



Asia-Pacific
Economic Cooperation

Advancing
Free Trade for Asia-Pacific
Prosperity

U.S. Global Positioning System

16 October 2018 – Lima, Peru

Presented by
Ken Alexander, U.S.

Overview



Asia-Pacific
Economic Cooperation

- GPS Policy
- GPS Overview
- GPS Performance
- GPS III Satellites
- GPS Control Segment
- GPS Aviation Growth
- Summary

GPS Enables and Enhances Life Everyday



Applications include:

- Aviation
- Agriculture
- Search & rescue
- Surveying & mapping
- Trucking & shipping
- Fishing & boating
- Scientific
- Timing
- Tracking
- Exploration
- Offshore drilling
- Military
- And More!



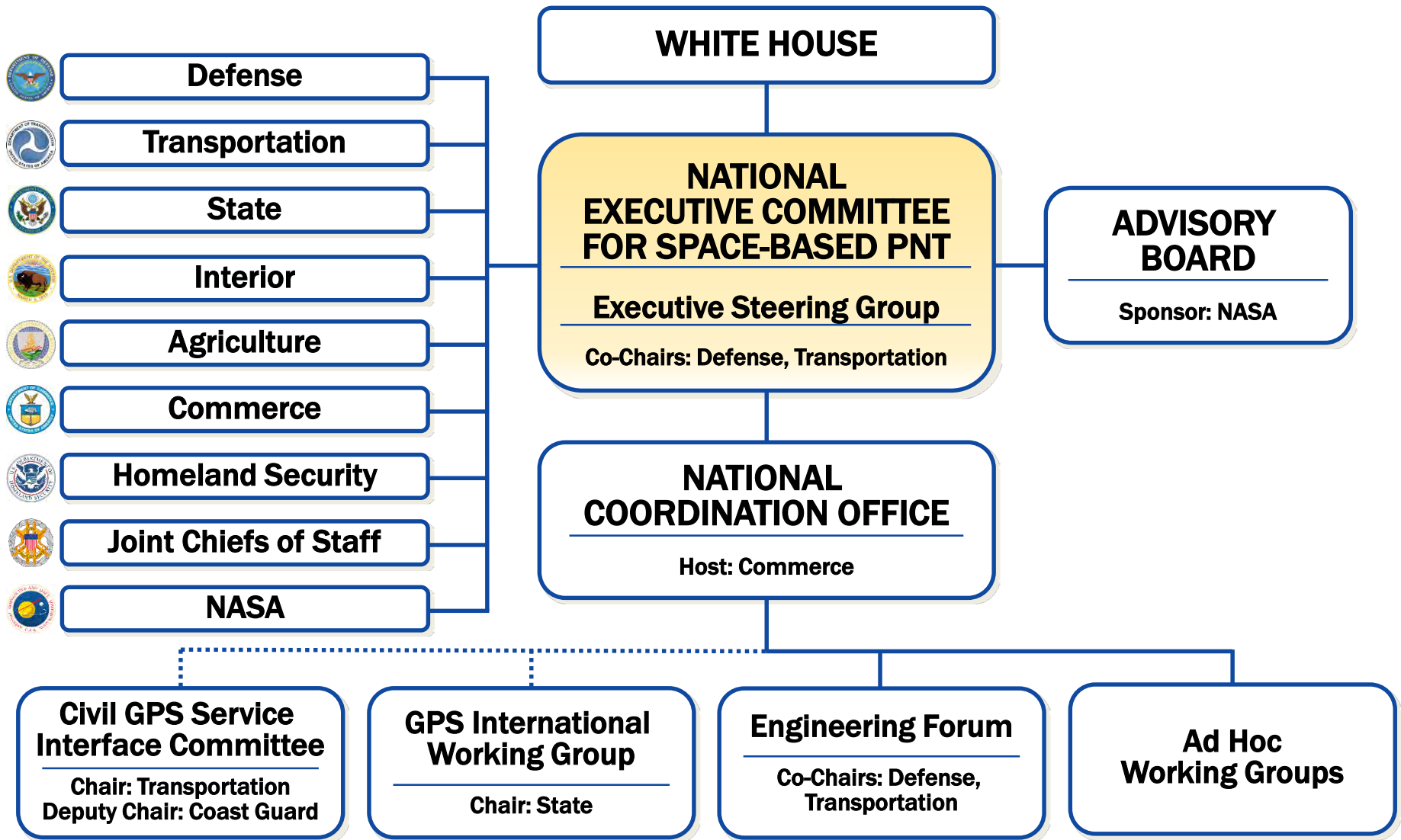
GPS provides Worldwide Utility

U.S. Policy Promotes Civilian GPS Use

- Continuous, worldwide, free of direct user fees
- Encourage compatibility and interoperability with other economies GNSS services and promote transparency in civil service provisioning
- Operate and maintain GPS constellation to satisfy civil and economy security needs
 - Other economies PNT services may be used to augment and strengthen the resiliency of GPS
- Invest in domestic capabilities and support international activities to: detect, mitigate and increase resiliency to harmful interference

