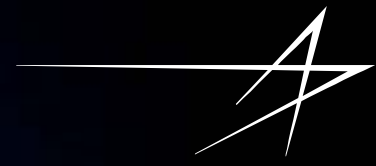


UN/UAE/US Workshop On GNSS Applications Dubai, UAE



Session 1: Trends in Satellite-based Navigation Systems

GPS Modernization: On the Road to the Future GPS IIR/IIR-M and GPS III

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- **GPS/GNSS has become a critical component of today's global information infrastructure**
- **Scalable applications enable broad capabilities facilitating innovations in efficiency, safety, security, environmental, and science**
 - **Mainstay of transportation systems worldwide, providing positioning, navigation and timing for aviation, ground and maritime operations**
 - **Farmers, surveyors, and geologists perform their work more efficiently, safely, economically and accurately using GPS signals**
 - **Disaster relief and emergency services depend upon GPS for location and timing capabilities in their life-saving missions**
 - **Banking, mobile phone operations and the control of power grids are facilitated by the accurate timing provided by GPS**

GPS/GNSS - a Component of the Global Critical Information Infrastructure



Precision Agriculture



Surveying & Mapping



Aviation



Communications



Disease Control



Power Grids



Trucking



Shipping



Oil Exploration



Fishing & Boating



Personal Navigation

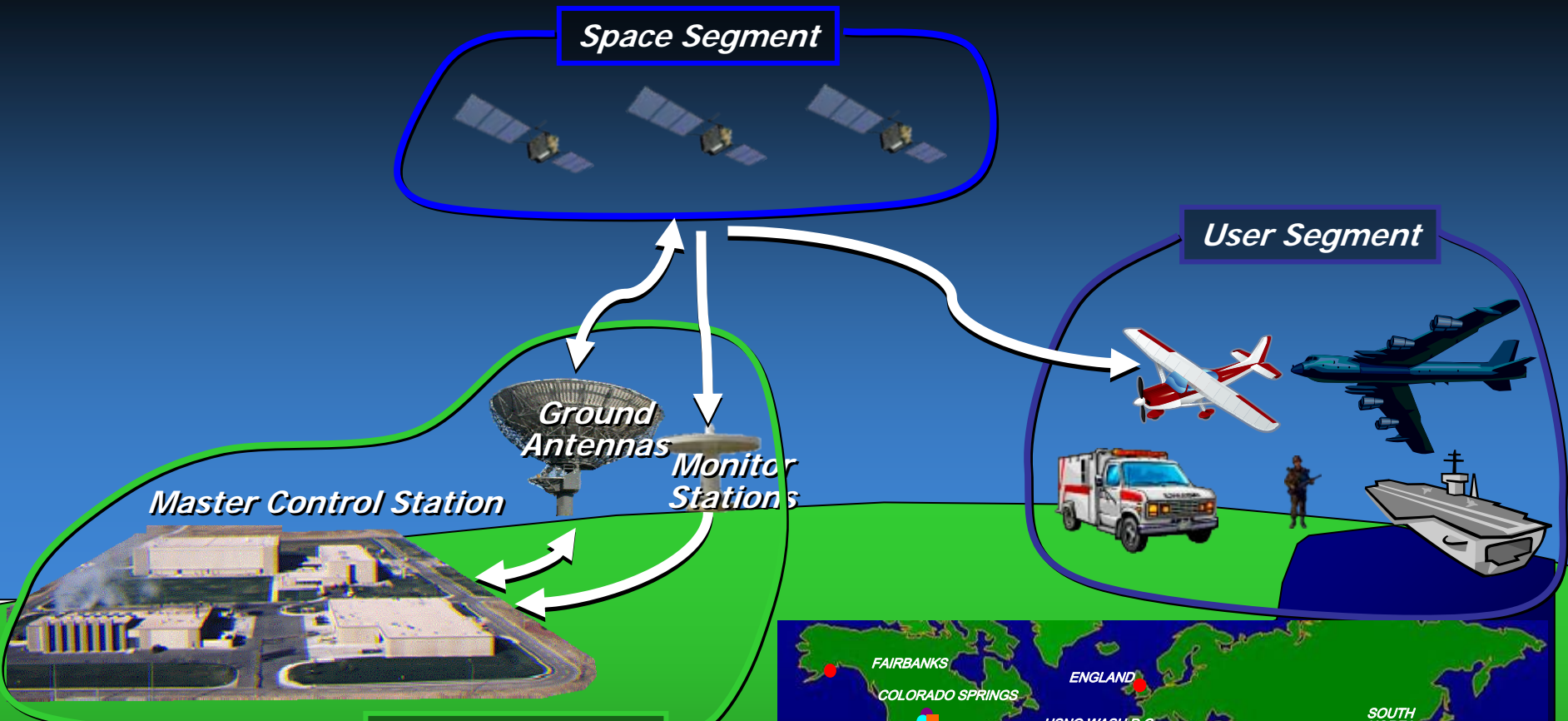


31 Healthy Satellites ***Baseline Constellation: 24***

- 11 Block IIA satellites
- 12 Block IIR satellites
- 8 Block IIR-M satellites (7 operational)
 - 1 IIR-M in “test” mode – SVN-49
- 1 Block IIF satellite (SVN 62, PRN 25)
 - Launched 27 May 2010
 - Set Healthy 30 August 2010
 - First Operational L5 (third civil signal)
 - Excellent GPS clock performance
- Next IIF Launch Mid 2011



