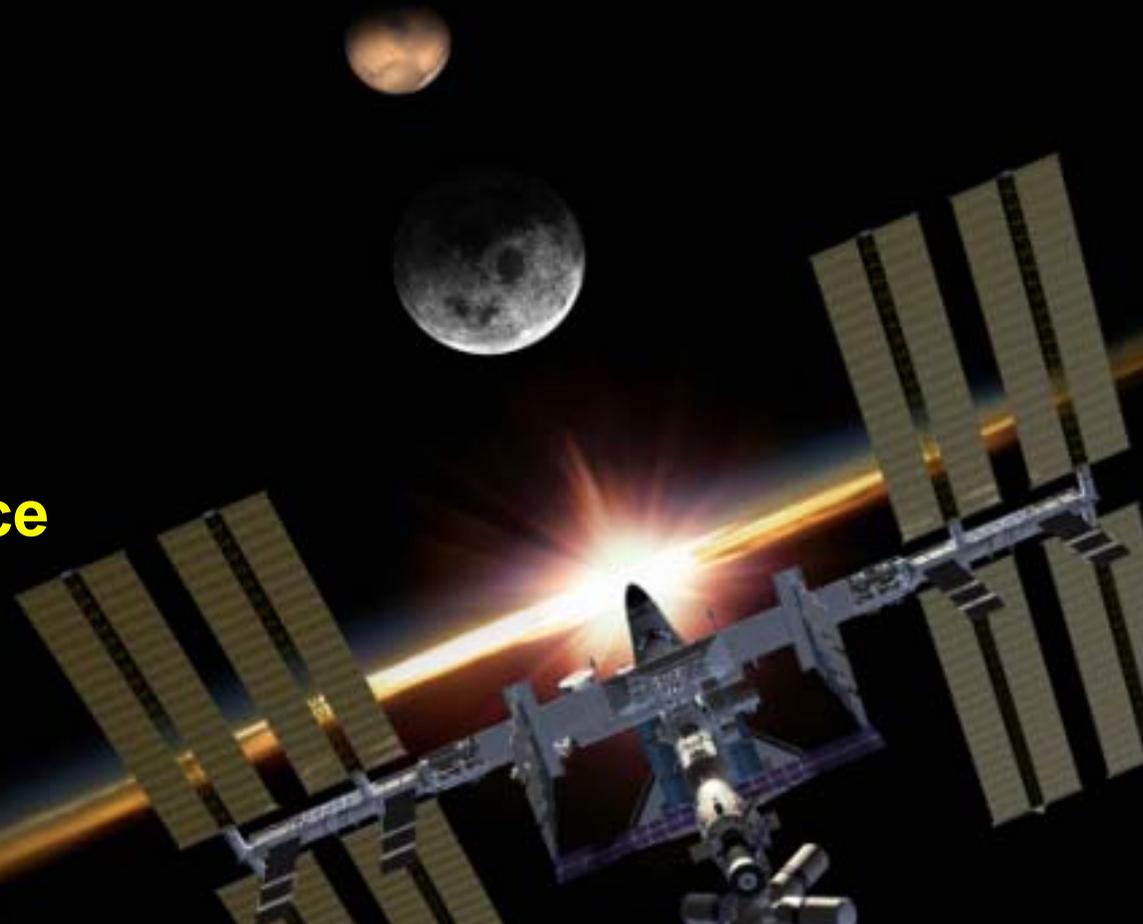


Space-Based PNT Modernization Update

J. J. Miller
Senior GPS Technologist
NASA

**Location 2006 Conference
Bangalore, India
June 6, 2006**



GPS Background

- **Active program for over 30 years**
 - **Created from separate programs in 1973**
 - **Developmental satellites began launch in 1978; operational satellites in 1989**
 - **Initial Operational Capability in 1993; Full Operational Capability in 1995**
- **Developed as a dual-use system**
 - **Military applications for US and Allied use**
 - **Civilian applications for worldwide use**

GPS Constellation Status

3

24 satellite nominal constellation

- **15 Block II/IIA satellites operational**
- **12 Block IIR satellites operational**
 - Modernizing remaining 8 Block IIR satellites
- **1 Block IIR-M in orbit (launched Sep 25)**
 - Set healthy on December 16, 2005
- **2nd IIR-M launch pending**
 - Expected in September 2006
- **Continuously assessing constellation health to determine launch need**
- **Global GPS civil service performance commitment met continuously since Dec 93**

