GPS Modernization, U.S. PNT Policy, and NASA Applications

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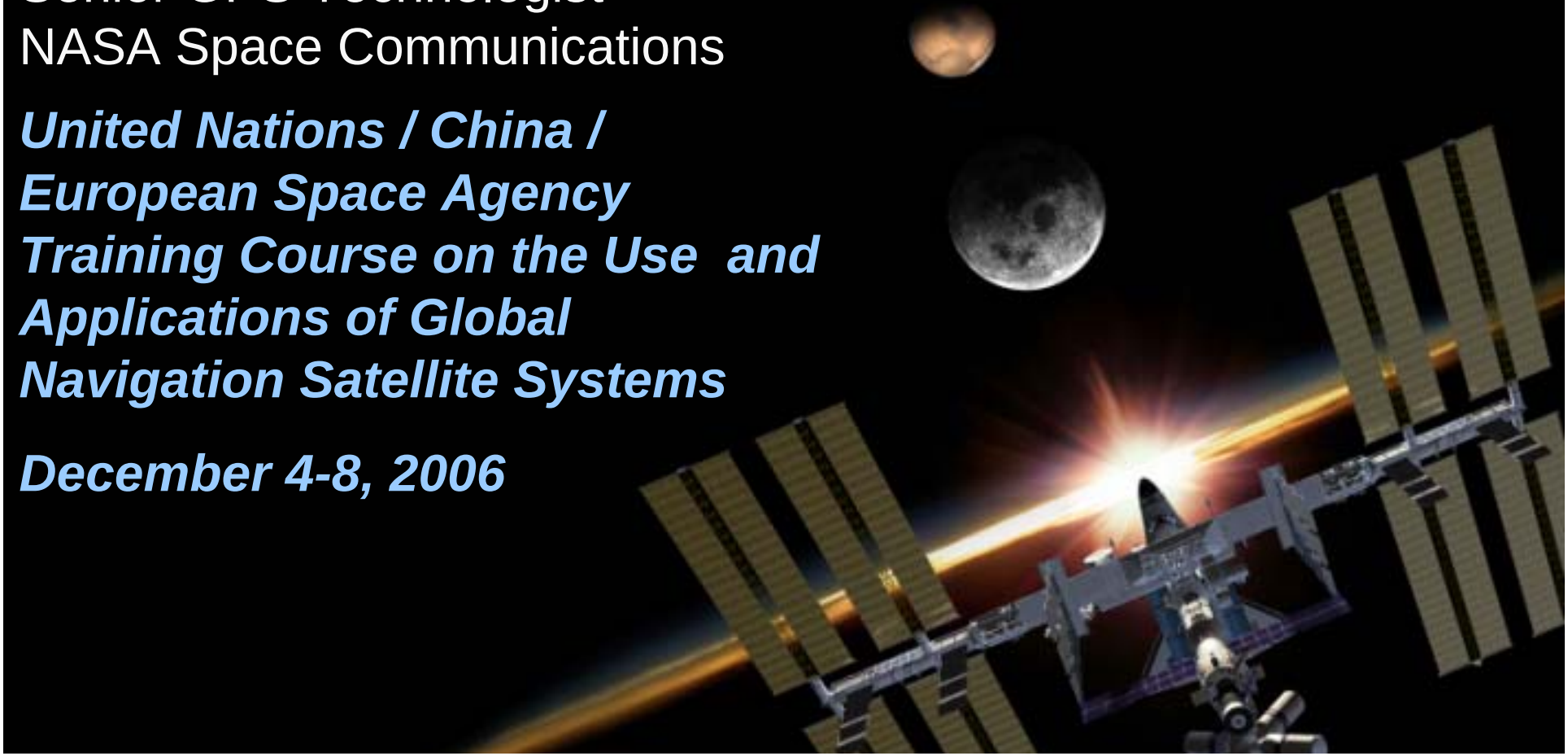
United Nations / China / European Space Agency Training Course on the Use and Applications of Global Navigation Satellite Systems

December 4-8, 2006

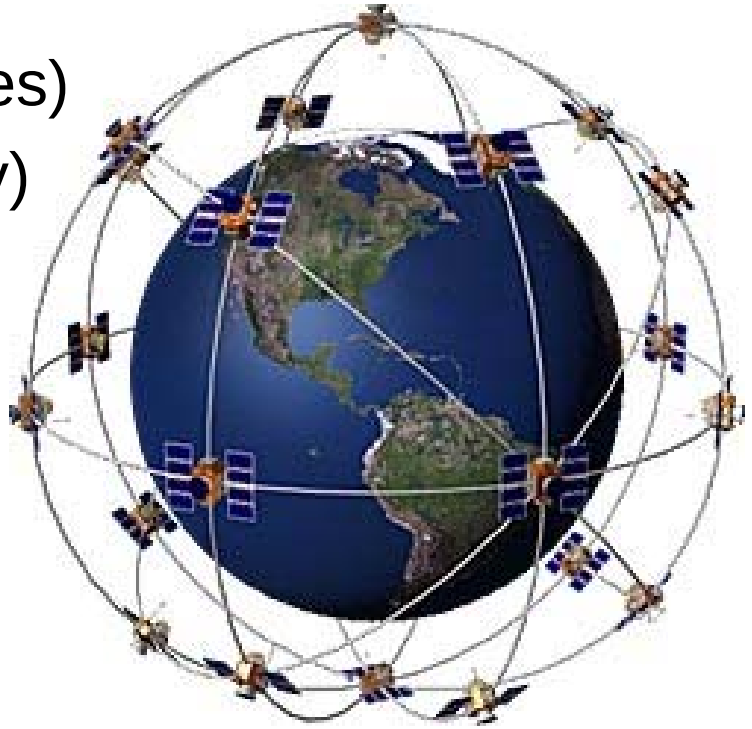


Overview

- GPS Introduction
- GPS Modernization
- U.S. PNT Policy
- Radio Spectrum
- NASA Applications

The Global Positioning System

- Baseline 24 satellite constellation in medium earth orbit
- Global coverage, 24 hours a day, all weather conditions
- Satellites broadcast precise time and orbit information on L-band radio frequencies
- Two types of services:
  - Standard (free of direct user fees)
  - Precise (U.S. and Allied military)
- Three segments:
  - Space
  - Ground control
  - User equipment



GPS is a Global "Public Good"

- **GPS services are like a "super lighthouse" – USG Owned & Operated**
  - **Paid for by U.S. taxpayers and provided free to the world**
  - **Users are not hailed at port for fee or tax collection**
  - **Managed at a national level as a multi-use asset**
  - **Acquired and operated by Air Force on behalf of USG**
- **GPS receivers are like AM/FM radios**
  - **Whenever, wherever -- without advertising!!**
  - **Adding users costs nothing**
  - **Tracking its usage is impossible through GPS itself**
- **GPS is <u>not</u> a fee-for-service utility like cable TV**
  - **Usage is not metered -- direct cost to user is "zero"**
  - **Civil access is open and unconstrained by "locks" or encryption**
  - **Public domain documentation**
    - Available on an equal basis to users and industry worldwide
    - Anyone can develop user equipment

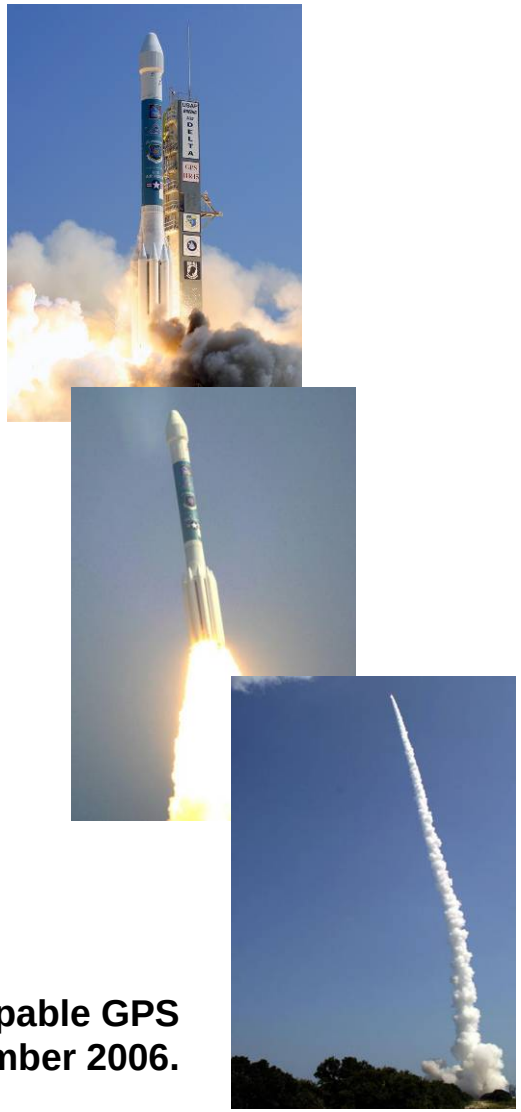
"Lighthouses in the sky, serving all mankind"

Dr. Ivan A. Getting (1912–2003)

