPS/INS aboard F/A-18
Jul	1997	First successful NAVSTAR Block IIR satellite launched
Aug	1997	First civil GPS landing system (Honeywell/Pelorus SLS-2000) receives FAA SCAT-I approval
Early	1998	FAA announces search for possible GPS ground-based backup system
Jul	1998	FAA allows GPS for non-precision approaches
Mid	1999	WAAS operational
May	2000	Use of Selective Availability signal discontinued by the US DoD
Early	2001	Fleetwide US Air Force B-1B JDAM capability scheduled
	2001	Final Block IIR deliveries; initial deliveries and launches of Block IIFs
	2005	Current deadline for availability of second civil GPS signal

Worldwide Distribution

GPS airborne terminals are available worldwide for all types of aircraft.

Forecast Rationale

The NAVSTAR GPS program was originally created by the US military to provide an accurate means to navigate land, sea and air vehicles. Since its deployment, the use of GPS has been expanded into a variety of areas ranging from weapons guidance to automated landing systems. As interest in GPS intensifies, the technology involved is becoming smaller, lighter and more accurate. For example a new GPS VME Receiver Card (GVRC) is able to replace 12 cards in a 3S receiver and provide a significant increase in reliability.

Sales for airborne GPS systems have been steady and are expected to remain strong for several years. A six-year, US8.7 million contract was awarded in December 1998 by the US Department of Defense for the production of MAGR 2000 GPS receivers for a variety of military platforms including the B-1B, F/A-18, AH-64, AV-8B and the F-117. The contract, which has a potential value of US$167 million, permits the purchase of the MAGR 2000 over six years and could generate a total production of 4,000 units.

More recently, production approval was received by Rockwell Collins in August 2000 for its Miniature Precision Lightweight Global Positioning System Receiver Engine (MPE-S), a jam-resistant, secure GPS receiver. This is one of the first GPS products to include Airborne Selective Availability Anti-Spoofing Module (SAASM); a tamper-resistant, multi-chip security module. Rockwell Collins' SAASM Receiver was also selected in September 2000 to be integrated into the Litton LN-25 Embedded Inertial Navigation System/Global Positioning System (INS/GPS). The LN-25X is the production version of DARPA's GPS Guidance Package (GGP). This smaller, lighter and less expensive INS/GPS system is used on a multitude of airborne, surface, missiles and maritime platforms. Starting in October 2002, all US military GPS receivers are to be equipped with SAASM.

Trimble also received production approval of their Selective Availability Anti-Spoofing Module (SAASM) in the summer of 2000. The Trimble SAASM is incorporated in their GPS Receiver Application Module (GRAM). In May of 2001 Trimble received a contract from Boeing for the US Air Force KC-10A Aircraft Global Air Traffic Management (GATM) upgrade program. Trimble will incorporate its SAASM capability in its TASMAN ARINC-12 (TA-12) GPS receiver.

NAVSTAR GPS technology is being incorporated in several airborne systems. One of the major new systems which will make a significant impact on the airborne GPS market is the Joint Precision Approach and Landing System (JPALS). Utilizing a GPS device, JPALS provides accurate, reliable landing guidance to both fixed-wing and rotary aircraft during Category I and II visibility conditions. This landing system is expected to replace over 15,000 aging landing systems throughout the US military.

With access to military GPS signals given to the public, airborne GPS systems have become very popular in civil aviation. Increased air traffic has made GPS an important tool in managing the crowded skies over the worlds most populated areas. One of the main GPS-equipped tools used in air traffic management is the Traffic Collision Avoidance System (TCAS), an air-to-air anti-collision system. In North America and Europe, regulations requiring TCAS will go into effect around the mid-term of the forecast period. In an effort to meet these requirements, several airlines are ordering TCAS equipment. For example, in July 2000, British Airways contracted L-3 Communications Corporation to supply 90 TCAS 2000 systems for its 747 and 777 aircraft. In that same month, Scandinavian Airlines, Swiss Air and Virgin Airlines selected Honeywell's new CAS 100 TCAS system for their new Airbus A321, A330 and A340-600 aircraft.

As NAVSTAR GPS technology advances and more applications are being discovered, it is only inevitable that demand for NAVSTAR airborne equipment will increase. However, with GPS being embedded into may other systems, it is becoming ever more difficult to identify a component as a NAVSTAR airborne terminal. Therefore, no production is forecast, and this report will be archived next year.

Ten-Year Outlook

Production chart has been omitted.

* * *