GPS System Overview



Control Segment

- Master Control Station
- ▲ Ground Antennas (GA)
- Monitor Stations (MS)
- National Geospatial-Intelligence Agency (NGA) Station
- Alternate Master Control Station (AMCS)






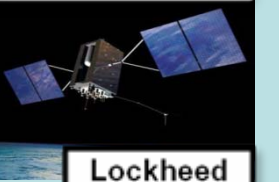




- **GPS Modernization**
- **GPS IIR/IIR-M**
- **GPS IIIA**
- **The Road Ahead**

Modernization Path – GPS Space Segment



1978 - 1985	1989 - 1997	1997- 2004	2005 - 2009	2010 - Present	2014 - 2024
 Rockwell	 Boeing (Rockwell)	 Lockheed Martin	 Lockheed Martin	 Boeing	 Lockheed Martin
Block I	Block II/IIA	Block IIR	Block IIR-M	Block IIF	Block III
11 (10) Satellites	28 Satellites	13 (12) Satellites	8 Satellites	12 Satellites	32 Satellites
Demonstration system	Basic GPS Provides Initial Navigation Capabilities		IIA/IIR Capabilities "Plus"	IIR -M Capabilities "Plus"	IIF Capabilities "Plus"
<ul style="list-style-type: none"> • L1 (CA) Navigation signal • L1 & L2 (P Code) Navigation signal • 5 Year Design Life 	<ul style="list-style-type: none"> • Std Service <ul style="list-style-type: none"> • Single Frequency (L1) • C/A code navigation • Precise Service • Two frequencies (L1 & L2) • P (Y) -Code navigation • 7.5 Year Design Life 		<ul style="list-style-type: none"> • 2nd Civil Signal L2 (L2C) • Earth Coverage M-Code on L1/L2 • L5 Demo • Anti-Jam Flex Power • 7.5 Year Design Life 	<ul style="list-style-type: none"> • 3rd Civil Signal L5 • Reprogrammable Nav Processor • Increased Accuracy requirement • 12 Year Design Life 	<p>IIIA</p> <ul style="list-style-type: none"> • Increased accuracy • Increased Earth Coverage power • 15 Year Design Life • 4th Civil Signal (L1C) <p>IIIB</p> <ul style="list-style-type: none"> • Real-time Communications <p>IIIC</p> <ul style="list-style-type: none"> • Navigation Integrity • Spot Beam for AJ

Increasing Space System Capabilities – Increasing Military/Civil User Benefits

GPS Modernization Path



- **GPS IIR/IIR-M** – majority of the on orbit satellites today
 - Modernization of last 8 GPS IIR satellites (IIR-M) accelerated acquisition of the GPS modernization capabilities
 - 2nd civil signal (L2C) and demonstration 3rd civilian signal (L5)
 - 1st GPS IIR-M in operation for over 5 years – December 2005
- 1st **GPS IIF** launched 27 May 2010– finished checkout Aug 30
 - Operational 3rd civilian signal (L5) and 2nd civil signal (L2C)
 - 11 additional GPS IIF satellites currently available for launch
- **GPS III** planned for up to 32 satellites
 - First GPS IIIA satellite planned available for first launch in 2014

GPS III built on heritage of highly successful IIR/IIR-M programs

GPS IIR/IIR-M History



- **Twenty GPS IIR/IIR-M space vehicles on orbit today**
 - 1st GPS IIR in operation for over 12 years – January 1998
 - 19 spacecraft currently operational with well over 120 spacecraft-years to date
 - Improved overall GPS constellation accuracy
 - Exceptional payload reliability (>99.7%)
- **Modernization of last 8 GPS IIR (IIR-M) added the following additional capabilities**
 - **2nd Civil Signal** - provides ionospheric correction capability for civil users with L2C capability
 - 1st L2C NAV broadcast - September 2009
 - Allowed manufacturers to start early receiver development
 - **M-code** - provides second set of military codes for L1 and L2
 - Improved anti-jamming through flexible power capability
 - **Flexible design allowed demonstration of third civilian signal (L5)**
 - 1st L5 signal transmitted in April 2009 to establish frequency filing