GPS Constellation Status

24 satellite nominal constellation

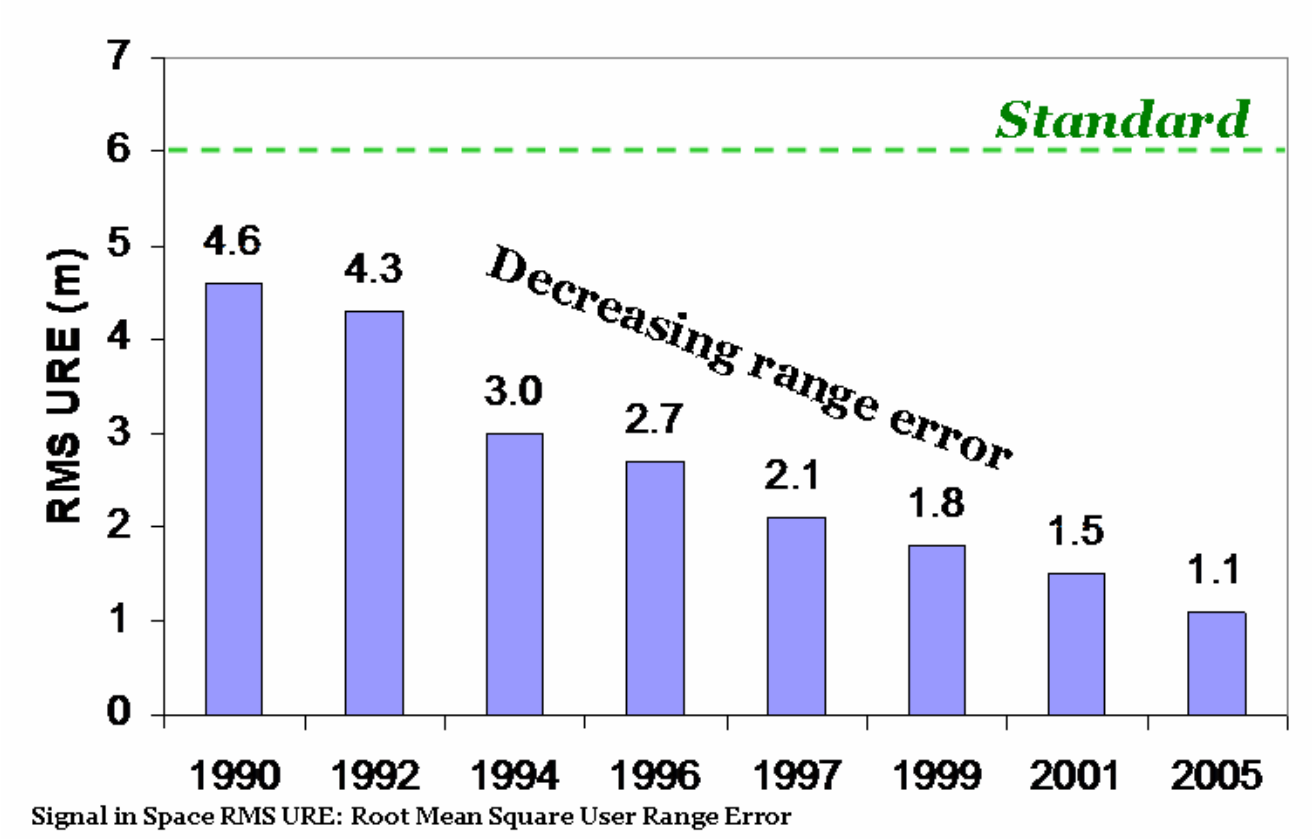
- 30 Operational satellites
- 15 Block II/IIA satellites operational
- 12 Block IIR satellites operational
  - Modernizing remaining 8 Block IIR satellites
- 3 Block IIR-M in orbit (latest launch on Nov 17, 2006)
- Continuously assessing constellation health to determine launch need
- Global GPS civil service performance commitment met continuously since Dec 93



Launch of the second L2C-capable GPS satellite, GPS II-R-15(M) on 25 September 2006.

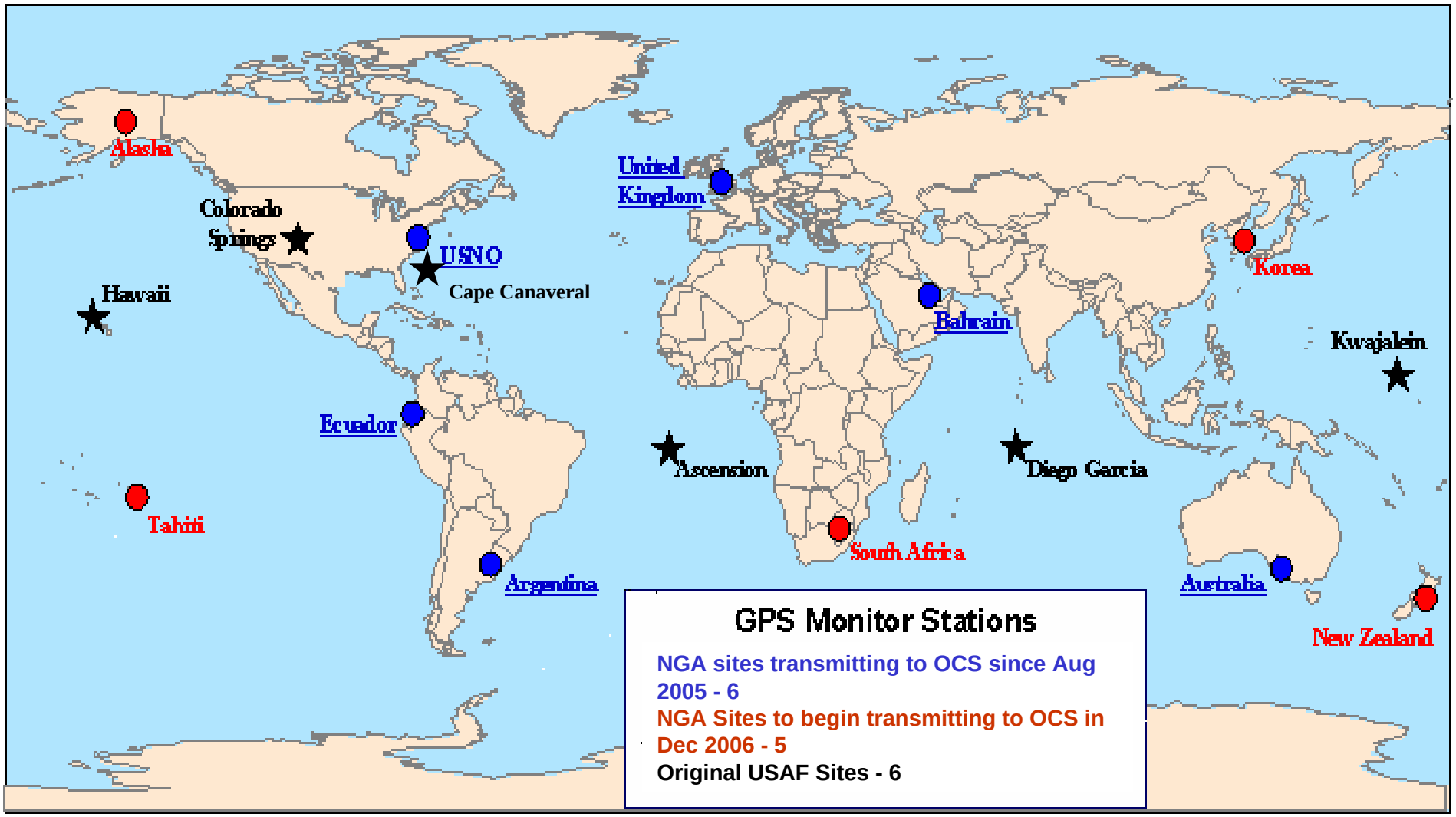
GPS Single Frequency Performance

Steady decrease in error due to improvements such as the addition of new monitoring stations, tighter control of clocks, etc.



System accuracy far exceeds current standard

GPS Monitoring Stations



GPS Applications continue to explode!

