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"NAVIGATION 2000"

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NAVIGATION AND SPACE IN THE NEXT MILLENNIUM

General Chair:
Ron Hatch, *Navcom Technology*

Program Chair:
Len Jacobson, *Global Systems & Marketing*

GPS IN THE YEAR 2000
ION National Technical Meeting Keynote Address
Brig Gen John Clay
21 Jan 98

I would like to thank the Institute of Navigation for inviting me to speak to you this morning. No other forum brings together the diversity of GPS, satellite navigation users, operators, manufacturers, and policy makers as the ION does. We are all very appreciative of the quality and diversity of the audience which is due to the tremendous effort the Institute of Navigation puts forth to host these events. The ability to create a consensus among the GPS community often starts and ends with the ION, and I am truly thankful that the ION performs that mission so successfully.

We at the Space and Missile Systems Center, or SMC, are proud to include the GPS Joint Program Office, or JPO, among our portfolio of programs. The JPO is responsible for the development, acquisition, and sustainment of GPS. SMC, which is located just up the road at El Segundo, began its role in satellite navigation all the way back in 1963, with the inception of the program designated 621B. Over time that program evolved into the genesis of the Navstar Global Positioning System, which was formally established as a program office at SMC almost a quarter of a century ago in July, 1973. Concept validation of GPS began in December 1973, and continued until full-scale development, which lasted from 1979, and to 1985. Finally, production and deployment of GPS started in 1985. We celebrated, continuing through Initial Operational Capability in December 1993, and Full Operational Capability in July 1995. I take this opportunity to publicly salute all of the early pioneers of GPS, some of whom may be in the audience today. SMC's role as the developer, acquirer, and sustainer of the system was crucial to successful completion of these milestones.

Equally important to the success of GPS, however, is the role of the managers of the system, Air Force Space Command. They operate the constellation of satellites, the ground antennas, and the control stations. They also ensure timely alerts of information on signal outages are available to all the users of GPS. Air Force Space Command has proven to be a very capable operator. Their operation, and their continued effort to improve GPS service has resulted in the accuracy of the signal in space, and is responsible for the ever increasing levels of accuracy, reliability, and availability of the GPS system.

Finally, before getting to the main point of my presentation, GPS in the Year 2000, I'd like to praise the efforts of one more group: our leaders in Washington. The soundstrong policy guidance we have received, from the President on down, has been crucial to our being able to provide a stable, healthy program, and ensured users worldwide continued free availability of GPS. GPS has generated high levels of interest among leaders worldwide, and this interest has enabled us to protect this ever-more-important global utility. I'd also like to thank the legislative branch for its ongoing support of GPS. As many of you are aware, the budgets of many governmental programs fluctuate from year to year. Congress has provided stable GPS funding and approved our requests for multi-year procurements. As a result, we've been able to maintain a steady supply of replenishment satellites at a cost effective price. Protecting GPS from these fluctuations has also aided us by allowing us to pursue multi-year procurements, which allows us to construct stable, long-term budgets and contracts free from the year-to-year perturbations that many other programs encounter. This stability is essential when you are sustaining a 24 satellite constellation and at the same time incorporating system enhancements which also address the continued evolution of satellite navigation. So my thanks go out to the Congress and the executive branch.

All of the organizations I have talked about are crucial to the success of GPS and ultimately, it is this cooperation that ensures its continued success.

As I mentioned, GPS was declared to be Fully Operationally Capable, or FOC, almost three years ago in July 1995. FOC was declared once the system had been completely tested for military functionality. IOC had occurred 18 months earlier, in December 1993, when the Department of Defense, in accordance with a Memorandum of Agreement between the Departments of Defense and Transportation, declared the Standard Positioning Service, or SPS, as sustainable. The Coast Guard and FAA subsequently approved GPS for civil transportation use.

FOC can be looked upon as the point in time when we entered the sustainment era of GPS. We have transitioned from a mode of developing, building, and populating the GPS constellation to one of replenishing, sustaining and improving it. The GPS Joint Program Office recognizes that its number one priority has shifted

from leading the development of GPS to supporting its sustainment. Now I'd like to update you on what the Space and Missile Systems Center has been doing since the FOC declaration.

First, as you are probably aware, we are in the process of operating, sustaining, and developing three generations of Block II GPS satellites. The first generation of Block II GPS satellites is the Block II/IIA, manufactured by Rockwell, which is now a part of Boeing. The Block II/IIA satellites are the backbone of the current constellation. In fact, all but one of the 27 healthy satellites currently on orbit is a II or IIA. This block has greatly exceeded all expectations in their on-orbit performance.