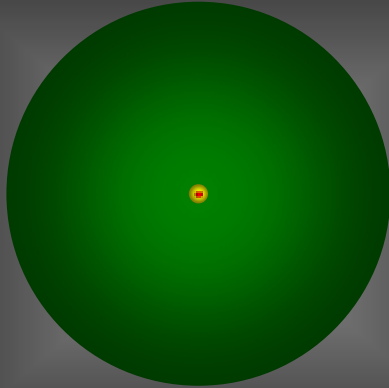


GPS IIR/IIR-M Performance

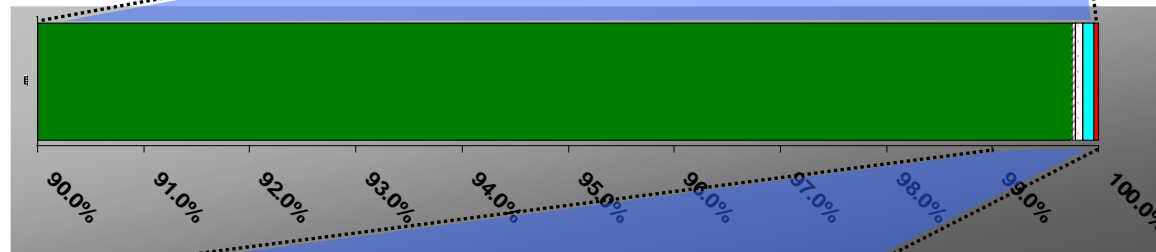
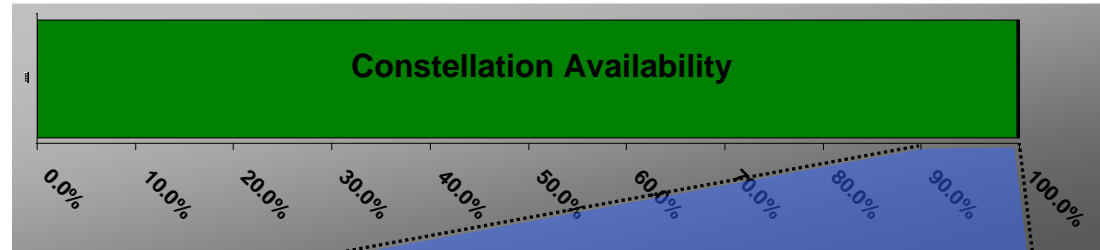
Availability



