GLOBAL POSITIONING SYSTEM (GPS) MODERNIZATION

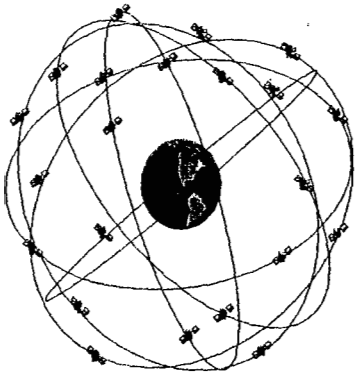
Lt. Col. C. McGinn, Capt. S. Rajotte
U.S. Air Force
GPS Joint Program Office
Los Angeles AFB, CA, USA

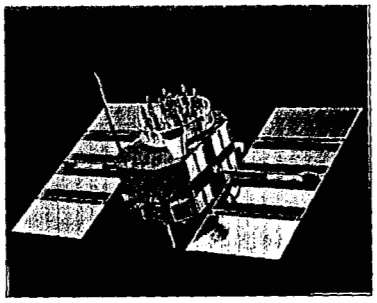
D. Latterman
Science Applications International Corporation (SAIC)
Torrance, CA 90501, USA

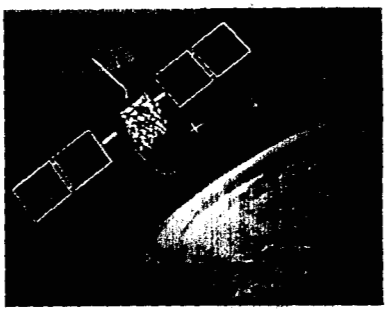
Abstract

The Global Positioning System (GPS) signal is now the primary means of obtaining precise time to an internationally accepted standard. Precise timing applications have become dependent on this space-based source of precise time and, therefore, depend on the constellation of satellites that provide it worldwide, anytime. This paper describes the efforts by the GPS Joint Program Office within the U.S. Department of Defense to modernize the GPS signal services to meet future military and civil user requirements. GPS timing users and timing receiver developers and integrators need to be aware of these new capabilities and when they will be available. This paper starts with a brief review of the system design and an overview of the current constellation status. The GPS Modernization program to modify the current block of satellites being placed into service and the next generation currently in design to provide additional system capabilities will be described. Next, the paper discusses the GPS-III program to look at future user requirements beyond the next 20 years for precise positioning and timing services. The paper summarizes what these new capabilities will mean to the GPS timing users and provides some suggestions on what GPS timing users can do to make their future needs known. The paper concludes with some challenges to the user community to support the continued mission of GPS to provide precise positioning and time to all users free of direct charge.

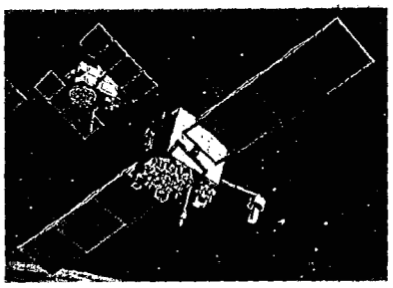
GPS Space Systems



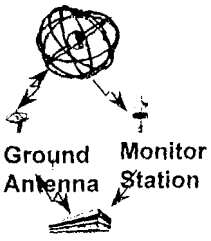




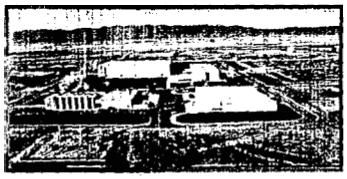
- 24-satellite (nominal) constellation
- Six orbital planes, four satellites per plane
- Semi-synchronous, circular orbits (~11,000 mi)