Space-Based PNT Policy Guidance: Maintain leadership in the service, provision, and use of GNSS

U.S. Space Based PNT Organization

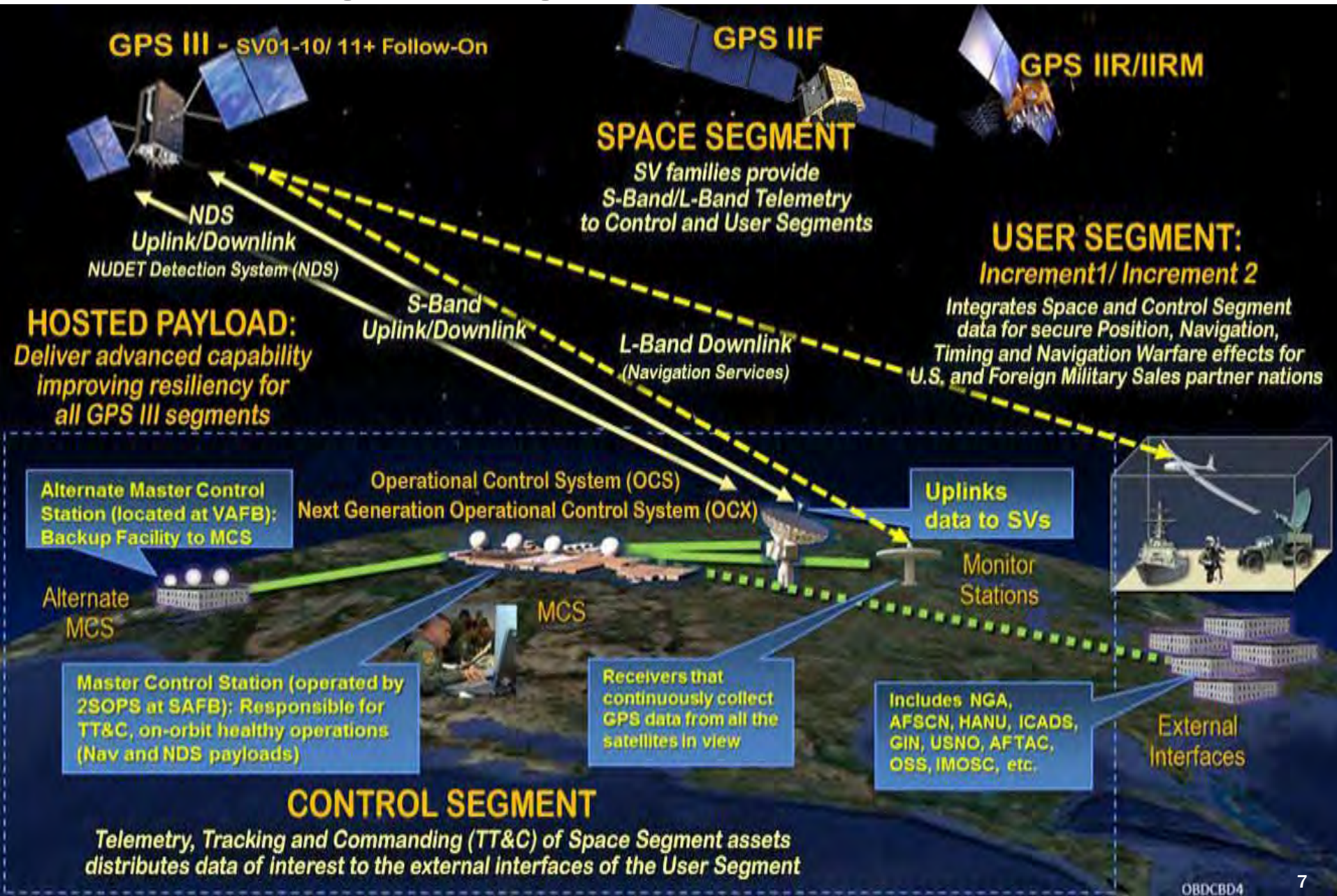


PNT Executive Committee (EXCOM)

Strategic Focus Areas include:

- **GPS Sustainment and Modernization**
- **International Cooperation**
- **Spectrum Management**
- **Critical Infrastructure**
- **PNT Resilience**
- **Outreach and Education**

GPS Enterprise Operational View



GPS Overview



Civil Cooperation

- 3+ Billion civil & commercial users worldwide
- Search and Rescue
- Civil Signals
 - L1 C/A (Original Signal)
 - L2C (2nd Civil Signal)
 - L5 (Aviation Safety of Life)
 - L1C (International)



Department of Defense

- Services (Army, Navy, AF, USMC)
- Agencies (NGA & DISA)
- U.S. Naval Observatory
- PNT EXCOMS
- GPS Partnership Council