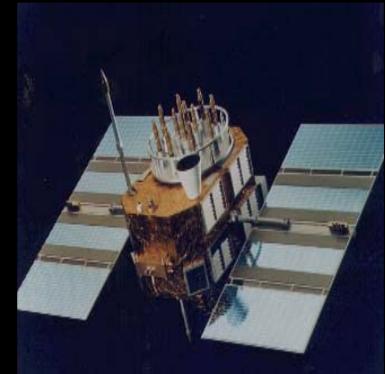
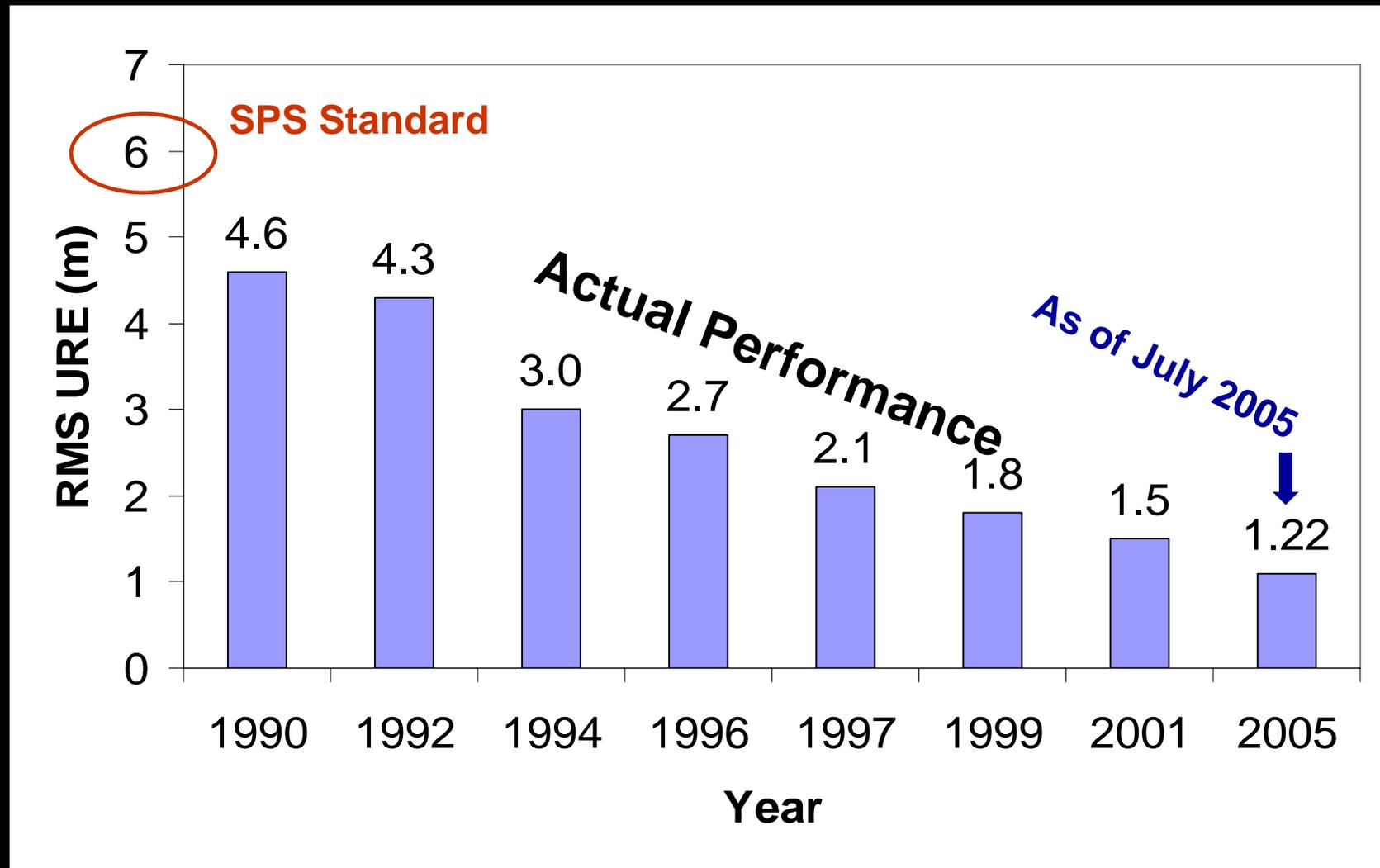