GPS Operational Control Segment

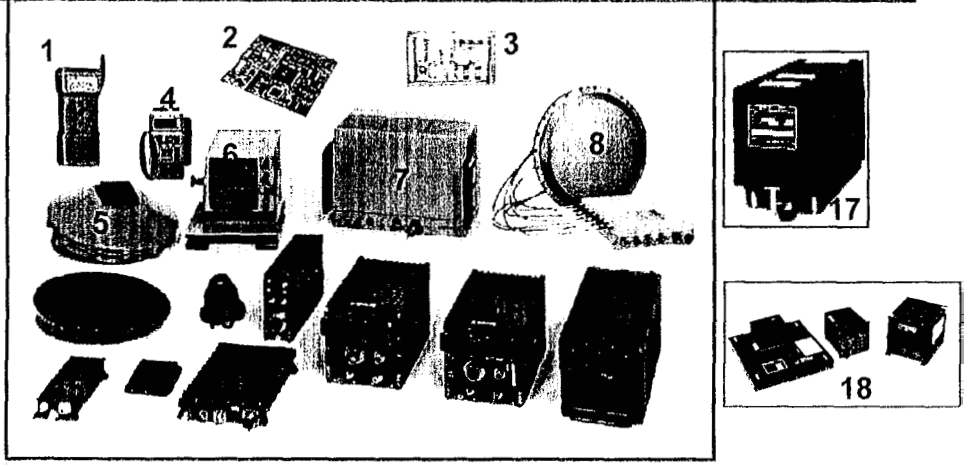


Master Control Station (Schriever AFB)



- ■ Master Control Station (MCS). Satellite control; system operations
- ■ Alternate Master Control Station (AMCS): Training; back-up (VAFB - FY04)
- ● Monitor Station (MS): Collect range data, monitor navigation signal
- ◆ NIMA Tracking Station (TS): Collect range data, monitor navigation signal
- • Ground Antenna (GA): Transmit data/commands; collect telemetry

GPS User Equipment (UE)

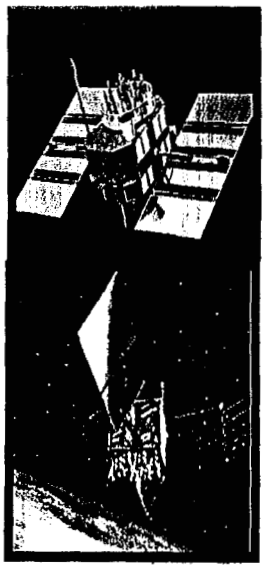


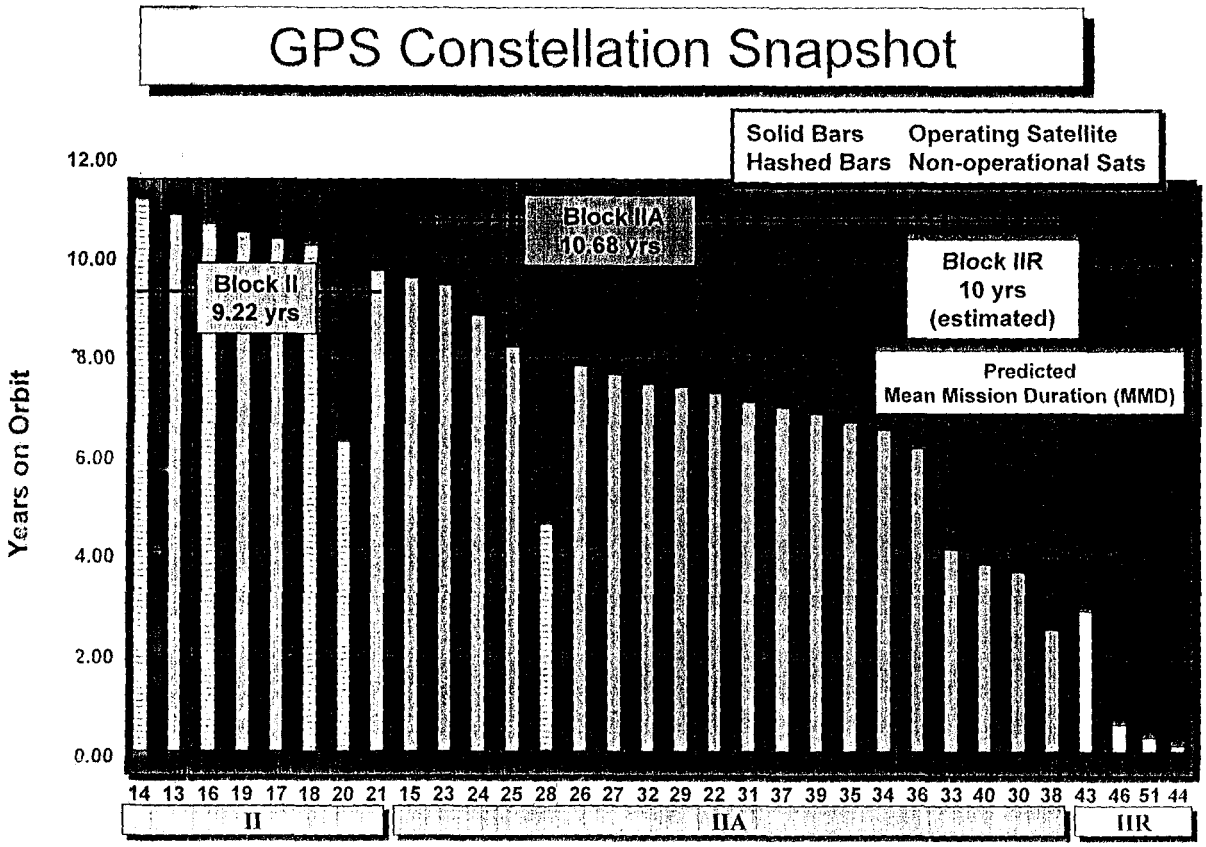
1. Combat Survivor/Evader Locator (CSEL)
2. GPS Receiver Applications Module (GRAM) with SAASM
3. Selective Availability Anti-Spoofing Module (SAASM)
4. Precision Lightweight GPS Receiver (PLGR)
5. FRPA Ground Plane (FRPA-GP)
6. Standard Control Display Unit (CDU)
7. Receiver 3S
8. GPS Antenna System (GAS) -1
9. **Controlled Radiation Pattern Antenna** (CRPA)
10. **Fixed Radiation Pattern Antenna** (FRPA)
11. **Miniature Airborne GPS Receiver** (MAGR)
12. **Receiver OH (MIL-STD-1553)**
13. **Receiver UH (ARINC 429)**
14. **Receiver 3A**
15. **Antenna Electronics AE-4**
16. **Antenna Electronics AE-1/AE-1A**
17. **Embedded GPS / INS (EGI)**
18. Doppler-GPS Navigation System (DGNS)