Based on measured performance to-date, the lifetime prediction for the block IIA has been revised, increasing the Mean Mission Duration from 6.75 years to 8.45 years, a 25 percent improvement! Since this greatly improves the prospects for maintaining 24 satellite availability, we can stretch the planned next generation Block IIR launch schedule. With little fanfare, the end of an era occurred in November, when the last Block IIA was successfully launched into orbit. Congratulations to Boeing/Rockwell, Rockwell for building and delivering a constellation of fully operational global navigation satellites, and to one of the most significant milestones in human technological history, Boeing/Macdonnell Douglas for the Delta rocket that successfully placed all 28 Block II/IIA satellites into orbit, the first global navigation and timing system.

The second generation of Block II GPS satellites is the Block IIR, developed and manufactured by Lockheed-Martin. Unfortunately, the Block IIR era started with a launch failure booster explosion in January of last year, proving once again that space launch cannot be taken for granted. However, we were prepared for that setback with the robust Block II/IIA constellation. The second attempt was a complete success and we now have our first Block IIR on orbit. To date, six Block IIR satellites have been accepted by the Air Force and 15 more will be delivered in the years ahead, with a total production of 21 satellites.

As you may have heard or read, the on-orbit testing of the first IIR satellite revealed a problem. During testing we identified an interference problem with the Block IIR satellite crosslink data transfer receiver that allows the GPS satellites to exchange data. Let me emphasize that the Block IIR satellite navigation package is performing well within specification and military and civilian users will experience no adverse effects. Block IIR on-orbit testing is currently planned to be complete near the end of the month. As far as the crosslink problem goes, the JPO is working with Air Force Space Command to implement an interim fix into two Block IIR satellites to support launch opportunities later this year. If the health of the constellation were to come into question, Air Force Space Command does have the ability to resume launches. We would consider launching immediately to sustain the navigation signal our users have come to expect, even if we had to launch without having fixed the crosslink problem.

Again, congratulations are certainly due to Rockwell, Boeing, and Lockheed for the fantastic job they did building the II, IIA, and IIR satellites. All of them have performed well within specification, and the phenomenal on-orbit life of the satellites is a tribute to the quality work done by the contractors and the Space and Missile Systems Center.

We expect continued success as the GPS Joint Program Office and Boeing develop the third generation of Block II satellite, the IIF. As you have surely been told, the IIF program is progressing nicely. The contract was awarded less than two years ago, in April 1996. We declared the preliminary design complete in February 1997, and we are due to declare the final design complete in April of this year.

The first Block IIF satellite will be delivered in 2001 and is currently scheduled to be launched in March, 2002. The IIF contract has options for up to 33 satellites, with the first six being delivered on the current multi-year contract. We also have follow-on options, an option for 15 additional satellites that must be exercised by 31 December 1998, and a further option for 12 more by 2003. The IIF is being integrated onto the Evolved Expendable Launch Vehicle, or EELV, which is our booster of the future.

One of the key Block IIF requirements was a payload growth capability. In fact, the contract required reserve is likely to be very important as we look ahead to future modernization options. By the way, we recently approved an increase to the size of the Block IIF solar array to enable even more reserve power, payload, and growth capability as part of the design. Boeing deserves praise for exceeding the contract requirements and enabling even more growth potential for evolving payloads and missions.

Our ground control segment is transitioning as well, with an upgrade program ongoing to support all on-orbit operations. The upgrade will improve the Human Machine Interface in the Satellite Operations Center and reduce operations and maintenance costs of the IIF

constellation. We have assigned total system performance responsibility, or TSPR, to Boeing. This means they are responsible for the overall performance of the IIF satellites and the ground control segment that operates them. This is another approach fostered by acquisition reform, and we are sure it's going to provide us dividends in the future.

Finally, our User Equipment segment has been very active since FOC. The Space and Missile Systems center is of course focused on military user equipment, so I'll leave it to others to address all the civil developments. However, I must briefly touch on the importance and impact the GPS User Equipment market is having.

The GPS Industry Council has estimated the current GPS commercial market to grow to about $8 billion per year by the turn of the century. That dwarfs the military user equipment market. This growing commercial market presents tremendous opportunities to us as acquirers of military GPS hardware, because we can exploit the economies of scale and technology enhancements coming out of the commercial marketplace. So without a doubt, free civil access to GPS has provided a tangible benefit to the military, a benefit that will pay ever increasing returns as the market continues to grow exponentially.