Satellite Operations

Power Grid Management

Personal Navigation

Surveying & Mapping

Trucking & Shipping

Aviation

Communications Network Synchronization

Recreation

Railroads

Fishing & Boating

Offshore Drilling

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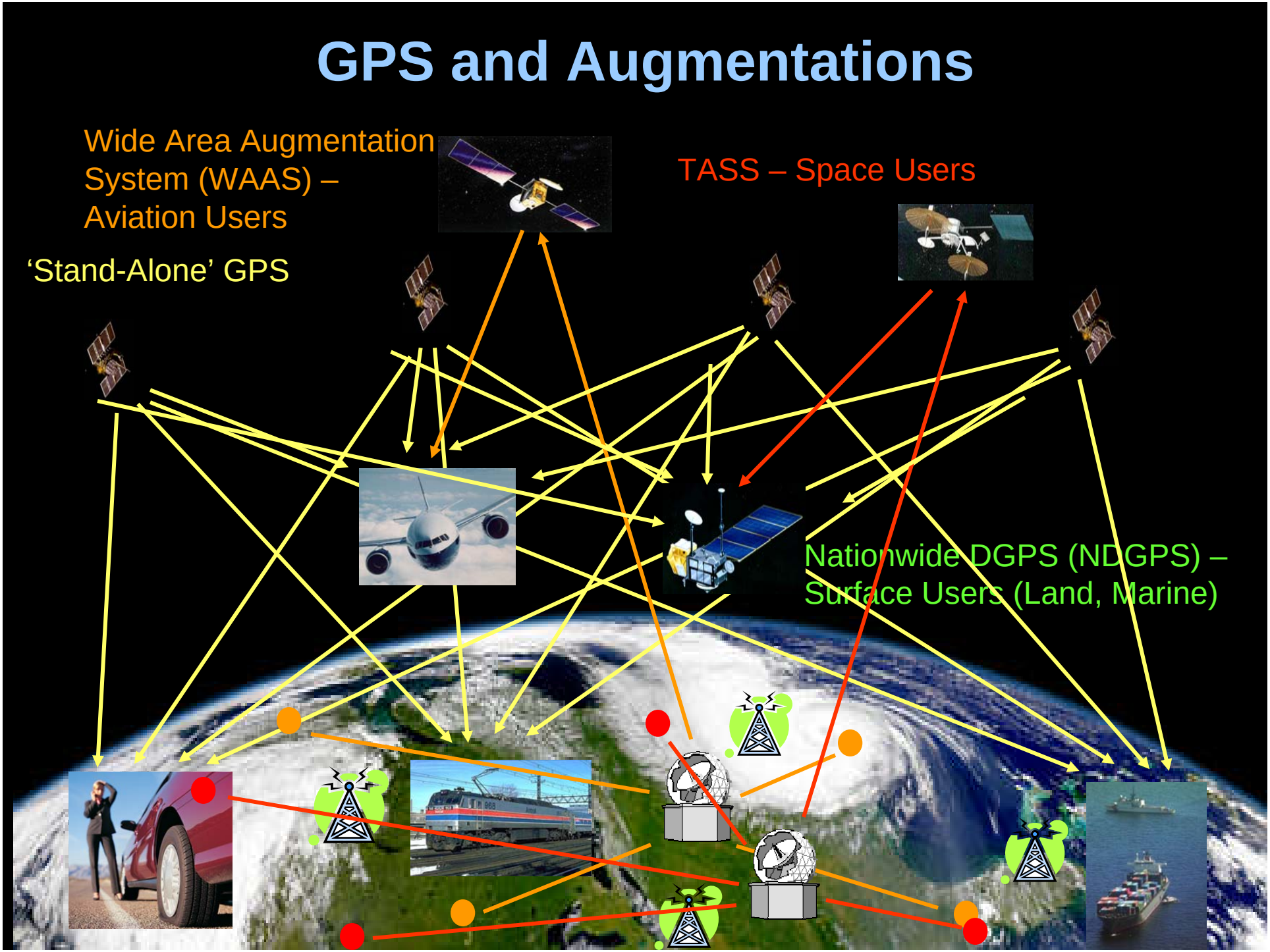
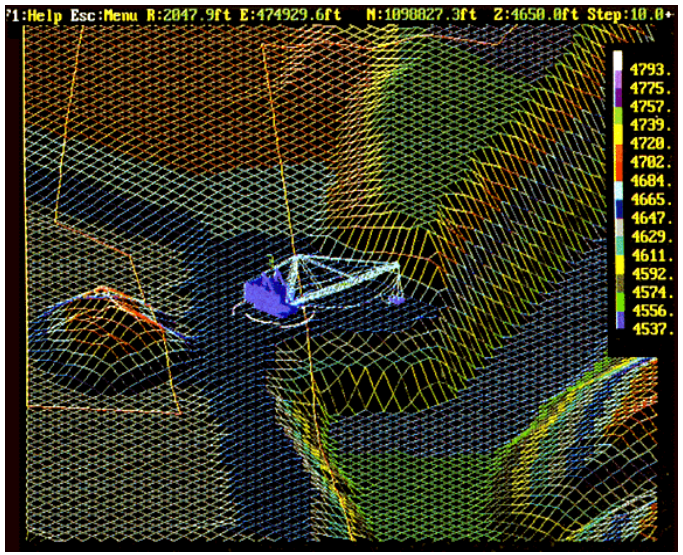
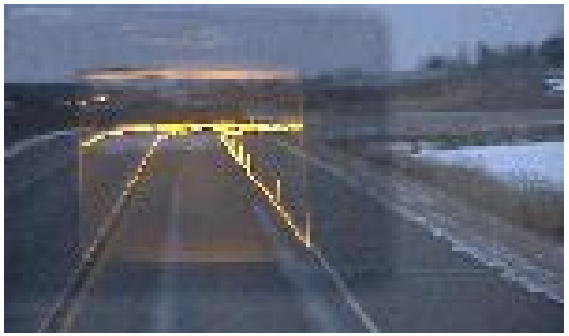
GPS and Augmentations

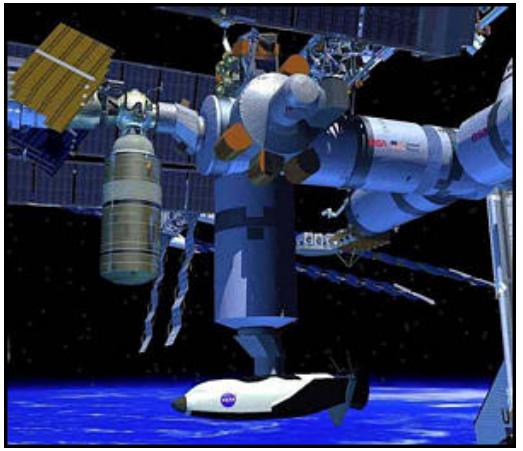


New Commercial Applications Are Refined Every Day



- Open pit mining
- Child safety
- **Automatic snowplow guidance**
- Spacecraft control
- Power grid management
- Wireless mobile applications



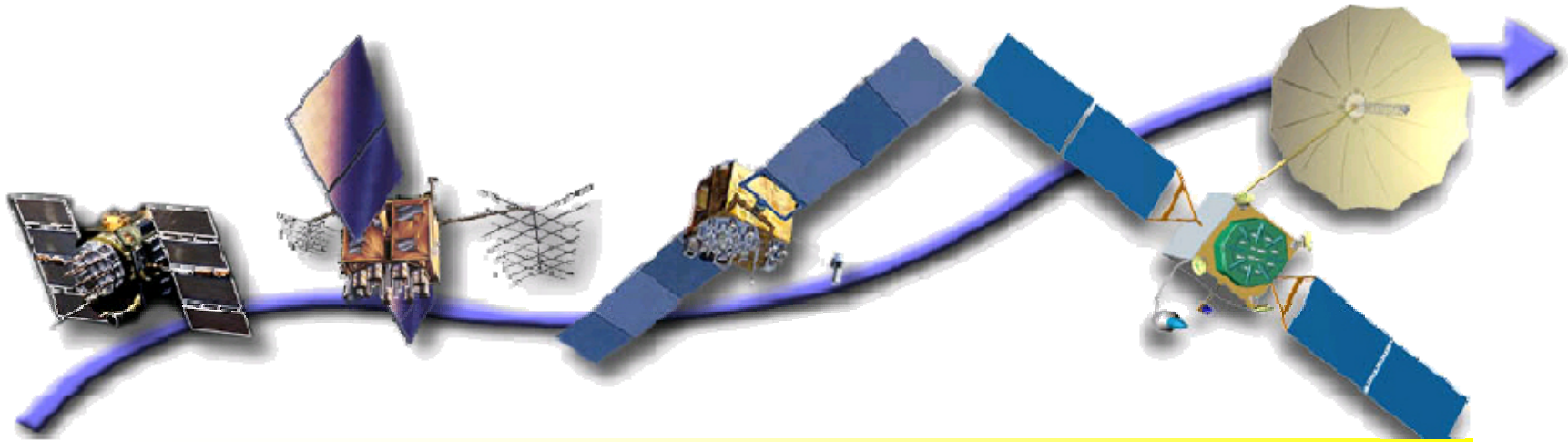


GPS IN ACTION!!