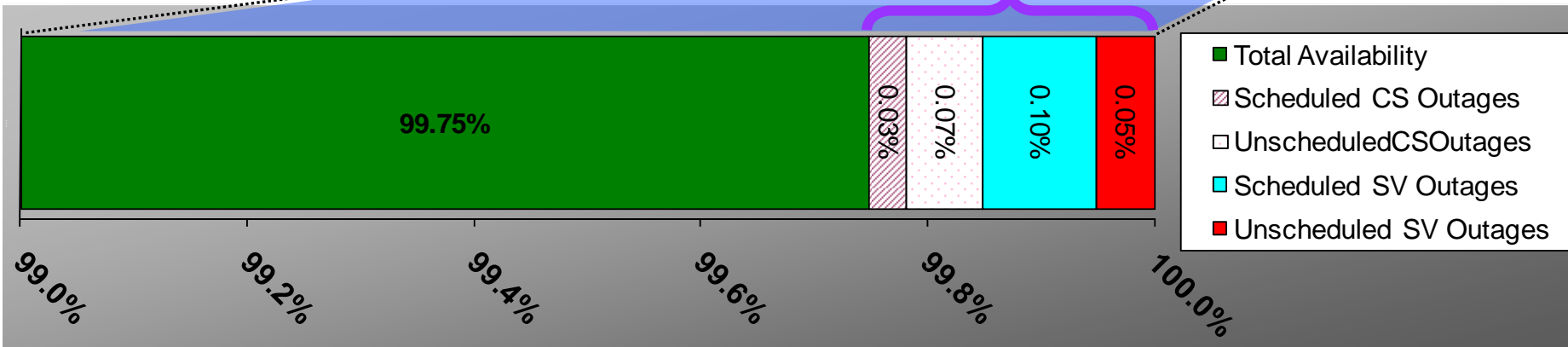
IIR Outage to Operational Ratio



Yellow Circle is Total Outage Time
Red is Unscheduled SV Outage Time



Total Outage Time

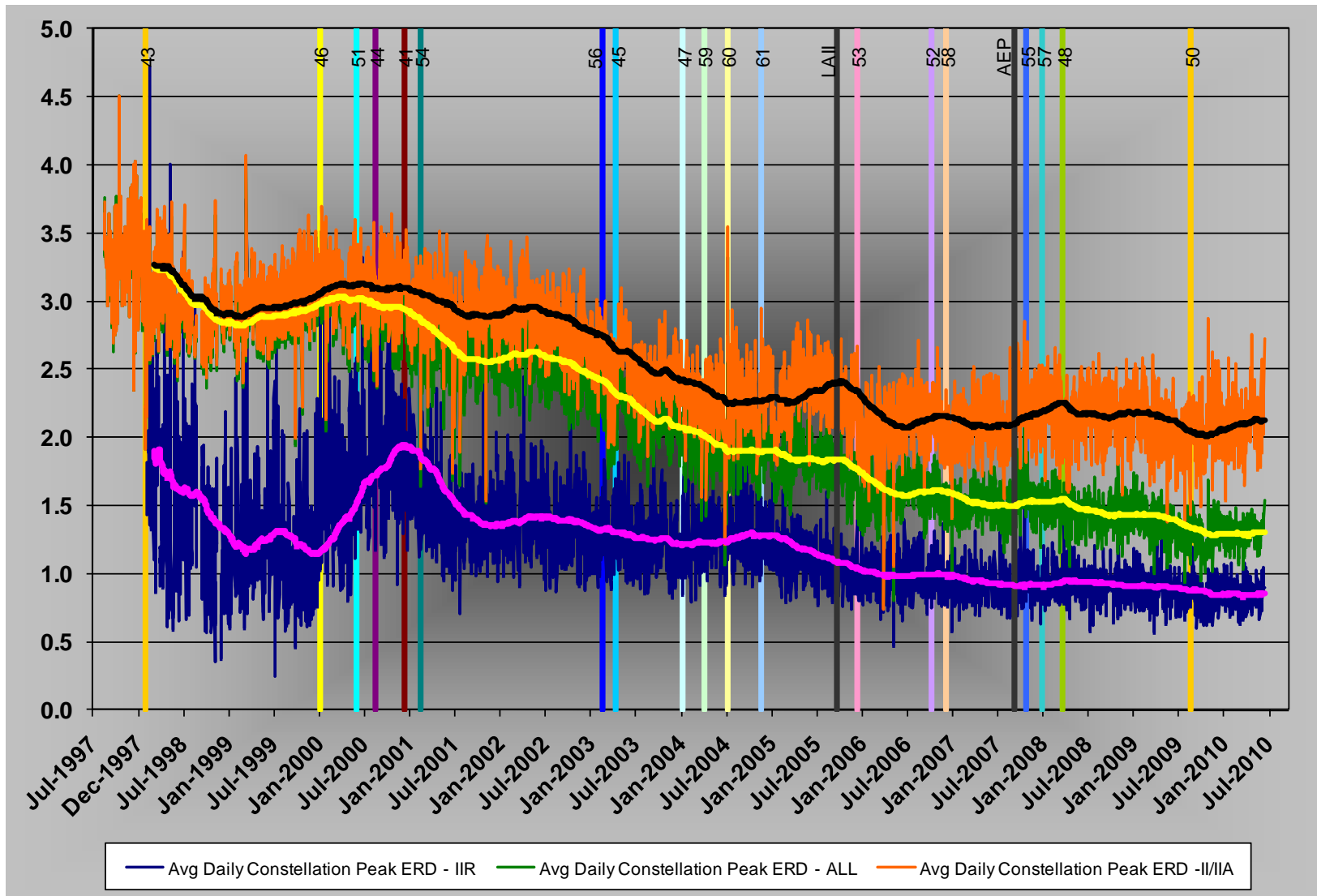


IIR SV Lifetime Navigation Availability greater than 99.7%

120 years of successful IIR/IIR-M on-orbit operations as of Jun 10

GPS IIR/IIR-M Performance

Lifetime Estimated Range Deviations (ERDs)



Growing GPS IIR/IIR-M constellation consistently decreasing user error



● Next Generation GPS

- Improved performance for both military and civilian users
- Superior system security, accuracy, and reliability

● Strategic Teammates

- U.S. Air Force (Los Angeles, CA)
- Lockheed Martin Space Systems Company (Newtown, PA)
- ITT Corporation (Clifton, NJ)
- General Dynamics (Scottsdale, AZ)

● Heritage of Success

- GPS IIR/IIR-M success
- Time-tested A2100 bus

Low risk solution to satisfying on-going GPS modernization



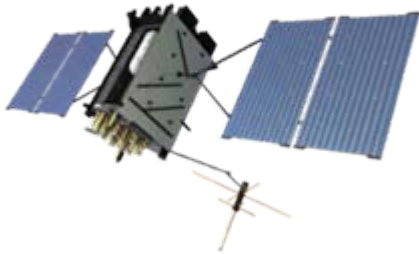
- **GPS III includes 32 vehicles in three blocks**
 - A -- 2 RDT&E space vehicles with 6 priced production vehicles
 - B -- 8 space vehicles adding network communications capability
 - C -- 16 space vehicles adding spot beam and integrity
- **15 May 08 - Lockheed Martin was selected as the prime contractor for designing and producing GPS IIIA**
- **Design work to be performed in Newtown, Pennsylvania**
- **Assembly, Test and Integration will be performed in the Lockheed Martin Waterton Facility in Denver, Colorado**

GPS III Capability Insertion



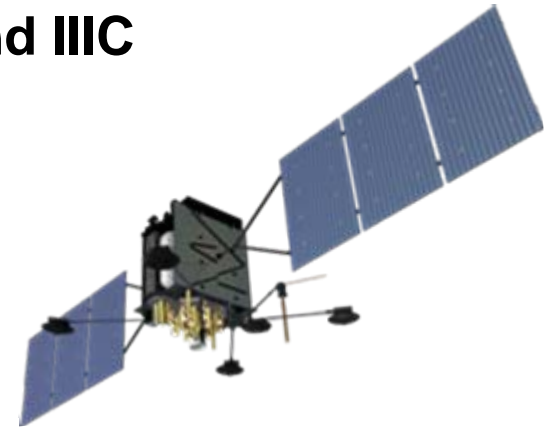
GPS IIIA

- Increased accuracy
- Increased Earth Coverage Power
- Additional civil signal (L1C)
 - Interoperable with Galileo, Compass, QZSS, etc.
- Bus capacity for IIIB and IIIC