Illustration reprinted courtesy of the GPS Joint Program Office

GPS User Range Error (URE) History

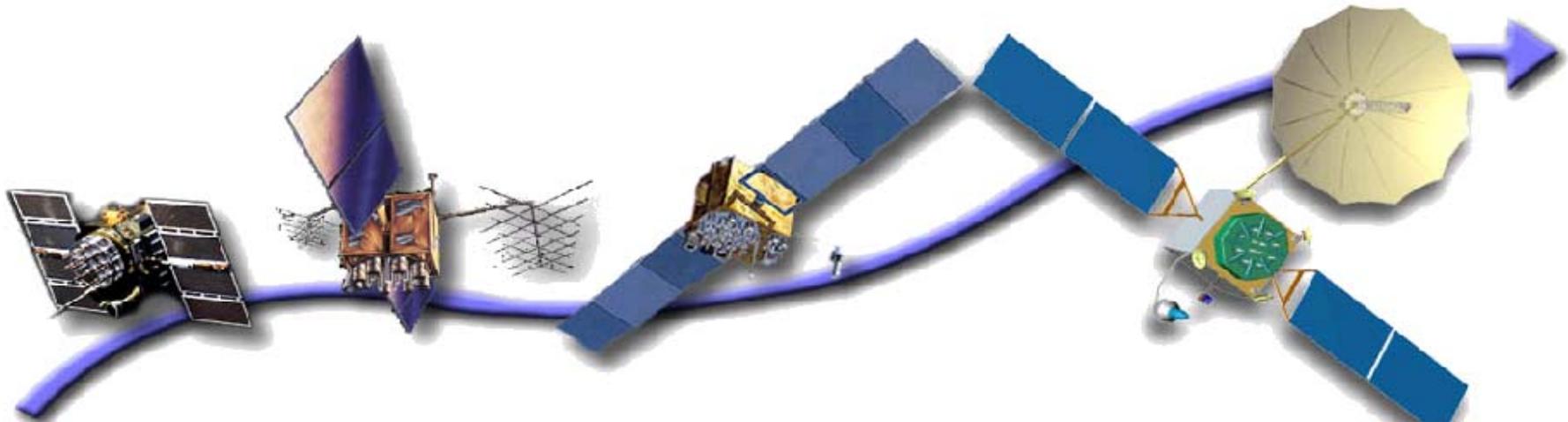


System accuracy far exceeds current standard

Why Modernize?

- **For civil users, new signals provide:**
 - **More robustness against interference**
 - **Compensation for ionospheric delays**
- **For military users, new spectrally separated signals provide:**
 - **Protection of friendly use**
 - **Prevention of adversary exploitation**
 - **Preservation of civil use outside area of operations**
- **For both civil/military, system improvements in accuracy, availability, integrity, and reliability**

The GPS Modernization Path



Increasing System Capabilities ♦ *Increasing Defense / Civil Benefit*

Block IIA/IIR

Basic GPS

- Std Service (16-24m SEP)
 - Single frequency (L1)
 - Coarse acquisition (C/A) code navigation
- Precise Service (16m SEP)
 - Y-Code (L1Y & L2Y)

Block IIR-M, IIF

IIR-M: IIA/IIR capabilities plus

- 2nd civil signal (L2C)
- M-Code (L1M & L2M)
 - Eliminates SA for denial
- Anti-jam flex power

IIF: IIR-M capability plus

- 3rd civil signal (L5)
- Anti-jam flex power

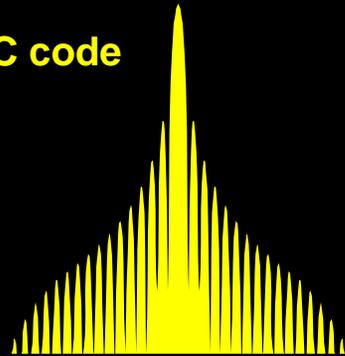
Block III

Block IIIA:

- Increased anti-jam power
- Increased security
- Increased accuracy
- Navigation surety
- Backward compatibility
- Assured availability
- Controlled integrity
- System survivability

Second Civil Signal (L2C)

L2C code



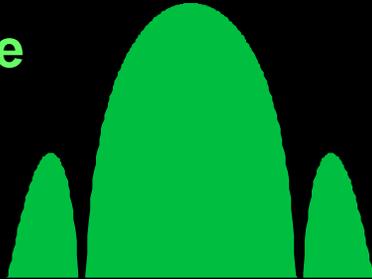
**Begins with IIR-M sats
24 Satellites: ~ 2012***

* Final number of GPS II-F
satellites under revision

- Improves service for ~ 50,000 current scientific / commercial dual-frequency users
- Overcomes some limitations of the existing civil GPS signal (L1 C/A)

Third Civil Signal (L5)

L5 code



Begins with IIF sats
24 Satellites: ~ 2015*

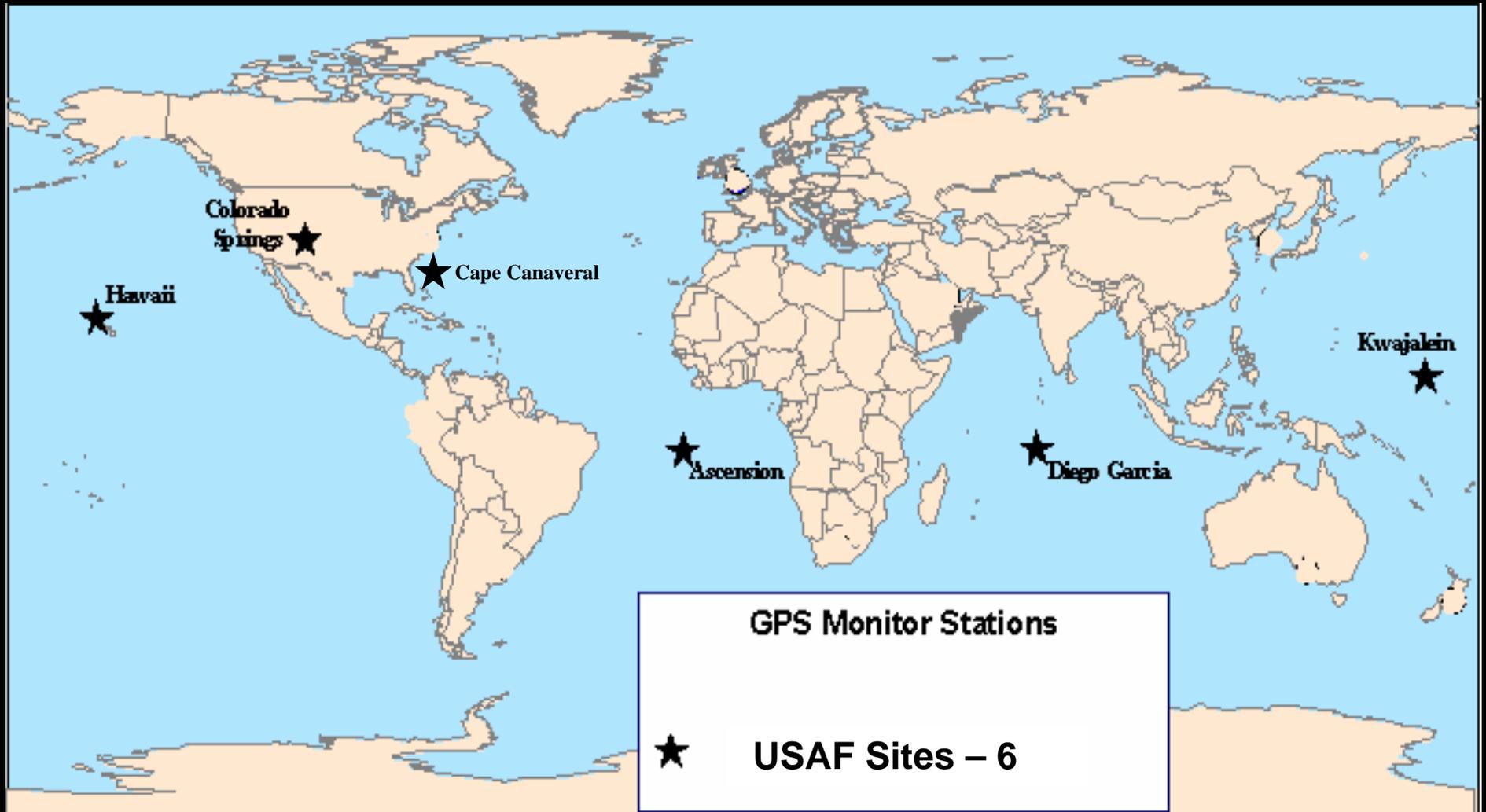
* Final number of GPS II-F
satellites under revision