GPS Modernization Goals

- System-wide improvements in:
  - Accuracy
  - Availability
  - Integrity
  - Reliability
- Robustness against interference
- Improved indoor, mobile, and urban use
- Interoperability with other GNSS constellations
- **Backward compatibility**

GPS Modernization Program



Increasing System Capabilities ◆ Increasing Defense / Civil Benefit

Block IIA/IIR

Basic GPS

- **Standard Service**
  - **Single frequency (L1)**
  - **Coarse acquisition (C/A) code navigation**
- **Precise Service**
  - **Y-Code (L1Y & L2Y)**
  - **Y-Code navigation**

Block IIR-M, IIF

IIR-M: IIA/IIR capabilities plus

- **2nd civil signal (L2C)**
- **M-Code (L1M & L2M)**

IIF: IIR-M capability plus

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

Block III

- **Backward compatibility**
- **4th civil signal (L1C)**
- **Increased accuracy**
- **Increased anti-jam power**
- **Assured availability**
- **Increased security**
- **System survivability**
- **Search and Rescue**

Modernized GPS – Civil Signals

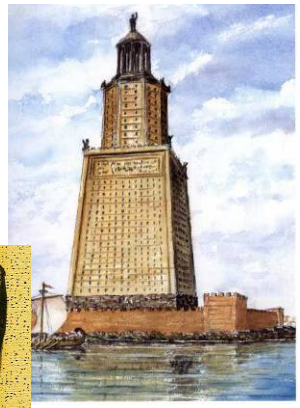
- **Second civil signal ("L2C")**
  - Designed to meet commercial needs
    - Higher accuracy through ionospheric correction
    - Higher effective power and improved data structure reduce interference, speed up signal acquisition, enable miniaturization of receivers, may enable indoor use
  - Began with GPS Block IIR-M in Sep 2005; 24 satellites: ~2014
- **Third civil signal ("L5")**
  - Designed to meet demanding requirements for transportation safety (safety-of-life)
    - Uses highly protected Aeronautical Radio Navigation Service (ARNS) band
  - Begins with GPS Block IIF
  - First launch: ~2007; 24 satellites: ~2016
- **Fourth civil signal ("L1C")**
  - Designed with international partners to enable GNSS interoperability
  - Begins with GPS Block III
  - First launch: ~2013; 24 satellites: ~2021

GPS Major Milestones

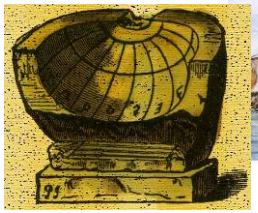
- **1973:** Decision to develop a satellite navigation system based on the systems TRANSIT, TIMATION, and Project 621B
- **1978:** First GPS Block I satellites launched
- **1983:** President Reagan offers free civilian access to GPS after Korean Airlines Flight 007 incident
- **1996:** President Clinton issues U.S. policy declaring GPS a dual-use system under joint civil/military management
  - Civil GPS remains free of direct user fees
- **1997:** U.S. Congress codifies policy provisions into law
- **2000:** Selective Availability on civil signal set to zero by President Clinton providing full GPS accuracy to users
- **2004:** President Bush W. issues new policy on space-based positioning, navigation, and timing (PNT)
  - Recognizes changing international conditions and worldwide growth of GPS applications
- **2005:** 1st Launch of modernized signals (L2C and M Code)

The Future of Positioning, Navigation, and Timing?

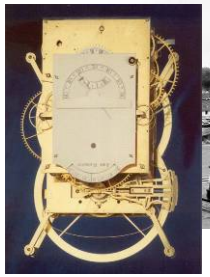
Pharos of Alexandria, Egypt



Ancient Sun Dial



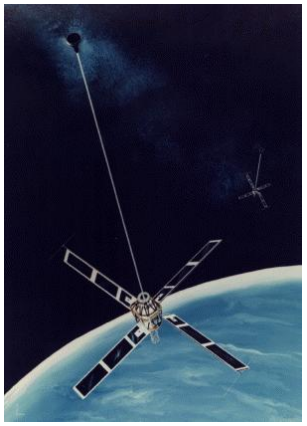
Harrison Clock



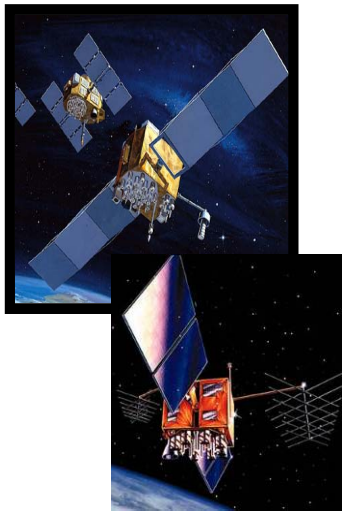
Cape Henry, VA, Lighthouses (old and new)

USCG Loran-C station, Pusan, South Korea, 1950s

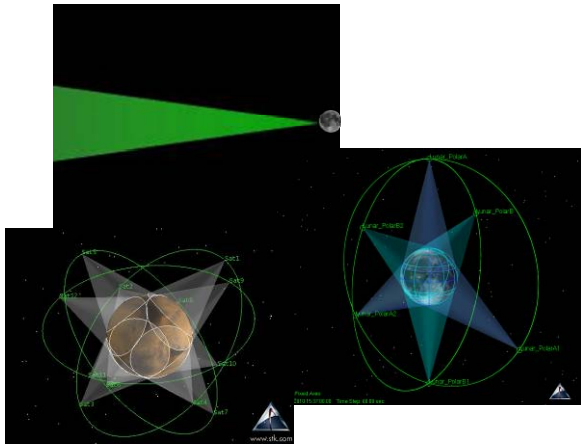
Transit Satellites



GPS Satellites



Beacons and/or GPS-like Satellites on other Planetary Bodies



2004 U.S. PNT Policy Overview (GPS!)

- **U.S. Space-Based Positioning, Navigation, and Timing (PNT) Policy**
  - **Signed on 8 Dec 04; publicly released on 15 Dec 04**
  - **Updated U.S. policy while retaining prior GPS principles**
- **Established a stronger National Space-Based PNT Executive Committee; IGEB disestablished**
  - **Chaired by Deputy Secretaries of Defense and Transportation**
- **Created a new National Coordination Office**
- **Created a new Advisory Board from private sector**
- **Enabled new ways to fund future GPS modernization for civil applications**

U.S. Policy Principles

- **No direct user fees for civil GPS services**
- **Open public signal structure for all civil services**
  - **Promotes equal access for user equipment manufacture, applications development and value-added services**
  - **Facilitates open market driven competition**
- **Use of GPS time, geodesy, and signal standards**
- **Global compatibility and interoperability of future systems with GPS**
- **Protect the current radionavigation spectrum from disruption and interference**
- **Recognition of national and international security issues and protecting against misuse**

New Policy: Goals

- Provide uninterrupted availability of PNT services
- Meet growing demands in national, homeland, economic security, scientific, and commercial uses
- Continue to provide civil PNT services
  - Ensure they exceed, or are at least equivalent to, those of foreign civil space-based PNT services
- U.S. space-based PNT services remain essential components of internationally accepted services

New Policy: Objectives

- Provide space-based civil PNT services free of direct user fees on a continuous, worldwide basis
  - Civil, commercial, homeland security and scientific use
- Provide open, free access to information necessary to use these civil services
- Improve the performance of space-based PNT
  - Includes robust resistance to interference for homeland security, civil, commercial, and scientific users worldwide
- Maintain the GPS as a component of multiple sectors of the U.S. Critical Infrastructure
  - IAW Homeland Security Presidential Directive-7
- Ensure that foreign PNT systems are interoperable with GPS
  - Or, at a minimum, are compatible