GPS IIIB

- Real-time command and control cross-links
 - Allows upload satellites via single contact
 - Improves constellation accuracy



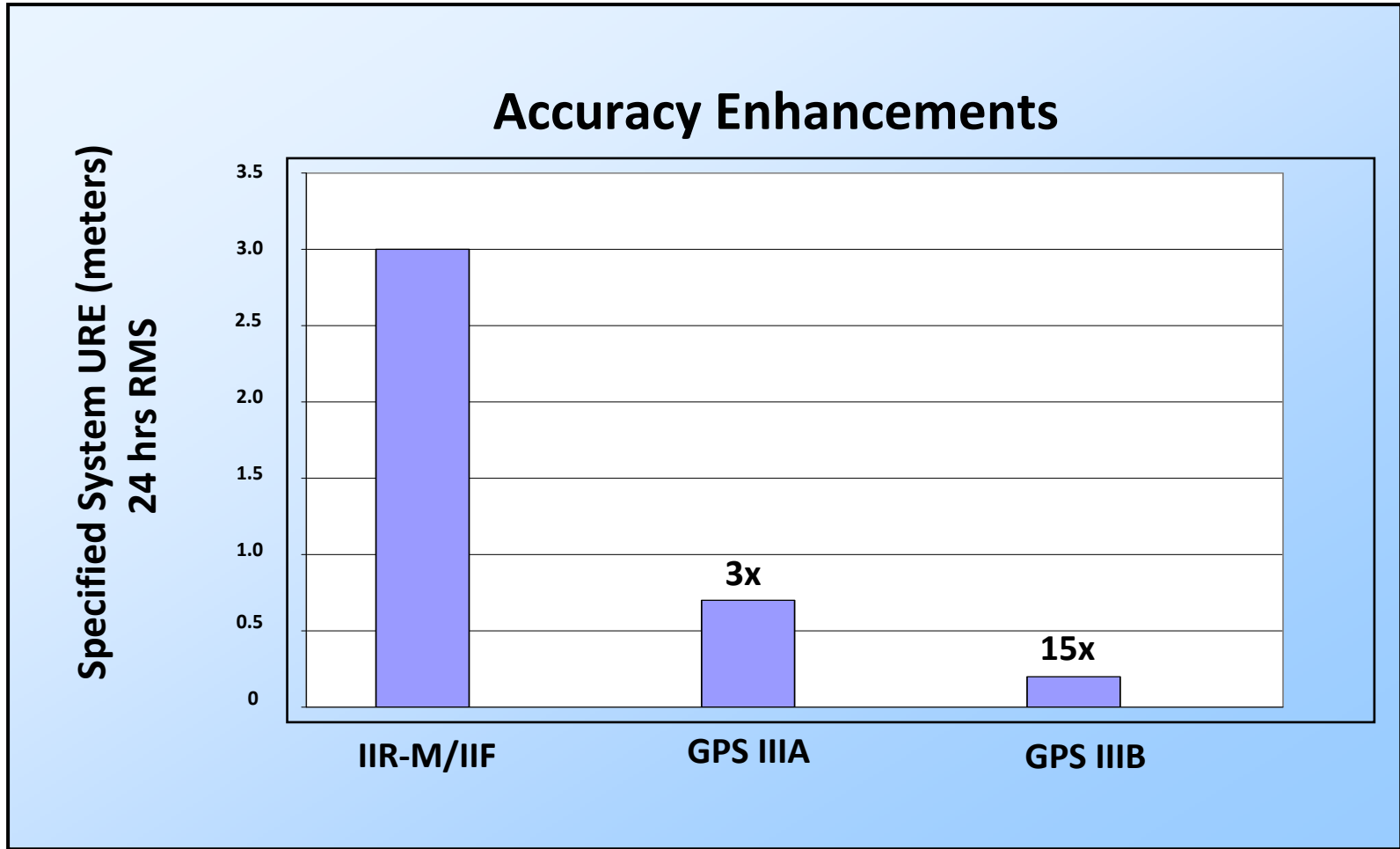
GPS IIIC

- High-power spot beam
 - Provides increased anti-jamming capability for the military
- Improved integrity