- New signal structure for enhanced performance
- Higher power & wider bandwidth than other GPS civil signals
 - Improves resistance to interference
- Frequency located in Aeronautical Radionavigation Services band (1164-1215MHz)

Ground Control Modernization

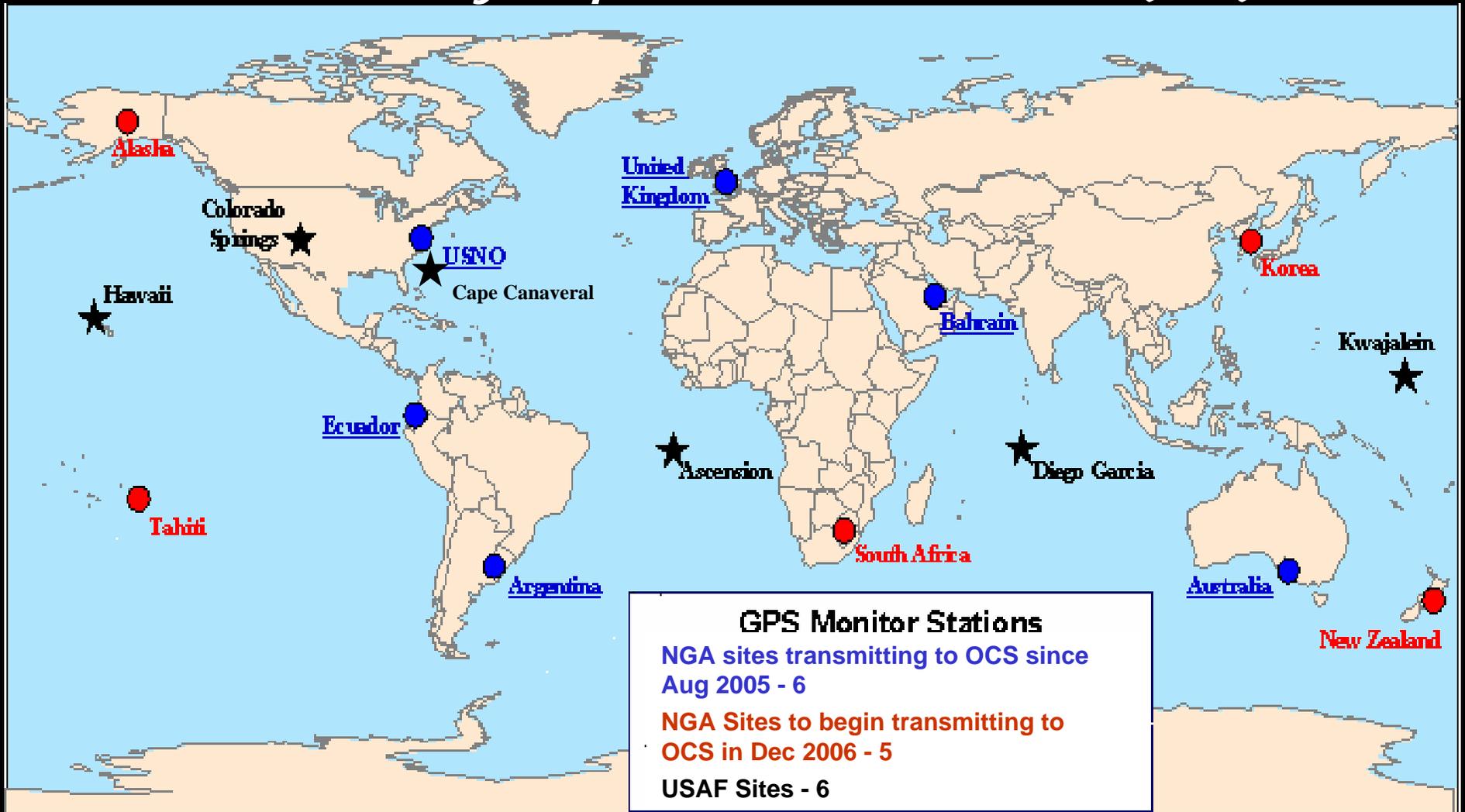
- New Master Control Station with:
 - Improved operator interfaces
 - IIR-M capabilities
 - Integrated Mission Operations Support Center
- Fully mission capable Alternate Master Control Station
- Legacy Accuracy Improvement Initiative
 - Information from additional reference stations:
 - Doubles amount of data being used for signal integrity and constellation performance monitoring
 - Doubles amount of data used for satellite time and position estimation, resulting in more accurate satellite orbital position and clock data available to users