CONSTELLATION STATUS

28 Operating Satellites

- 23 Block II/IIA operational satellites
  - Block IIA life expectancy was extended two years (to 10.68 years)
- 5 Block IIR satellites on orbit
  - Last launch 10 Nov 00
  - 16 of 21 Block IIR satellites available
  - Modernizing up to 12 Block IIR satellites
- Next Launch: 30 Jan 01
- Tentative launch dates: Jun 01
- Continuously assessing constellation health to determine launch need





RECENT PROGRAM CHANGES

Vice Presidential Announcements
Second And Third Civil Frequencies

- "Enhancements to the Global Positioning System that will Benefit Civilian Users Worldwide" - 30 Mar 98
  - ***Second civil signal*** on L2 at 1227 MHz
    - Improve accuracy of the overall system
    - Redundant signal for safety critical users
  - ***Third civil signal*** for safety of life services by 2005 at frequency to be determined
  - New signals intended to be added to the Block IIF satellites
- "New GPS Modernization" Initiative - 25 Jan 99
  - Location of third civil frequency at 1176.45 MHz
  - Spectrum allocated for Aeronautical Radio Navigation Services (ARNS)
  - Beginning with a satellite scheduled for launch in 2005

Use Of Selective Availability (SA) Discontinued

Presidential Decision - 1 May 00

- US stopped the intentional degradation of the GPS signals available to the public (called Selective Availability or SA) on 1May 00
- Decision based on a recommendation by the SecDef
  - In coordination with the Departments of Transportation, Commerce, the Director of Central Intelligence (DCI), and other Executive Branch Departments and Agencies
  - Worldwide transportation safety, scientific, and commercial interests could be best served by discontinuation of SA
  - Supported by threat assessments which conclude that setting SA to zero at this time would have minimal impact on national security
  - Demonstrated capability to selectively deny GPS signals on a regional basis when our national security is threatened
- Increase in accuracy will allow new GPS applications to emerge and continue to enhance the lives of people around the world

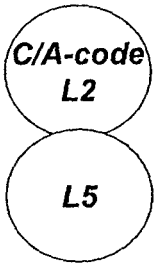
SA is off !!

Why Modernize GPS?