Military user equipment is undergoing evolutionary changes. I'll briefly touch on some of the high points of our development and acquisition programs. The first program is GRAM, or the GPS Receiver Applications Module. GRAM is not a piece of hardware but rather a standard to which future GPS receiver cards will be built. By standardizing GPS cards across multiple applications, the military can reduce costs, allow rapid insertion of technology improvements to fielded equipment, and increase commonality between military user equipment types.

GRAM will reduce costs by allowing multiple vendors to supply receiver cards for a variety of applications. This allows smaller procurements, such as specialized avionics receivers, to exploit the economies of scale enjoyed by much larger procurements such as handheld receiver. GRAM also allows technology improvement to reach the field much more rapidly. For example, today many of our aircraft have receivers that must be removed and replaced with an entirely new receiver in order to incorporate a technology enhancement such as Receiver Autonomous Integrity Monitoring. With a GRAM based receiver, only the GRAM card must be replaced, an action that can be accomplished with minimal impact to the availability of the weapon system.

The Joint Program Office has initiated an effort to assist the civil community in developing a civil GRAM standard as well. This could have the same benefits to the civil users of GPS. As has been demonstrated by many rapidly-evolving technological industries, such as the PC industry, the development of standards is crucial to the long-term viability of that industry.

Another important development in military user equipment is the selective availability/anti-spoofing module, or SAASM. SAASM is the new Precise Positioning System decryption module for future military receivers. It uses electronic keying, rather than the current paper keys, which increases the security of the system. As SAASM matures, the module price continues to decrease, allowing it to be added to more and more future receiver procurements. Eventually, electronic-keying SAASM-based receivers will supplant our current receivers.

The largest procurement underway, being undertaken by the user equipment program, is the next-generation handheld receiver, the DAGR, or Defense Advanced GPS Receiver. It will continue the phenomenal success of its predecessor, the Precision Lightweight GPS Receiver, of which over 90,000 have been produced. Current projections indicate an even greater number of DAGRs will be fielded.

The development of small, affordable, and effective handheld receivers is undoubtedly one of the greatest accomplishments of the GPS program. While the use of GPS for aircraft navigation is certainly remarkable and garners most of the attention, it is an evolutionary change to aircraft navigation. On the other hand, the ability of individual soldiers to use satellite navigation is a revolutionary change. Never before has real-time radio navigation been available to individual soldiers. So the leap to handheld GPS has revolutionized the battlefield and is changing the way armies operate.

Hopefully you have found my update of the DoD space and user equipment programs useful. Let me now talk about some of the key subjects and issues we will be addressing in the years ahead.

It's been almost two years since the President approved the national policy for the future management of the Global Positioning System in the Presidential Decision Directive (U.S. Global Positioning System Policy, National Science and Technology Council-6 (NSTC-6), 29 Mar 96). Recognizing the nation's reliance on GPS as an issue of national security and economic well being, the Presidential Decision Directive established policy guidelines which address a broad range of military, civil, commercial, and scientific interests, both national and

The U. S. Government has a serious effort underway to modernize GPS by providing an updated system architecture and signal structure that meets the needs of the civil and military user communities. I predict that 1998 will be a pivotal year for GPS.

In March the Interagency GPS Executive Board will determine the location of a second civil signal frequency. Options being considered include obtaining new spectrum for a civil or military signal, or inserting new civil and military signals into the existing GPS frequency spectrum. Because of the difficulty of finding and getting international acceptance for GPS use of new spectrum, adding more signals into the existing L1/L2 spectrum is receiving serious consideration. This approach requires no new frequency allocation, allows separation of civil and military signals, allows use of existing user equipment antennas, is RF compatible with the existing system and has a manageable impact on the Block IIF satellite design. Although adding signals to L1 and L2 appears to be a viable solution, we have not given up looking for new spectrum.

In August the Department of Defense plans to consider upgrades to the entire GPS system architecture based on Navwar and modernization requirements. Program changes are likely to be approved for the space, control, user equipment, and electronic warfare segments. Upgrades will include performance improvements for all users and capabilities to better protect the allied military use of GPS in an electronic warfare environment while denying an adversary's hostile use of navigation services. As always, funding is the major hurdle and modernization dollars within the Department of Defense are very scarce. Non-DoD customers wanting new system capabilities should be willing to pay for them.

Now let me discuss something that is on everyone's mind: the Year 2000 rollover, or Y2K, and the GPS-unique End of the Week Rollover, or EOW, that will occur in August 1999.

Ensuring the Global Positioning System continues to operate smoothly into the next century is a top SMC and Headquarters Air Force Space Command priority. We have prepared for the rollovers and are confident that the space segment and the military user equipment will survive both events. The JPO is also providing assistance to civil equipment and service providers and users to ensure they weather these events as well. Col Armor will address GPS Y2K actions in more detail during the plenary session.