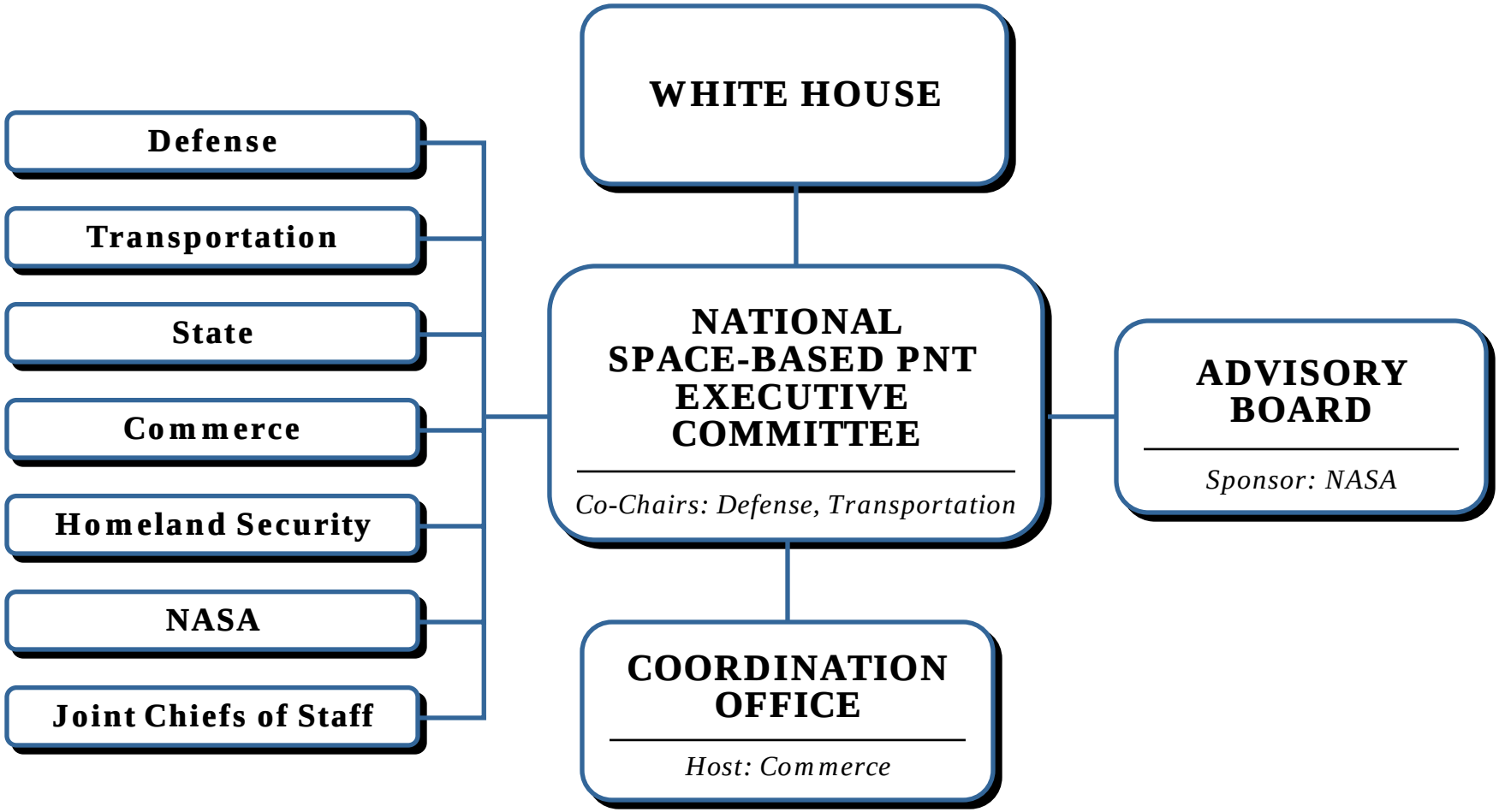
New Policy: Management

- Establish a stronger National Space-Based PNT Exec Committee; IGEB disestablished
- Chaired by Deputy Secretaries of Defense and Transportation
  - Or their designated representatives
- Membership includes: State, Commerce, Homeland Security, JCS, and NASA
  - Other Agencies as required
  - NSC, OSTP, OMB, and HSC as observers
- Executive Committee will advise and coordinate among Departments
- Establish a National PNT Coordination Office
- Establish a Space-Based PNT Advisory Board

Exec Committee: Responsibilities

- Ensure that national security, homeland security, and civil requirements receive full consideration
- Coordinate Departments' PNT program plans, requirements, budgets, and policies
- Assess the adequacy of funding and schedules to meet validated requirements in a timely manner
- Promote plans to modernize U.S. space-based PNT infrastructure, including:
  - Development, and operation of new and/or improved national security and public safety services
  - Determining the apportionment of requirements between GPS and its augmentations, including use of user equip
- Review proposals and provide recommendations for international cooperation
  - Includes spectrum management and protection issues

National Management of GPS



GPS Radio Spectrum

Spectrum – What is it and why do we care?

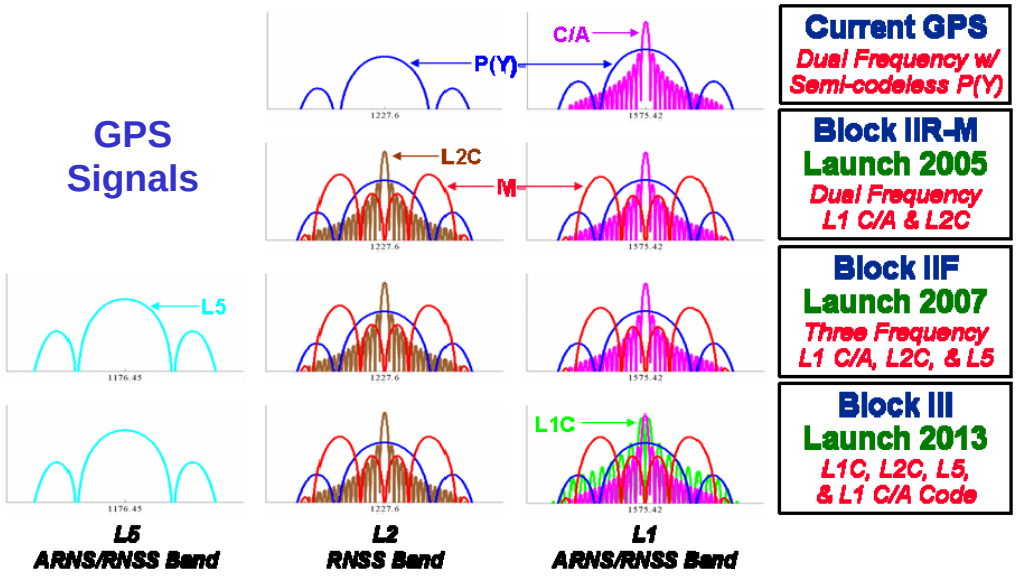
- The "Invisible Infrastructure"
- A "Public Good" that needs to be Protected
- A Critical Enabler of all things Radio
- A finite resource generating urgent demand

$ Prime "Beach Front" Property!

RADIO FREQUENCY SPECTRUM IS THE ELECTRONIC FOUNDATION OF NATIONS

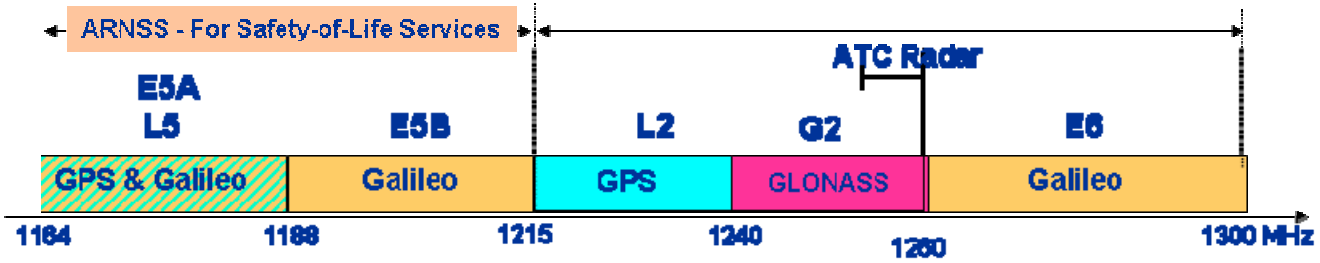
$ 21ST Century Gold!

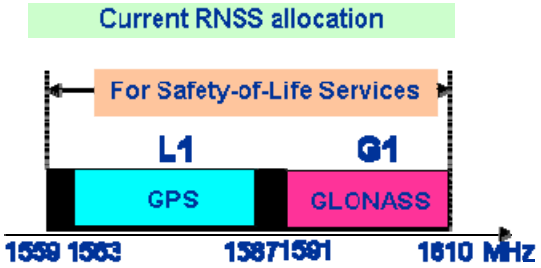
RNSS Frequency Spectrum

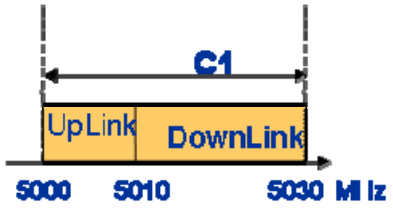


Two is company, three is a crowd, four is … ?

RNSS Allocations





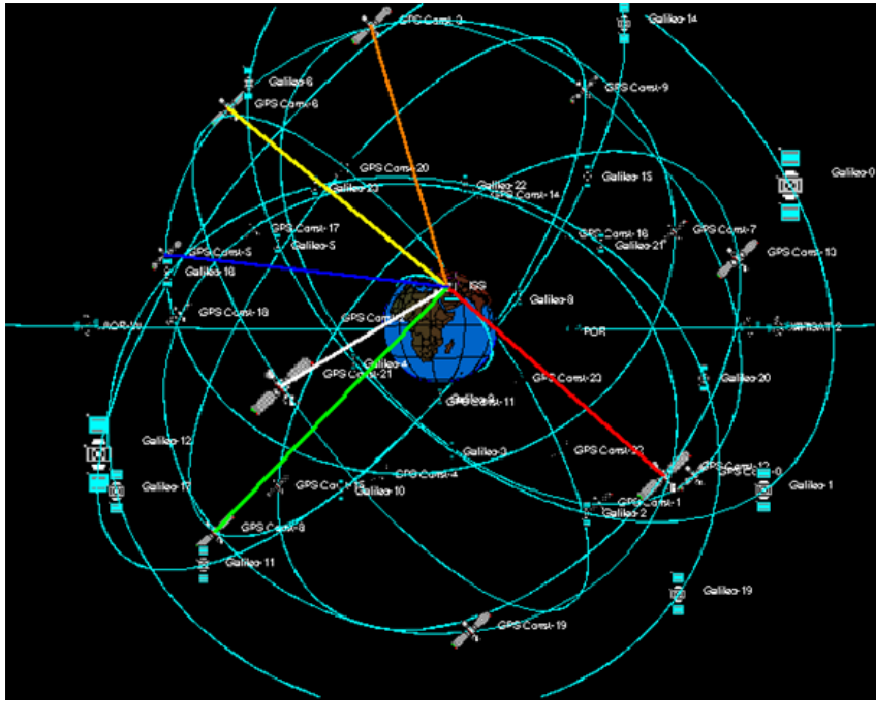


"Spectrum Sharing" or "Encroachment"?