Images Courtesy of USAF

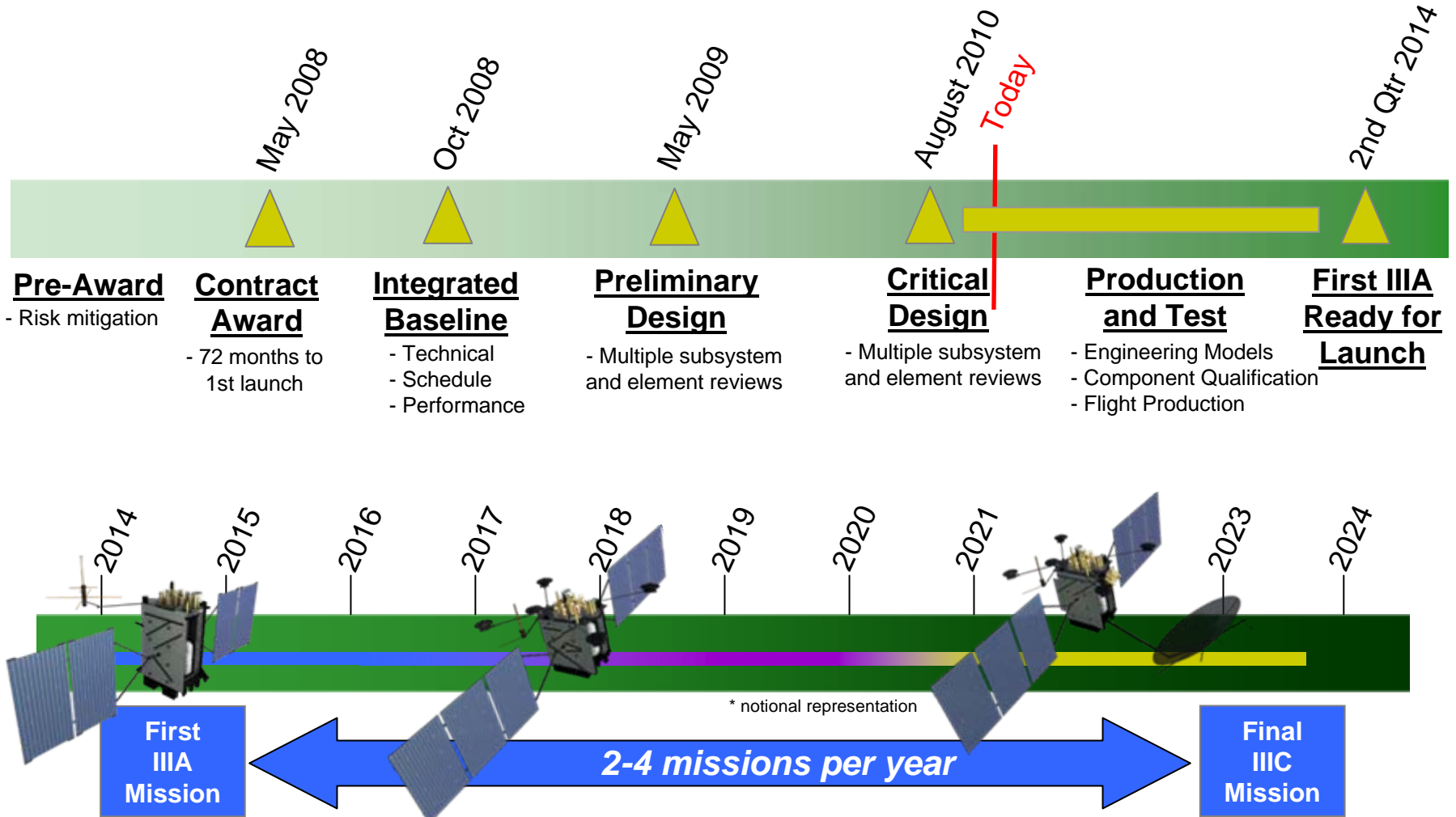
Flexible transition and content of future blocks reduces program risk

Accuracy Improvements



Specified URE Impacts User Platform Cost and Complexity

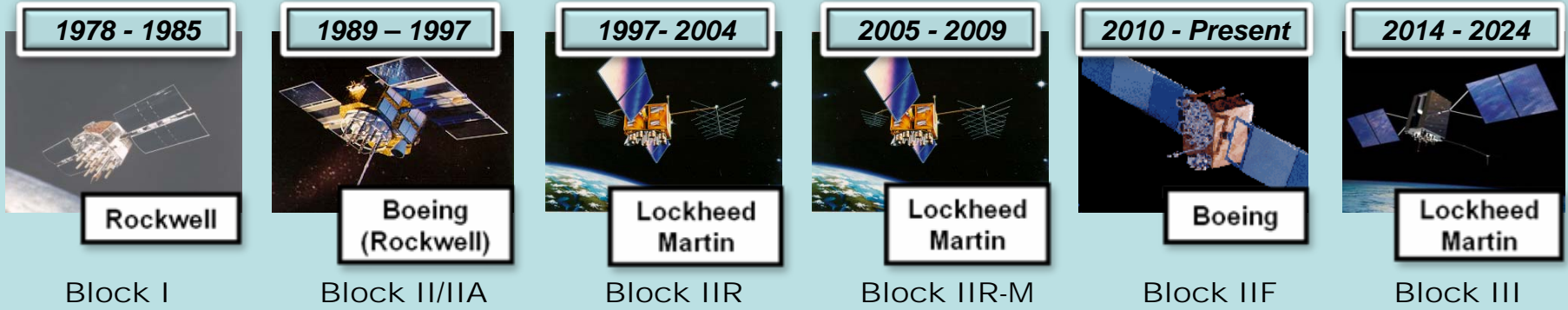
GPS III Schedule



Images Courtesy of USAF

Critical Design Review – August 2010 (2 months ahead of schedule) : Validated detailed GPS IIIA design; production phase started