- Better support the warfighter in the evolving threat environment
  - More signal power = more anti-jam
  - More secure new military code structure
  - More User Equipment anti-jam capability = more protection
  - Better able to deny an enemy use of GPS

Joint Requirements Oversight Council (JROC) validated requirements in Jun 99

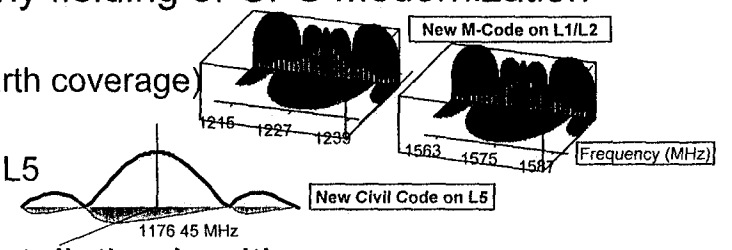
- Better support to civil GPS customers
  - New civil signals for improved accuracy, integrity and continuity of service = robustness
  - Global utility = economic enabler



Presidential Decision Directive - Mar 96
Vice Presidential Announcements - Mar 98 and Jan 99

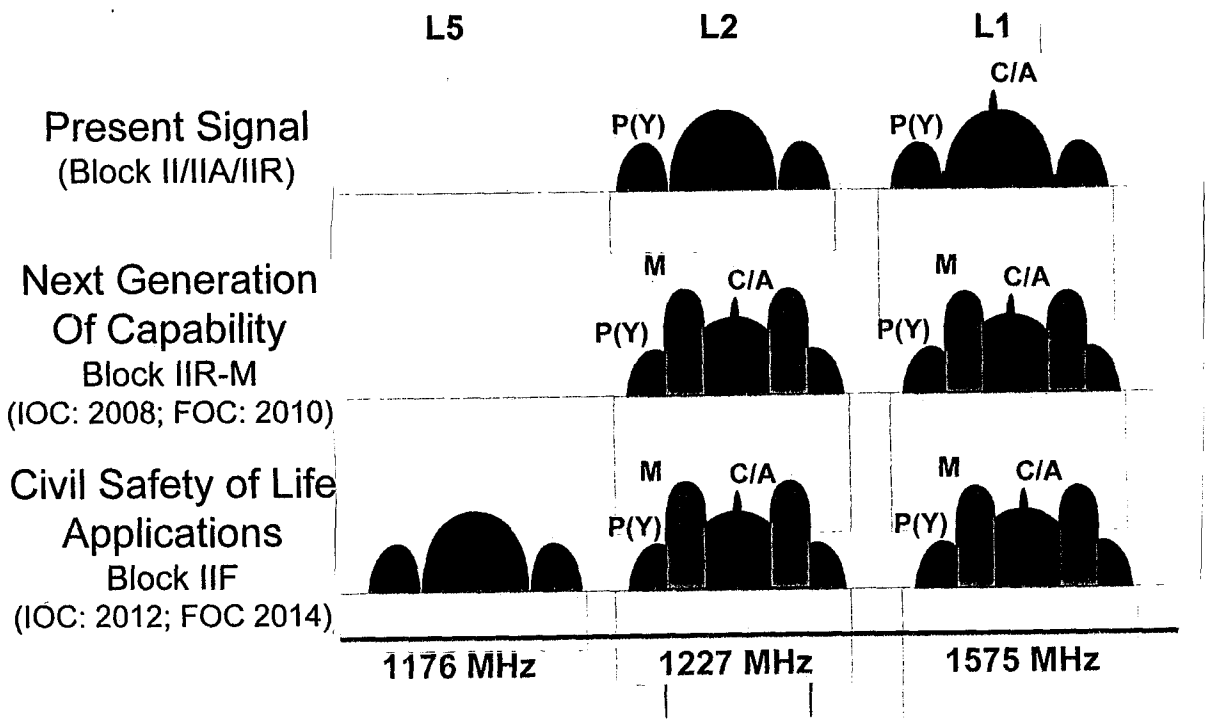
GPS Modernization Strategy Goals

- Commitment to early fielding of GPS Modernization capabilities
  - Military M-code (earth coverage)
  - C/A code on L2
  - New civil signal on L5
  - More signal power