- Potential for harmful interference to safety-of-life signals forces constraints on critical operations
  - **Limits infrastructure and equipage options**
- Spectrum encroachment will force costly upgrades to current user and service provider equipment
  - **Complicates future certification processes**
- Rise of electromagnetic "Noise Floor" in sensitive bands could prevent critical services from maturing
  - **GPS positioning, navigation, & timing (PNT), Earth observation, radio astronomy, space research, etc.,**

NASA Activities: RNSS Space-to-Space Spectrum Protection

- Space-to-Space direction added to RNSS allocations in 1164-1300 MHz, 1559-1610 MHz and 5010-5030 MHz at WRC-2000
- Spaceborne GPS receivers are used for spacecraft autonomous navigation as well as scientific measurements requiring precise orbital position determination
- Spaceborne RNSS receivers are potentially more susceptible to RF interference than ground based receivers
- Spaceborne RNSS receiver applications need to be taken into consideration when coordinating new or enhancing existing RNSS constellations to ensure compatibility
- NASA is involved in activities relating to RNSS space-to-space spectrum protection

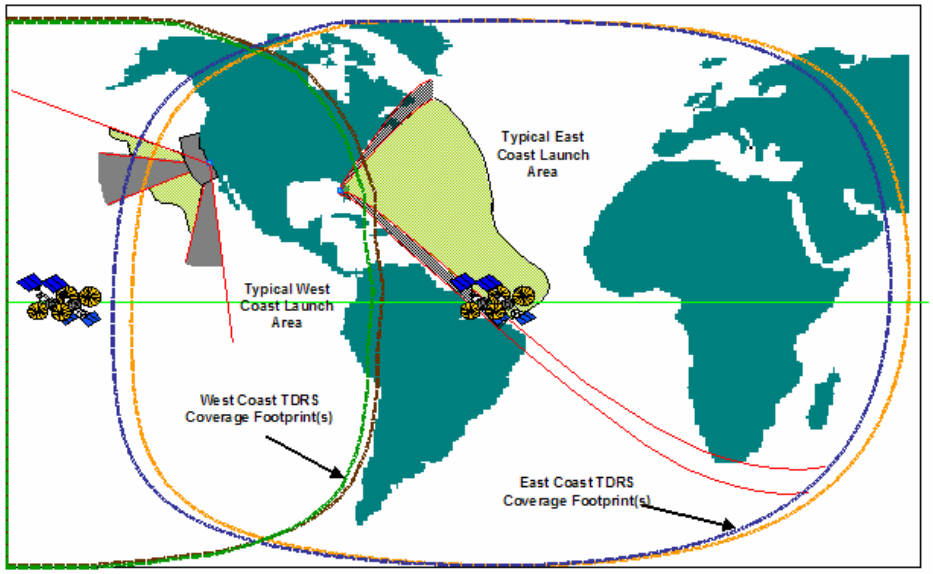


NASA Applications: Uses of GPS

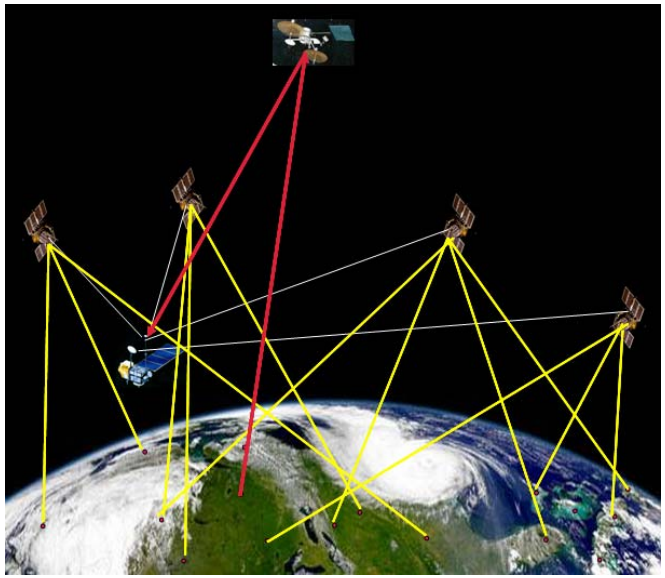
- GPS used on Space Shuttle for re-entry and landing and International Space Station (ISS) for orbit and attitude determination
- Launch vehicles will use GPS tracking after 2010
  - Space-based Range
- TDRSS Augmentation Service for Satellites (TASS) already broadcasting GDGPS corrections
- Many emerging space users of GPS technology beyond Low Earth Orbit
  - Geosynchronous and High Earth Orbits (Apogee above GEO altitude)
  - Earth-Moon navigation, and beyond

ISS: 4 GPS antennas on T1 truss

STS-115: 1st time GPS taken to navigation



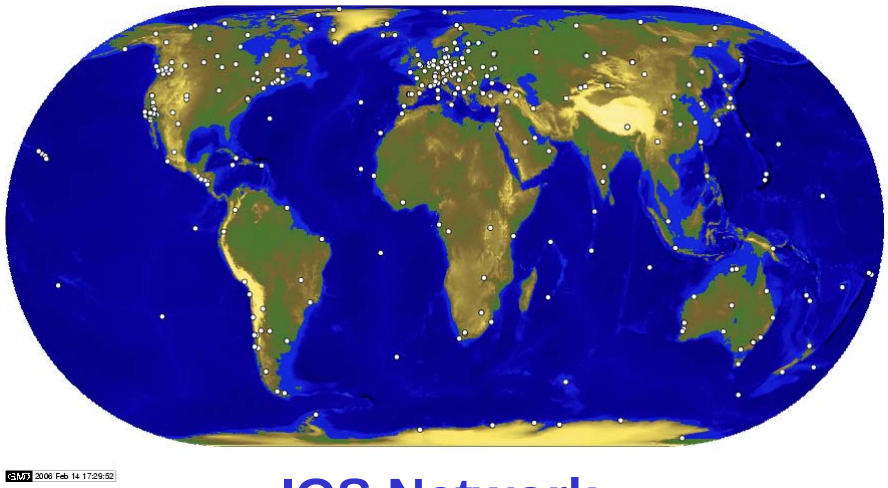
TDRSS Space-Based Range



TASS

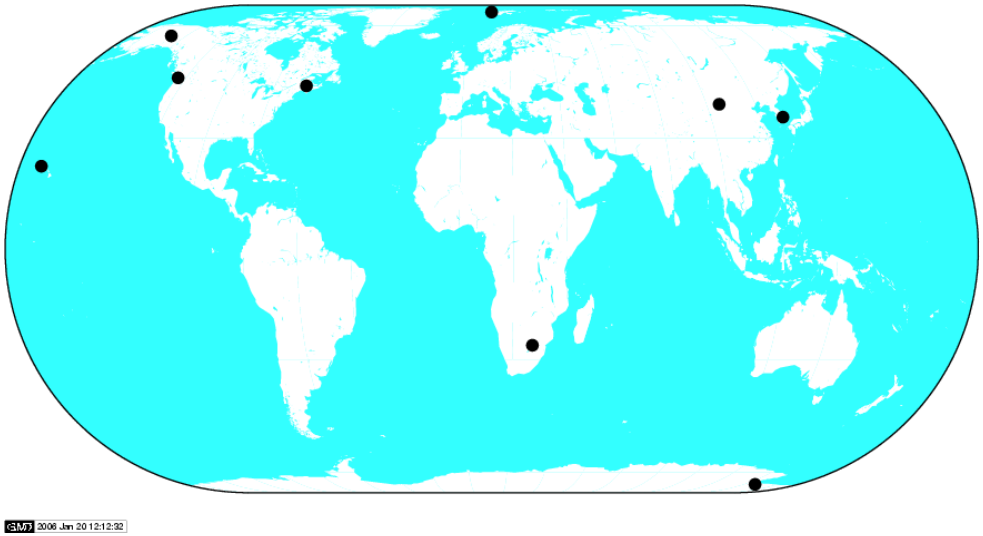
NASA Activities: GPS Tracking

- The International GNSS Service is a voluntary federation of more than 200 worldwide agencies that pool resources and permanent GNSS station data to generate precise GNSS products.
- Over 350 permanent geodetic GNSS stations operated by more than 100 agencies worldwide comprise the IGS network. Currently the IGS supports two GNSS: GPS and GLONASS. To be extended to Galileo.
- NASA funds two centers, JPL and GSFC.



IGS Network

L2C Tracking Network

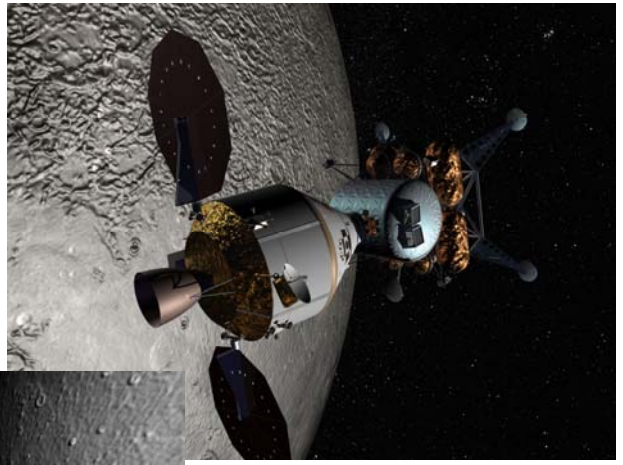


- NASA/JPL has deployed a global network of L2C receivers with real-time communications.
- The new civil signal, L2C, has been tracked by JPL since October 21, 2005.
- Additional L2C-capable receivers were deployed by IGS partners.
- Enables a robust assessment of the civilian performance of the new L2C capability.