Modernization Path – GPS Control Segment



Legacy Control System

- Master Control System (MCS)
- Tracking, Telemetry & Control (TT&C)
- L1 & L2 Monitoring
- Satellite health and welfare monitoring
- GPS signal performance monitoring (P(Y) code only)
- Satellite navigation payload analysis

Architecture Evolution Plan (AEP)

- Distributed System
 - Launch, Anomaly, Disposal Ops (LADO)
- Increased capacity for signal monitoring
 - IIR, IIR (M), IIF
- Increased worldwide commanding capability
 - New MCS/AMCS

OCX

- Controls more capable GPS constellation
 - GPS III
- Monitors all GPS signals
 - Legacy plus L1C, L2C and L5
 - Flex Power
 - Real-Time C2



Increasing Control Segment Capabilities - Increasing Military/Civil User Benefits

Modernized GPS – New Signals



● Second civil signal (“L2C”)

- Designed to meet commercial needs
- Higher stand-alone accuracy through ionospheric correction
- Began with GPS Block IIR-M in **Sep 2005**; 24 satellites with L2C: **~2016**

● Third civil signal (“L5”)

- Meets demanding requirements for transportation/aviation (safety-of-life)
- GPS IIR-M Demo – **10 Apr 2009** – brought L5 frequency into use
- Begins with GPS Block IIF
 - 1st launch (GPS IIF): **28 May 2010**; 24 satellites (GPS IIF/GPS III): **~2018**

● Fourth civil signal (“L1C”)

- Begins with GPS Block IIIA; 1st launch: **~2014**; 24 satellites: **~2021**
- Designed with international partners to enable GNSS interoperability

More Signals and Higher Power Means More Robust to Interference

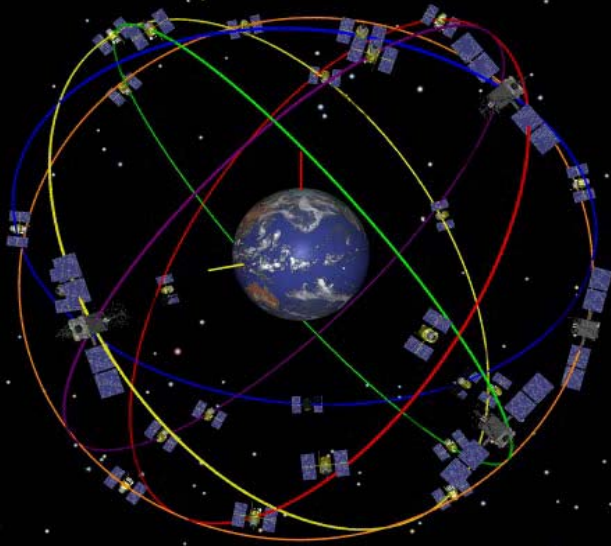


- **GPS modernization is in progress**
 - New GPS signals/services for both civil and military users
- **GPS IIR/IIR-M generation complete**
 - More than 100 years successful on-orbit performance
- **First GPS IIF launched 27 May 2010**
 - Completed on-orbit check out period; next launch mid 2011
- **GPS III generation is coming in 2014**
 - Program is on schedule and moving forward successfully
 - Completed Critical Design Review - Program moving into production
 - Will bring new capabilities for global civil users
 - Compatible/interoperable with int'l systems (e.g. GLONASS, Galileo, QZSS, Compass, etc)



Thank you

GPS System Overview



Program Facts

- 24-satellite constellation/ 34 on-orbit
- 6 Orbital Planes, Min of 4 Satellites/Plane
- Semi-Synch Orbit (20,200 km / 10,900 miles)
- Launched from Cape Canaveral on Delta II/EELV
 - First launch 1978; FOC 1995
- Prime Contractors
 - Boeing - Seal Beach, CA II, IIA and IIF
 - Lockheed Martin – Newtown, PA IIR, IIR-M and III