Finally, a word about protecting the spectrum is in order. A proposal from Inmarsat at the Geneva World Radio Communication Conference to share the GPS bandwidth with other mobile satellite services was strongly objected to by the United States based on potential interference affects on the GPS signal and by the International Civil Aviation Organization for safety reasons.

Inmarsat wanted to use a portion of the GPS spectrum to provide mobile multimedia services to laptop terminals within a few years. WRC delegates were unsure of how the proposal would affect the reliability of GPS signals and were especially concerned about the potential affect on airline safety. As a result, the proposal was held in abeyance until WRC 99 and will be studied over the next two years.

There are several resolutions that are being studied and reviewed related to sharing the GPS bandwidth that will be reported on at WRC 99. As a community interested in the health and welfare of GPS, I encourage each of you to become familiar with the resolutions. Please pass information about your position on the resolutions to the GPS JPO and to other organizations that participate in the WRC in order to protect the bandwidth of a national resource and worldwide utility.

Thanks you so much for allowing me to speak at this important forum. I can tell you that while I thoroughly enjoy my current position as the Vice Commander of Space and Missiles Systems Center, my most enjoyable Air Force job was the short period that I served as the GPS Joint Program Office Director. It's truly a magnificent system.

Let me end with a short anecdote from a previous ION. Lieutenant General Aloysious Casey--who was one of my former bosses--spoke to ION a little over ten years ago on 23 June 1987 in Dayton Ohio. And I quote:

Looking ahead, the basic technology of the space segment of GPS is not going to change. The real revolution to take place will be in the user equipment.

The ground based segment represents a good opportunity to show what the American Manufacturing community can do using their initiative and ingenuity.

No less than 52 manufacturers are developing user equipment. These range from the size of a large backpack to that of a pack of cigarettes.

The size is determined in large part by the number of channels and the state of the art of the electronic components.

The cost of the military 5 channel set is now about 70

international. Let me talk about where we are on several of the directives:

The first directive states that "we will continue to provide the GPS Standard Positioning Service for peaceful civil, commercial and scientific use on a continuous, worldwide basis, free of direct user fees." As you know, there is no serious talk of imposing any user fees and we have been successful at providing continuous, worldwide service. We have done this by Sustaining the Constellation. Furthermore, we will preserve the integrity of the 24 satellite constellation the Air Force has into the foreseeable future. We have planned and budgeted to acquire the satellites and launch services necessary to sustain a 95% probability of at least 24 satellites in the constellation through at least 2012.

The second directive states, "It is our intention to discontinue the use of GPS Selective Availability (SA) within a decade in a manner that allows adequate time and resources for our military forces to prepare fully for operations without SA." Again, this will be accomplished. It will occur within a decade, although the specific timing is not yet determined. Since this is an operational issue, U. S. Space Command, the other Unified Commands, and the Joint Chiefs of Staff will no doubt have significant involvement in the decision. I expect that a key factor will be the progress of DoD's Navwar program which provides an alternate means of achieving the objective of ensuring that the U. S. and its allies preserve a navigation advantage in any future conflict. We have further augmented the Navwar effort with an additional $15M in the FY98 budget to address satellite modernization needs, including 2nd civil frequency options. The Air Force, in partnership with the other services, has made steady analytical and test progress and plans to have a major program review go-ahead decision this August. We are totally committed to turning off SA as soon as possible, consistent with the President's direction.

The third directive states that, "The GPS and U.S. Government augmentations will remain responsive to the National Command Authorities. Air Force and U.S. Space Command have a superbly responsive command and control infrastructure with planned upgrades that insures this. We will cooperate with other governments and international organizations." Our standard interfaces are openly published and available for use by anyone, worldwide. We have also worked with the FAA to insure GPS augmentation systems, like WAAS, are suitable for worldwide operation. The Joint Program Office also includes members from 3 of our Allies and we cooperate with many others on all aspects of the GPS program. Further, the JPO has supported OSD and State Department initiatives for bilateral agreements with Japan and Europe on common systems and usage.

An additional directive states, "We will advocate the acceptance of GPS and U.S. Government augmentations as standards for international use." In large measure this has happened naturally as a result of the quality of service from dependability of the GPS constellation. Further, to increase this acceptance, the U. S. Government is pursuing a second civil signal, and there is even serious interest in a third. Our standard interfaces are openly published and available for use by anyone, worldwide. We have also worked with the FAA to insure GPS augmentation systems, like WAAS, are suitable as a worldwide standard.