Original GPS Monitoring Stations



On-Going Expansion

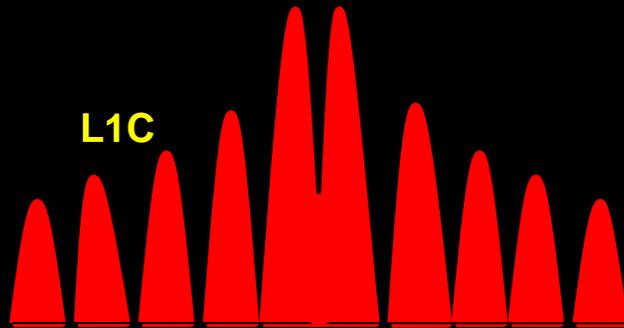
Accuracy Improvement Initiative (AII)



GPS III Civil Benefits

- Significant increase in system accuracy
- Improved availability of accuracy with integrity
- Backward compatibility with existing receivers
- Operational capability for L2C and L5
 - In combination with GPS IIR-M and IIF satellites
- Flexibility to respond to evolving requirements with limited programmatic impacts
- Opportunity to converge with Galileo Open Service

L1C Signal



Begins with GPS III sats
First launch: ~ 2013*

* Based on current schedule

- Modernized L1 civil signal
 - In addition to C/A code to ensure backward compatibility
 - Binary Offset Carrier [BOC] (1,1) modulation
 - Increased robustness and potentially accuracy for civil users
- Proposed as a common baseline L1 open service signal for GPS & Galileo

For additional information see draft IS-GPS-800
at <http://gps.losangeles.af.mil/engineering/icwg>

GPS Modernization Schedule

Activity	Implementation Date
SA set to zero	May 2000
GPS IIR-M Enhancements <ul style="list-style-type: none"> - New L2 Civil (L2C) Signal - M-code on L1 & L2 	1 st satellite operational on December 16, 2005
GPS IIF Enhancements <ul style="list-style-type: none"> - New L2 Civil (L2C) Signal - M-code on L1 & L2 - L5 	1 st launch currently scheduled for 3 rd quarter 2008
GPS III Enhancements <ul style="list-style-type: none"> - New L2 Civil (L2C) Signal - M-code with greater power - L5 - L1C 	1 st launch ~ 2013
OCS Enhancements	On-going

US PNT Policy

- The 1996 policy introduced GPS as a dual-use system, and presented a strategic vision for management and use of GPS.
- The 2004 US Space-Based Positioning, Navigation, and Timing (PNT) policy responds to changing international conditions and the worldwide growth of GPS applications.



U.S. SPACE-BASED POSITIONING, NAVIGATION, AND TIMING POLICY

December 15, 2004

FACT SHEET

The President authorized a new national policy on December 8, 2004 that establishes guidance and implementation actions for space-based positioning, navigation, and timing programs, augmentations, and activities for U.S. national and homeland security, civil, scientific, and commercial purposes. This policy supersedes Presidential Decision Directive/National Science and Technology Council-6, U.S. Global Positioning System Policy, dated March 28, 1996.