NASA Activities: The Vision for Space Exploration (VSE)

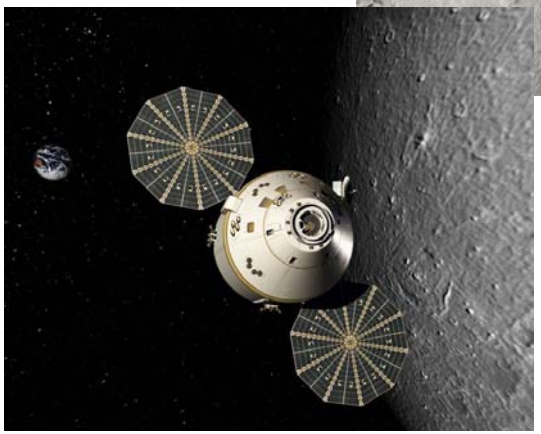
- On January 14, 2004 the US President announced a new vision for NASA to
  - Implement a sustained and affordable human and robotic program to explore the solar system and beyond;
  - Extend human presence across the solar system, starting with a human return to the Moon by the year 2020, in preparation for human exploration of Mars and other destinations;
  - Develop the innovative technologies, knowledge, and infrastructures both to explore and to support decisions about the destinations for human exploration; and
  - Promote international and commercial participation in exploration to further U.S. scientific, security, and economic interests.

Orion crew vehicle launches on board the Ares I crew launch vehicle



Orion docked with Lunar Surface Access Module (LSAM)

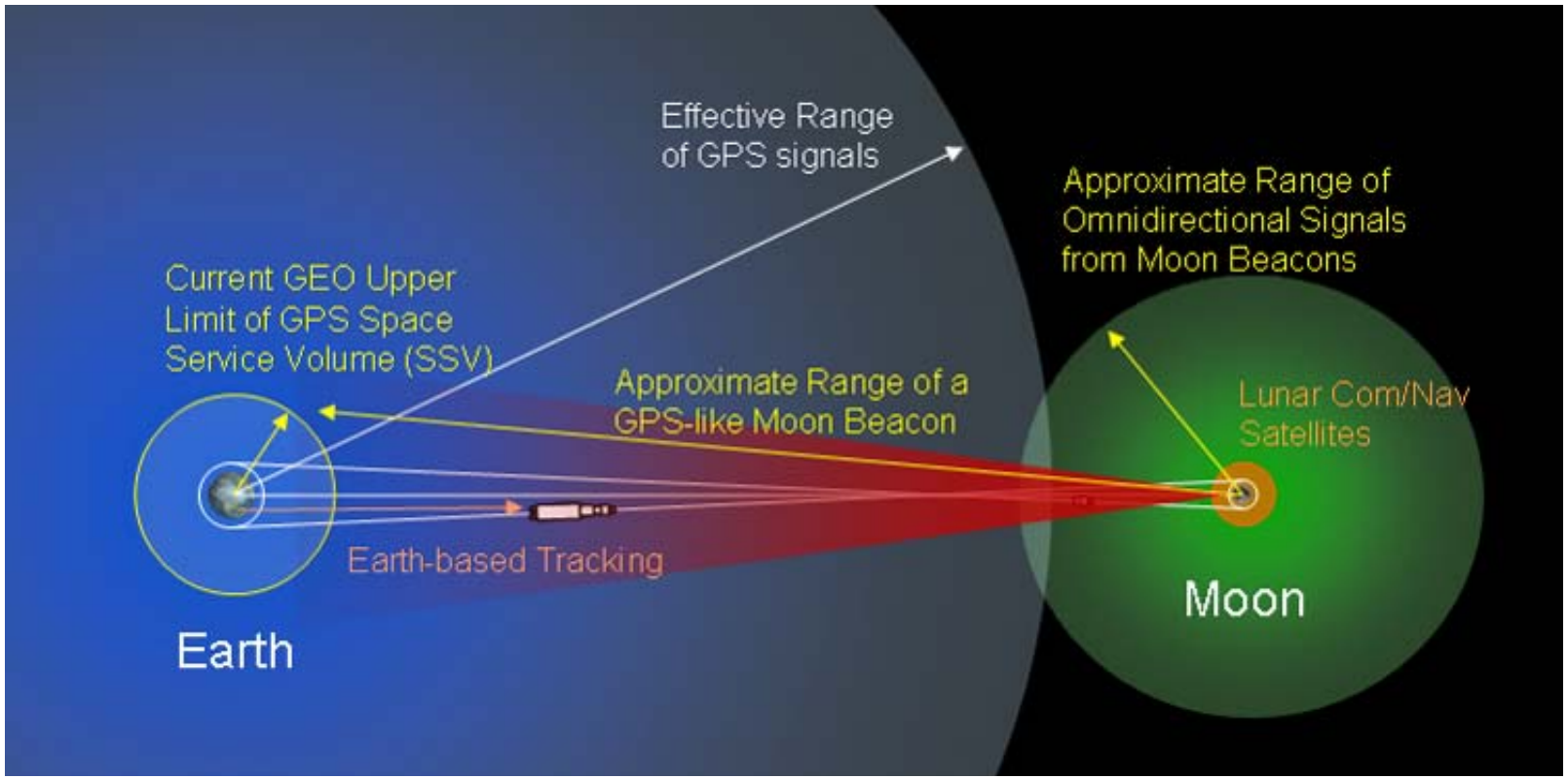
Ares V cargo launch vehicle



Orion in Lunar Orbit

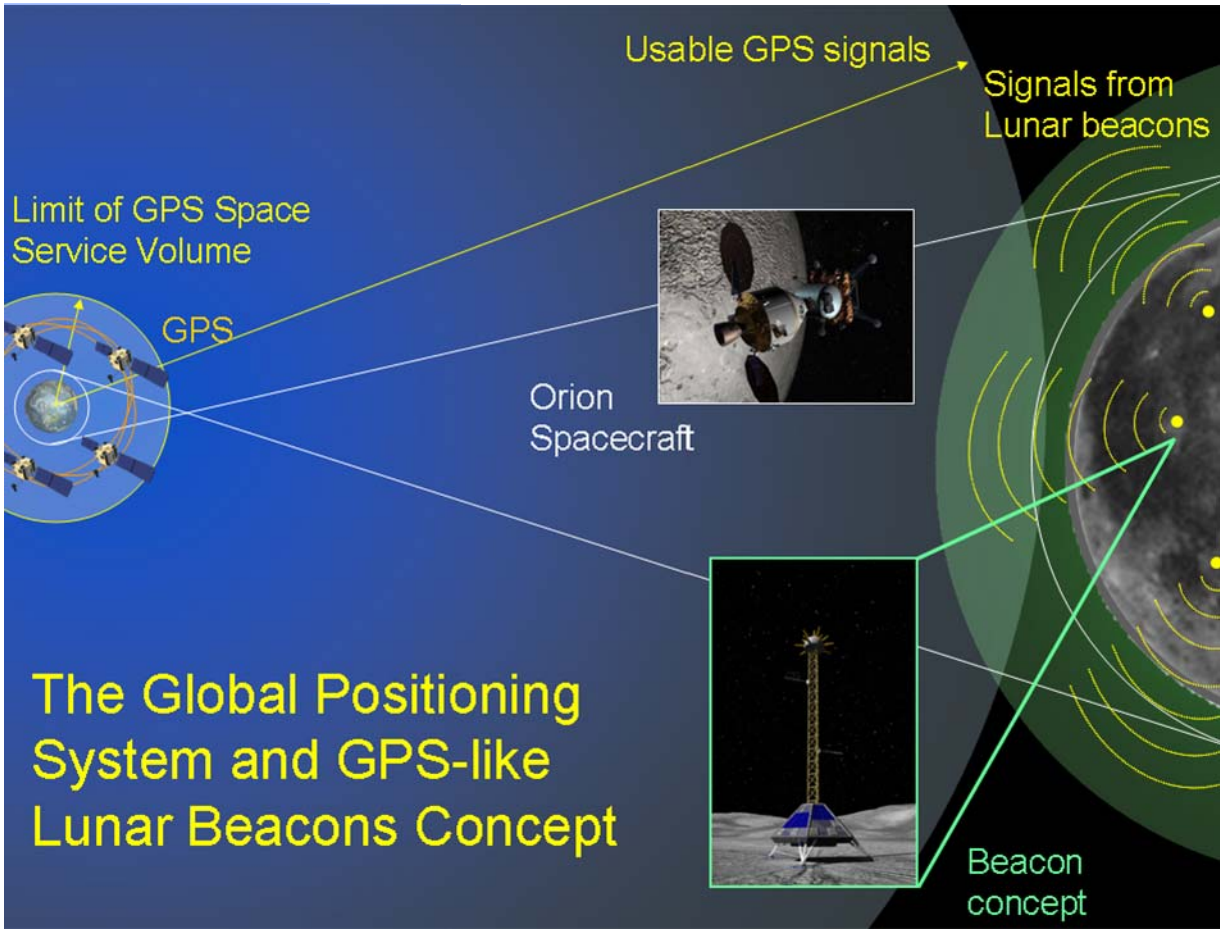
NASA Activities: Earth-Moon PNT Architecture