"To the fullest extent feasible, we will purchase commercially available GPS products and services that meet U.S. Government requirements and will not conduct activities that preclude or deter commercial GPS activities, except for national security or public safety reasons." The JPO runs competitive procurements for all their user equipment we have, but many military units are using commercial GPS receivers for non-combat operations

Finally, the Presidential Directive states that, "A permanent interagency GPS Executive Board, jointly chaired by the Departments of Defense and Transportation, will manage the GPS and U.S. Government augmentations." The Interagency GPS Executive Board or IGEB has met twice since the Presidential Decision Directive was released and we expect the pace to pick up. They will meet again at the end of March to decide on the location for a 2nd civil signal frequency. There are many other issues the IGEB is now starting to consider. The IGEB has also established at least two steering committees, one for spectrum issues including identifying a 2nd civil frequency and preparing for WRC-99; and one for dealing with interference issues.

As you can see, the Air Force has been working hard to achieve these policy goals supporting civil and commercial users while protecting U.S. national security and foreign policy interests. We are very serious about our stewardship of GPS. Acceptance of our accelerating dependence on the GPS as an essential part of the U.S. civil infrastructure obligates DoD, as steward of the GPS utility, to meet civil and military desires, demands for stability and improved performance. We are up to the challenge.

Let me now shift gear and talk about specific plans to improve GPS.

thousand dollars per copy. We expect that to come down to the 50 thousand dollar range in the early 90s. Civilian sets are running in the 25,000 dollar range and should be below one thousand dollars in the early 90s. Unquote.

As always, Gen Casey was right on the mark. What no one could have responsibly predicted is that the trend would continue into the late nineties with the availability of 100 dollar receivers and the almost certain prospect of receivers on a chip--fully an order of magnitude improvement over even the most bullish expectations a decade ago. What does that portend for the future?

Thank you very much.

NAVSTAR GLOBAL POSITIONING SYSTEM
JOINT PROGRAM OFFICE

"ANY TIME, ANY PLACE
RIGHT TIME, RIGHT PLACE"

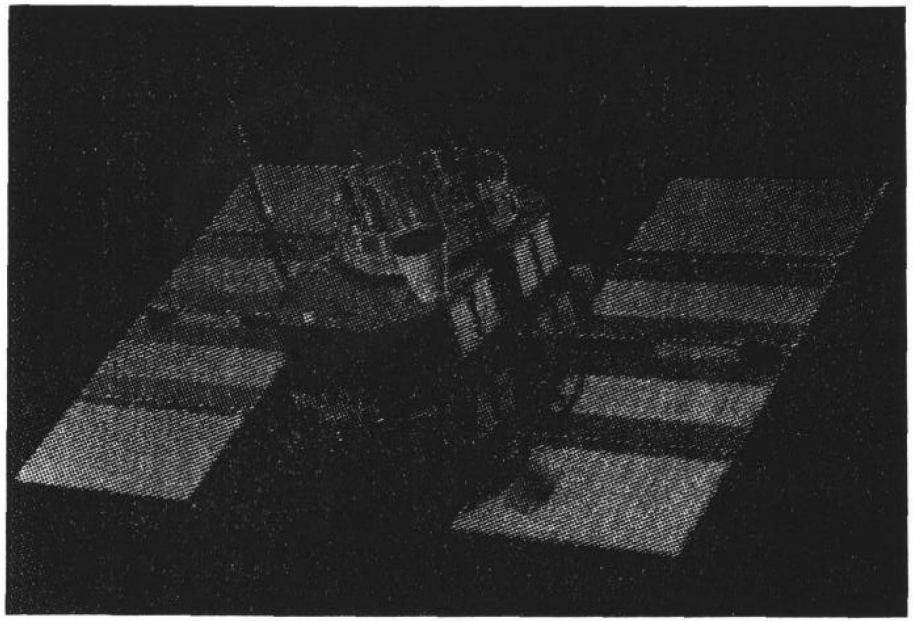
ION NATIONAL TECHNICAL MEETING

21 January 98

Col James B. Armor, Jr.
System Program Director

AIR FORCE MATERIEL COMMAND

Constellation Status



- 26 operational Block II/IIA satellites on-orbit
  - Final Block IIA launch occurred on 5 Nov

CONSTELLATION IS HEALTHY

Constellation Status

First Block IIR undergoing on-orbit testing

- Launched 22 July 97
- Navigation payload performing well within specifications
- Testing scheduled to be complete by end of January
- Identified a problem with crosslink data transfer receiver
  - Radio signal interference
  - Affects ability of IIR to exchange data with other GPS satellites
  - No adverse effects to navigation signal
  - Developing tests and solutions to resolve problem
- The program office is working to implement fix into IIR satellites to support launch opportunities later this year