Program Description

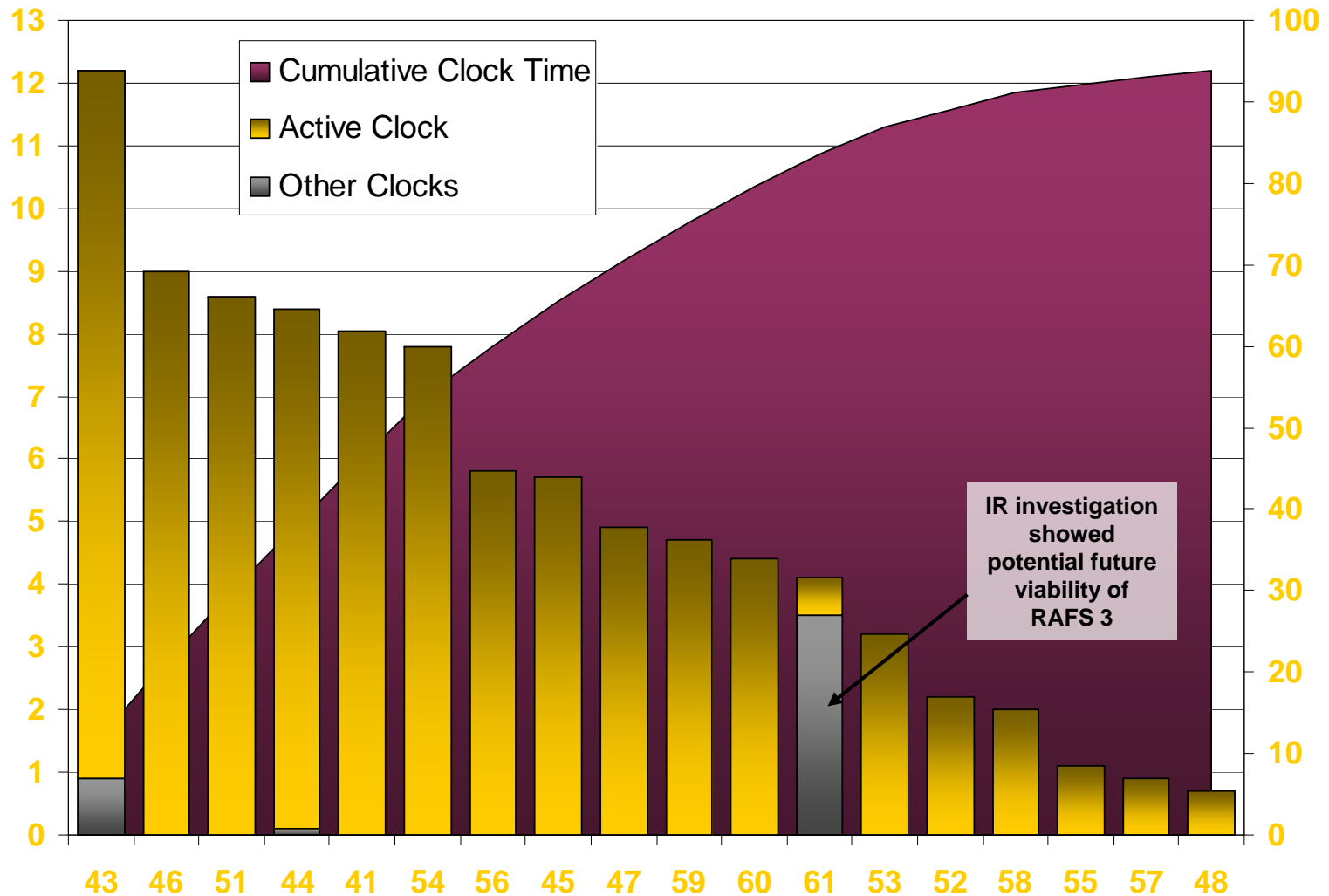
- Space-based radio-navigation system
- Satellites broadcast precise time signals to allow users to estimate their own position, velocity, and time
- Two levels of service
 - Standard Positioning Service (SPS)
 - Precise Positioning Service (PPS)
- Three “Segments”
 - Ground – Operational Control Segment
 - Space – Nominally 24 satellites
 - User – Receivers

Current/Future Constellation

- 34 satellites / 31 healthy to users (As of Jan 1, 2011)
 - 15 IIA satellites including
 - 4 residual spares; set to test mode (LADO)
 - 12 IIR satellites; 7 IIR-M satellites
 - 1 IIF satellite
 - 12 satellites on the watch list
- 12 IIF
 - 1st launch Aug 2010; next launch mid 2011
 - Increased capabilities
- 32 III
 - Ready for launch starting in 2014
 - Increased capabilities

GPS IIR/IIR-M Performance

Clock Performance



Single Clock issue (Rubidium) over entire history of IIR clock operations

A2100 History



- **Thirty-eight A2100s on-orbit today**
 - 1st A2100 in operation for over 13 years
 - No satellite vehicle failures after over 250 spacecraft-years accumulated to date
 - Received Frost and Sullivan’s Satellite Reliability Award: “Most reliable and efficient of its class”
 - Key customers: **SES World Skies** **Echostar** **Telesat**
SES ASTRA **SPJSAT** **BSAT**
US Air Force **US Navy** **NASA**
- **A2100 modular design accommodates wide range of payloads and launch vehicles**
 - Increased on-orbit reliability
 - Features parts reduction/simplified construction
 - Proven production cycle time
 - Exceptional earth pointing reliability



A2100AX vehicle at Newtown facility

GPS III built on highly reliable satellite bus platform