I. Scope and Definitions

This policy provides guidance for: (1) development, acquisition, operation, sustainment, and modernization of the Global Positioning System and U.S.-developed, owned and or operated systems used to augment or otherwise improve the Global Positioning System and/or other space-based positioning, navigation, and timing signals; (2) development, deployment, sustainment, and modernization of capabilities to protect U.S. and allied access to and use of the Global Positioning System for national, homeland, and economic security, and to deny adversaries access to any space-based positioning, navigation, and timing services; and (3) foreign access to the Global Positioning System and United States Government augmentations, and international cooperation with foreign space-based positioning, navigation, and timing services, including augmentations.

For purposes of this document:

- "Interoperable" refers to the ability of civil U.S. and foreign space-based positioning, navigation, and timing services to be used together to provide better capabilities at the user level than would be achieved by relying solely on one service or signal.
- "Compatible" refers to the ability of U.S. and foreign space-based positioning, navigation, and timing services to be used separately or together without interfering with each individual service or signal, and without adversely affecting navigation warfare; and
- "Augmentation" refers to space and/or ground-based systems that provide users of space-based positioning, navigation, and timing signals with additional information that enables

U.S. Policy Update

- **Policy expanded to address all Space-Based Positioning, Navigation, and Timing**
 - **GPS and augmentations**
 - **Recognizes other States as service providers**
- **New U.S. Management Processes**
 - **National Space-Based PNT Executive Committee and National Coordination Office**
- **Establishing a formal Advisory Committee**
 - **Assessing best means for international participation**

Demonstrates U.S. Government commitment to all stakeholders, including international community

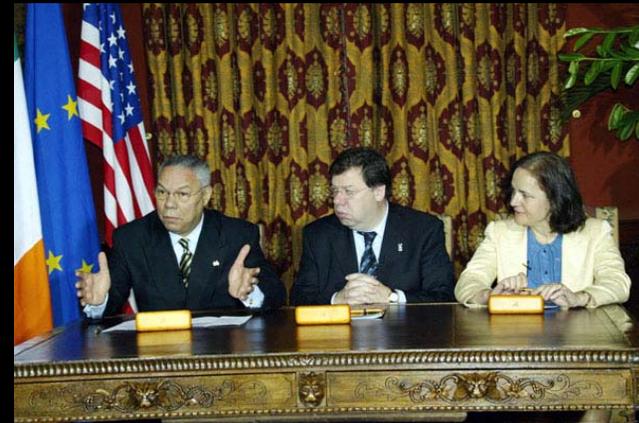
U.S. Policy Update

- Recognizes increased civil, commercial, homeland security and scientific use
 - Spans economic and critical infrastructures
 - Need to plan for backup capabilities and services
- Commits to continued modernization of GPS and its augmentations for improving global services
 - Keeps GPS free of direct user fees
 - Maintains open, free access to information necessary to use these civil services
 - Reaffirms end of civil service degradation (SA)
 - Performance to meet, or exceed, foreign PNT systems
- Work to ensure that foreign PNT systems are interoperable, as well as compatible, with GPS

GNSS International Cooperation

- Long cooperative relationship with Japan on GPS and the US is looking forward to their progress on a GPS-compatible augmentation known as QZSS.
 - Joint Statement of the United States of America and Japan on Global Positioning System Cooperation in 1998.
- On-going consultations with Russia on potential cooperation, as well as compatibility and interoperability, between GPS and GLONASS.
- On-going consultations with India on their development of GAGAN.
- The agreement in 2004 between the US and the European Union (EU) on GPS and Galileo recognized the benefits of interoperable systems for both parties.
- The EU and US agreed to implement a common, open, civil signal on both Galileo and future GPS III satellites.

Space-based PNT services must serve global users and should have transparent interfaces and standards



June 26, 2004 Press Conference at US-EU Summit in Shannon, Ireland (left to right: US Sec. of State Colin Powell, Irish Foreign Minister Brian Cowen, EU Vice-President Loyola De-Palacio)

Summary

- **GPS is rapidly evolving into a key part of the global infrastructure**
- **Civil service continues to exceed performance standards**
- **Next step in Modernization has begun**
 - **IIR-M launch with L2C and M-code**
 - **Enhancements will continue through GPS III**
- **Augmentations continue to be an integral component of U.S. Space-Based PNT Services**

Continuously Improving GPS & Augmentation Services are benefiting users worldwide

Vision For Space Exploration: A New Era that begins now