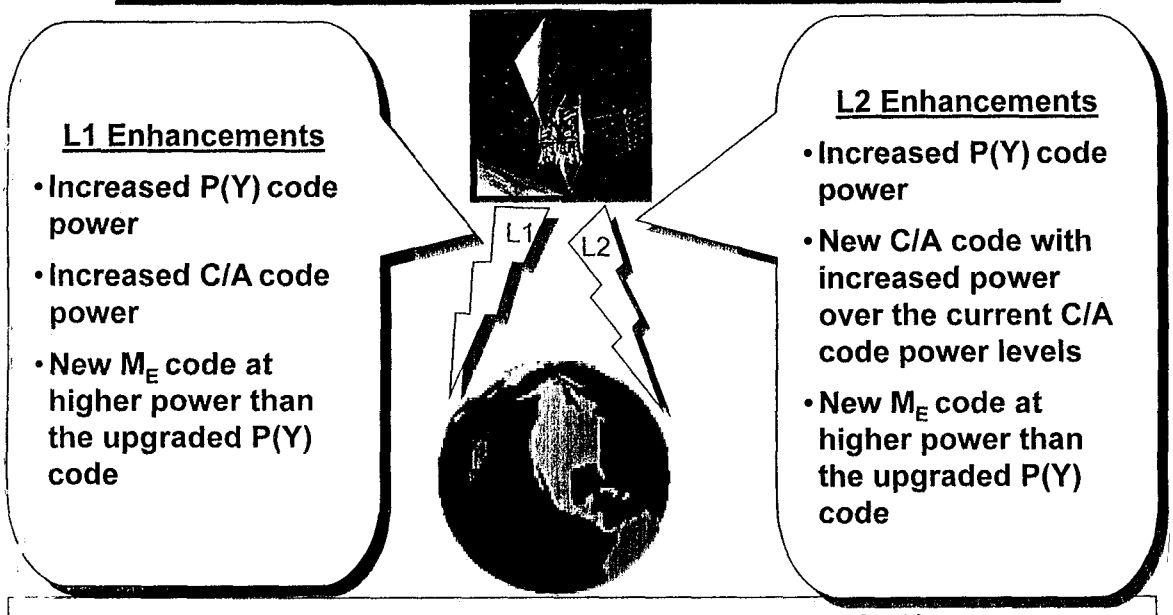


- Keep the GPS constellation healthy
- Backward compatibility
- Ensure the right strategy to design and field the best GPS System for the user's needs in the long term
  - Better match to user requirements
  - Reduce total cost of ownership
  - Design-in flexibility for future changes
  - Provide multiple decision points for tailoring to meet evolving requirements

Modernized Signal Evolution

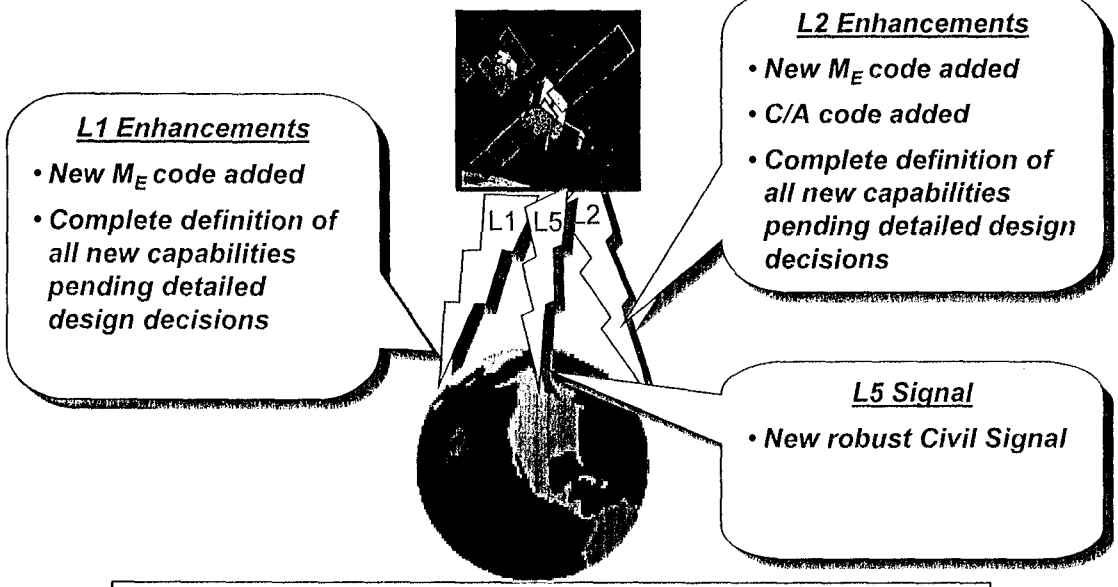


Block IIR- Modified Satellites



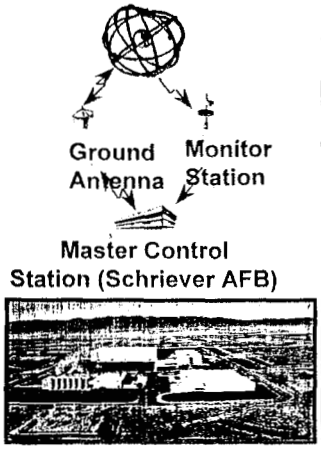
- Two new military signals (M_E on L1 and L2)
- One new civil signal (C/A code on L2)
- Increased power on all existing navigation signals (no changes required to batteries or solar arrays)