- Options for Navigation:
  - Earth-based tracking, GPS, Lunar-orbiting communication and navigation satellites, Lunar surface beacons and/or Pseudolites
- Objective: Integrated Interplanetary Communications, Time Dissemination, and Navigation



Lunar Beacons and Pseudolites

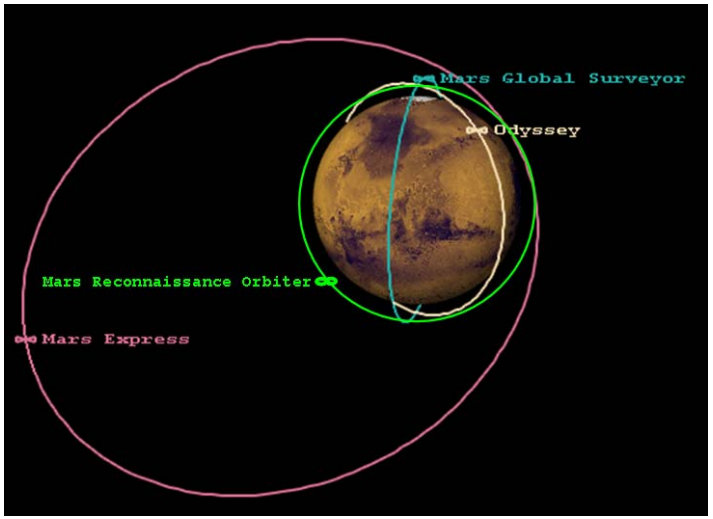
- Lunar beacons and pseudolites are being considered in the space architecture for their possible benefits
- Could become a first step towards deployment of radionavigation 'lighthouses' throughout the solar system



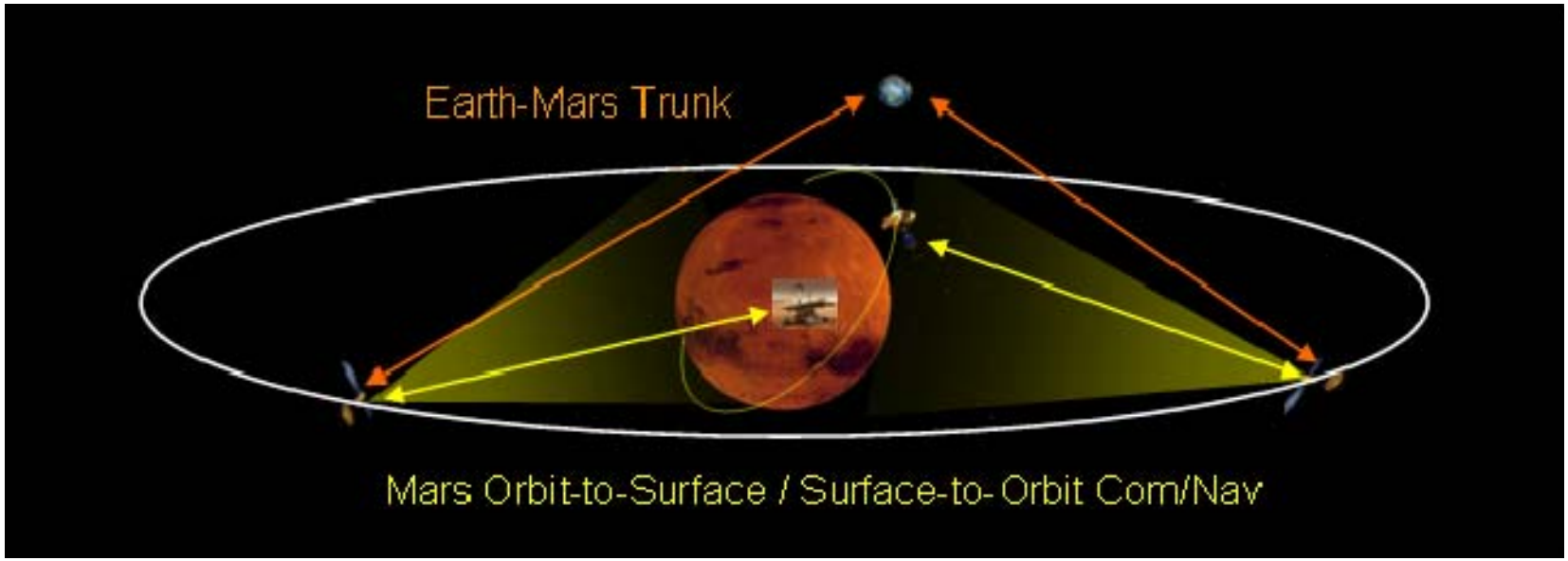
Aviation Week and Space Technology, 25 September 2006, pp. 59, 60

NASA Activities:Mars PNT Architecture

- **A PNT architecture can accommodate evolutionary use of science orbiters as relays prior to deployment of any dedicated telecom/navigation satellites at Mars**
- **Surface beacons/pseudolites are possible in areas of interest**
- **Use of all available radiometric signals for positioning, navigation, and timing**



Current Mars Orbit Infrastructure



Evolutionary concept: Add Satellite/s in Areostationary orbit for communications & PNT

Summary

- **GPS demonstrated performance is excellent**
- The **NASA Vision for Space Exploration** will continue to build on the many PNT benefits enabled by GPS applications
- U.S. is actively implementing the 2004 National Space-Based PNT Policy **to encourage and promote worldwide use of GPS** and augmentations
  - International coordination and cooperation is a key priority

Web-based Information

- **PNT.gov** established to disseminate information on the U.S. National Executive Committee
  - Contains information on Membership, Policy, the Advisory Board, frequently asked questions, and recent public presentations

- **GPS.gov** established to disseminate information on GPS applications
  - Brochure on GPS applications available in hardcopy upon request
  - Contains additional links to various other websites

www.PNT.gov


National Space-Based PNT Executive Committee - Microsoft Internet Explorer
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Google
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No popups
Settings
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Meetings
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FIRSTGOV
The National Space-Based Positioning, Navigation, and Timing (PNT) Executive Committee was established by Presidential directive in 2004 to advise and coordinate federal departments and agencies on matters concerning the Global Positioning System (GPS) and related systems.
The Executive Committee is chaired jointly by the Deputy Secretaries of Defense and Transportation. Its membership includes equivalent-level officials from the Departments of State, Commerce, and Homeland Security, the Joint Chiefs of Staff, and NASA. Components of the Executive Office of the President participate as observers to the Executive Committee, and the FCC Chairman participates as a liaison.
A permanent Coordination Office located in Washington, D.C., provides day-to-day staff support to the Executive Committee. It consists of an interagency staff headed by a Director, Mr. Michael Shaw of the Department of Transportation. The Coordination Office is a point of contact for inquiries regarding PNT policy.
The U.S. Space-Based PNT Advisory Board will provide independent advice to the Executive Committee through its sponsor agency, NASA.
An organizational chart is available in Portable Document Format (PDF).
The National Space-Based PNT Executive Committee replaced the Interagency GPS Executive Board (IGEB), which oversaw GPS policy matters from 1996 to 2004.
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National Space-Based PNT Executive Committee
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Revised: March 14, 2006 / Site hosted by NOAA, U.S. Department of Commerce / Disclaimer

www.GPS.gov


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GLOBAL POSITIONING SYSTEM
Serving the World
The Global Positioning System (GPS) is a U.S. space-based radionavigation system that provides reliable positioning, navigation, and timing services to civilian users on a continuous worldwide basis -- freely available to all. For anyone with a GPS receiver, the system will provide location and time. GPS provides accurate location and time information for an unlimited number of people in all weather, day and night, anywhere in the world.
The GPS is made up of three parts: satellites orbiting the Earth; control and monitoring stations on Earth; and the GPS receivers owned by users. GPS satellites broadcast signals from space that are picked up and identified by GPS receivers. Each GPS receiver then provides three-dimensional location (latitude, longitude, and altitude) plus the time.
SYSTEM INFORMATION
The Global Positioning System
GPS Augmentations
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http://www.gps.gov/french.html
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LE SYSTEME DE POSITIONNEMENT MONDIAL
au service de la planète
e Système de positionnement mondial (GPS, Global Positioning System) est un système américain de radionavigation basé dans l'espace qui propose aux usagers civils des services de géolocalisation, de navigation et de référence temporelle fiables, 24 eures sur 24 et dans le monde entier -- gratuitement. Il suffit d'être quipé d'un récepteur GPS pour connaître la position et la référence emporelle d'un objet. Le GPS fournit des informations précises en matière e positionnement et de référence temporelle à un nombre illimité de ersonnes, sous toutes les conditions météorologiques, de jour comme de uit, partout au monde.
e GPS se compose de trois groupes d'éléments : des satellites en orbite utour de la Terre ; des stations de contrôle au sol ; et les récepteurs GPS es utilisateurs. Les satellites GPS émettent des signaux qui sont captés et dentifiés par les récepteurs. Ces derniers peuvent alors situer précisément n trois dimensions (latitude, longitude et altitude) le point et la référence
PRESENTATION DU GPS
Le Système de positionnement mondial
Compléments GPS
APPLICATIONS
Espace-temps
Routes et autoroutes
Espace
Aviation
Agriculture

POINT OF CONTACT INFO.

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