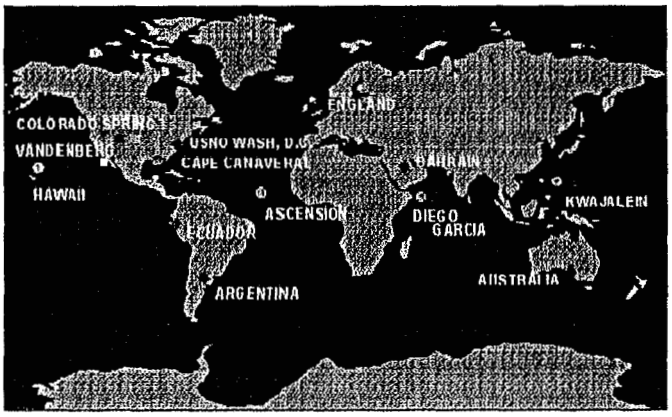
Block IIF Satellites



• Two new military signals (M_{earth}) L1 and L2
• Two new civil signals (C/A on L2 starting with Block IIR - Modified and new civil code on L5)
• Could increase power on some of these signals

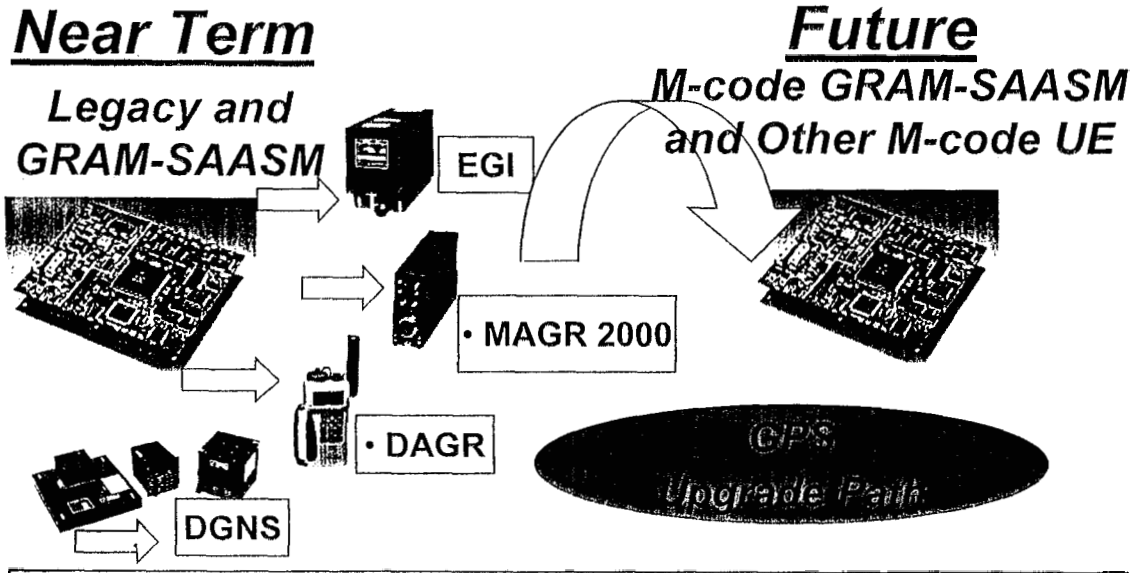
GPS Operational Control Segment





Incremental software versions and hardware upgrades to support modernization requirements

User Equipment Modernization Path



Open system architecture allows easier upgrades for future capability

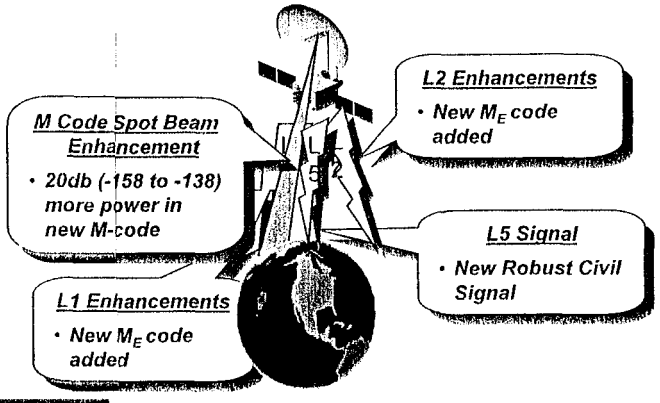
GPS Modernization and GPS-III Program Approval

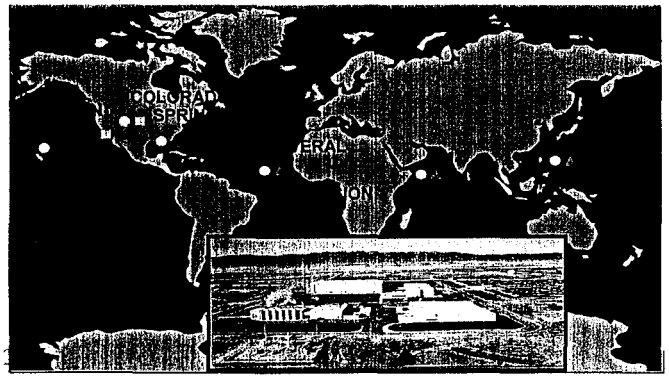
- Operational Requirements Document (ORD) signed
- Amendment to President's Budget (PB) sent to Congress
- Congressional approval for GPS Modernization and GPS-III Program as "New Starts" received
  - Block IIR Modification letter contract awarded - Aug 00
  - Block IIF Undefinitized Contract Change for Modernization development issued on current contract - Aug 00
  - GPS-III Systems Architecture and Requirements Definition (SARD) Phase contracts for GPS-III competitively awarded to two contractors - Nov 00

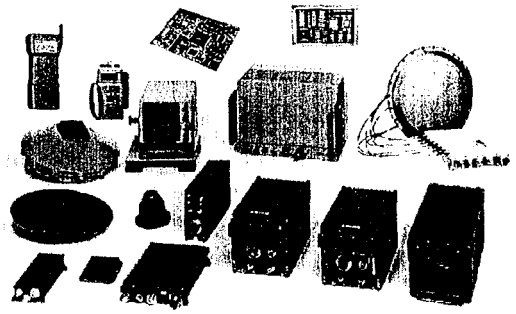
GPS III Program

Involves looking at the whole system

- Space
- Control
- User Equipment







GPS III Program Objectives

Ensure best GPS system for the nation for the next 30 years

- Plan and grow system capabilities to meet future user needs for precise positioning and timing services
  - GPS ORD objective values as the target
- Procure most cost-effective system to meet future military and civilian requirements through 2030
  - Reduce Total Ownership Costs
  - Conscientious cost - benefit analyses for future requirements
- Make optimal use of system augmentations and complementary systems
- Re-look at entire GPS system architecture
  - Identify system-level trades for all system segments - space, control segment and user equipment

GPS III Program Approach

- System Architecture / Requirements Definition (SA/RD)
  - Space, UE and OCS system-level trades - open, iterative process
  - Define system architecture to lead into a System Requirements Review (SRR)
- Preliminary Design and Risk Reduction (PD/RR)
  - Competitive Source Selection after SA/RD phase
  - Two qualified sources compete for system design to reduce risk in Engineering, Manufacturing and Design (EMD) phase
- EMD / Production
  - Down-select to single contractor at Preliminary Design Review (PDR) - FY03
  - Conduct risk analysis for EMD
  - Solidify EMD Phase strategy

Three phase approach -
flexible, allows future changes, reduces risk

WHAT DOES THIS MEAN TO THE GPS TIMING USER?

System-Level Time Transfer Accuracy Requirements

System Operational Requirements Document (SORD) Jan 90

Time transfer data in the in the UTC coordinate system
for Precise Time and Time Interval (PTTI)
for Global Timing System users
with an error of less than **100 nsec** (1-sigma)
and availability of 0.98 (Para 4.1.1.1.c)

Operational Requirements Document (ORD)
AFSPC/ACC 003-92-I/II/III - Global Positioning System - Feb 00

... the OCS shall maintain a steady state (sampled over 1 year)
time transfer accuracy of the GPS signal to
an error of less than or equal to
20 nsec (95 percent) relative to UTC(USNO) (**threshold**) and
10 nsec (95 percent) relative to UTC(USNO)(**objective**)
Key Performance Parameter (KPP) (Para 4.1.10.1)

GPS Modernization and GPS-III Implications for the Timing Users

Military User

- More anti-jam resistance – higher signal power
- More secure access to the military code – m-code
- Faster PPS signal acquisition – m-code
- Separation from civil signal service – m-code
- Backward compatibility with current signal architecture – m-code

Modernization

- More anti-jam resistance – higher signal power
- More accurate time transfer – GPS-III system architecture

Civil User

- More interference resistance – higher signal power
  -- spectrum protection for L5
- More robust signal service – C/A code on L2; L5 signal
- More accurate time transfer – SA off

Modernization

- More accurate time transfer – GPS-III system architecture

Modernization Impacts on the User

- Backward compatibility
  - New capabilities will not interfere with current capabilities
  - Current signal services will continue to be supported
  - Changes will be required to take advantage of new capabilities
- Equipment changes required to take advantage of capabilities offered by new signal architectures
  - M-code capable user equipment for the military user
  - Dual frequency C/A code and L5 capable civil receivers for civil applications requiring more robustness of service
- Start planning now for transition to future capabilities
  - M-code / C/A-code on L2 – IOC 2008; FOC 2010
  - L5 – IOC 2014; FOC 2016

User Involvement

Military

- Participate through the formal DoD requirements process
  - Using Command – mission needs (MNS)
  - USNO -- DoD Precise Time/Time Interval (PTTI) manager
  - AFSPC – GPS operational requirements (ORD)

Civil

- Participate through the more informal civil requirements process
  - DoD / DoT Interagency GPS Executive Board (IGEB) – individual agency requirements processes
  - GPS Civil Signal Interface Committee (CGSIC)
  - Federal Radio Navigation Plan (FRNP) coordination process
- Take active role industry / professional associations
  - GPS Industry Council (GIC)
  - Radio Telecommunications Committee – Aeronautical / Maritime (RTCA/ RTCM)

GPS JPO Challenges

- Maintaining a healthy constellation while adding system capabilities
  - Constellation sustainment strategies
  - Operational Control Segment (OCS) upgrades
  - Testing / validating new signals - design and operations
- Adequate expression of future GPS user needs - military and civil
  - Best way to understand military operational needs and civil "value added" needs
- Flexibility in procurement strategies to allow for future growth
  - Ability to forecast GPS user requirements through 2030
- Reducing Total Ownership Costs
  - Weigh costs and benefits to make the right system trade-offs

GPS User Challenges

- Promote compatibility among precise positioning and timing services; protect critical frequency spectrum
- Use current system capabilities to the maximum extent – be innovative and creative!
- Advocate military and civil future requirements
  - Take an active role in the formal requirements processes
  - Leverage informal involvement and professional activities
- Plan to use future GPS capabilities to the fullest extent
- Build strong military and civil advocacy for precise positioning and timing services and applications

Innovate!!
...use GPS to its fullest capability

Questions and Answers

HUGO FRUEHAUF (Zyfer, Inc.): How much is JPO interfacing with the Galileo folks?

CAPT. STEVEN RAJOTTE: Actually, I refer that to Don Latterman, who works for SAIC. He's our lead technical for the GPS modernization program.

DONALD LATTERMAN: Actually, we are working a lot with the Galileo folks informally. The State Department right now is handling formal negotiations with the EU on Galileo, and we have been participating actively in that process. However, we have had some informal tactical discussions, one on one with the EU, trying to come to agreement on common standards and put some issues on the table in terms of inter-operability and common standards in architectures. The State Department is really taking the lead on that. We follow technically and programmatically; however, the political environment works the issues. Then we're following State's lead on that.

FRUEHAUF: How much complaining are you getting from Galileo concerning the increase to power on M-code since the original level of GPS was very carefully selected for tons of reasons as to its spectrum noise?

LATTERMAN: Well, obviously right now, we are looking at the influence of higher-power requirements across the board, not only as far as interfering with the Europeans, but also looking at how that is compatible with our current both military and civil architectures. The 20 additional dB spot beam is being deferred to GPS III, so we can really look at that whole architecture and all those issues that we would also look at in the consideration for Galileo. We kind of pushed that decision out as far as to whose systems' architecture is concerned so as to take a hard look at it.