Maintenance/Security

- All Level I and Level II
 - Worldwide Infrastructure
 - NATO Repair Facility
- Develop & Publish ICDs Annually
 - Public ICWG: Worldwide Involvement
 - Materials at: gps.gov/technical/icwg
- Update GPS.gov Webpage
- Distribute PRNs for the World
 - 120 for U.S. and 90 for GNSS

Spectrum

- World Radio Conference
- International Telecommunication Union
- Bilateral Agreements
- Adjacent Band Interference

34 Satellites / 31 Set Healthy Baseline Constellation: 24 Satellites

Satellite Block	Quantity	Average Age	Oldest
GPS IIA	1	24.8	24.8
GPS IIR	11	16.6	21.1
GPS IIR-M	7	11.1	12.9
GPS IIF	12	4.6	8.2
Constellation	31	11.0	24.8

AS OF 24 AUG 18

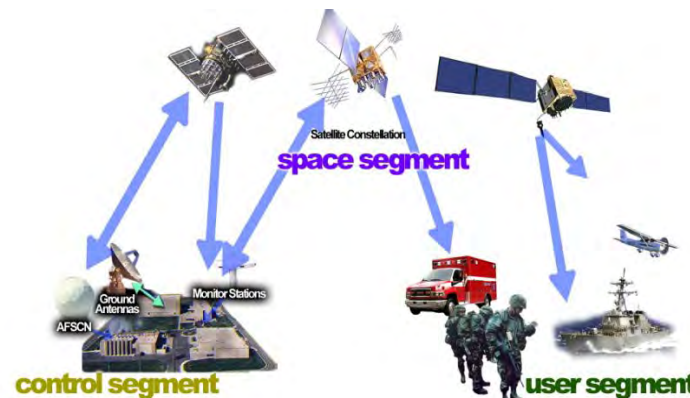


Department of Transportation

- Federal Aviation Administration

Department of Homeland Security

- U.S. Coast Guard



International Cooperation

25+ Years of Cooperation

- Europe - Galileo
- China - Beidou
- Russia - GLONASS
- Japan - QZSS
- India - NAVIC
- Republic of Korea - KASS
- Multiple States - SBAS

GPS Modernization

Space System (Satellites)

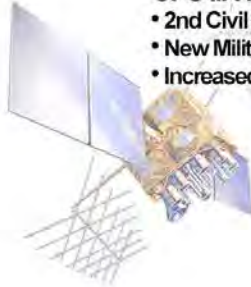
Legacy (GPS IIA/IIR)

- Basic GPS
- NUDET (Nuclear Detonation) Detection System (NDS)



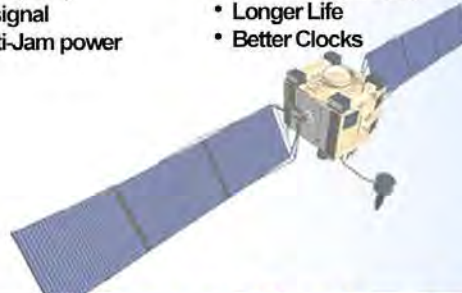
GPS IIR-M

- 2nd Civil signal (L2C)
- New Military signal
- Increased Anti-Jam power



GPS IIF

- 3rd Civil Signal (L5)
- Longer Life
- Better Clocks



GPS III (SV01-10)

- Accuracy & Power
- Increased Anti-Jam power
- Inherent Signal Integrity
- Common L1C Signal
- Longer Life



GPS III (SV11+)

- Unified S-Band Telemetry, Tracking & Commanding
- Search & Rescue (SAR) Payload
- Laser Retroreflector Array
- Redesigned NDS Payload
- Regional Military Protect (RMP)

Ground System

Legacy (OCS)

- Mainframe System
- Command & Control
- Signal Monitoring

AEP

- Distributed Architecture
- Increased Signal Monitoring Coverage
- Security
- Accuracy
- Launch And Disposal Operations



OCX Block 0

- GPS III Launch & Checkout

GPS III Contingency Ops (COps)

- GPS III Mission on AEP

M-Code Early Use (MCEU)

- Operational M-Code on AEP

OCX Block 1

- Fly Constellation & GPS III
- Begin New Signal Control
- Upgraded Information Assurance

OCX Block 2+

- Control all signals
- Capability On-Ramps
- GPS III Evolution

User Equipment System (Receivers)

Legacy (PLGR/GAS-1/MAGR)

- First Generation System



User Equipment

- Improved Anti-Jam & Systems
- Reduced Size, Weight & Power

Upgraded Antennas

- Improved Anti-Jam Antennas



Modernized

- M-Code Receivers
- Common GPS Modules
- Increased Access/ Power with M-Code
- Increased Accuracy
- Increased Availability
- Increased Anti-Tamper/ Anti-Spoof
- Increased Acquisition in Jamming



GPS IIF Launches



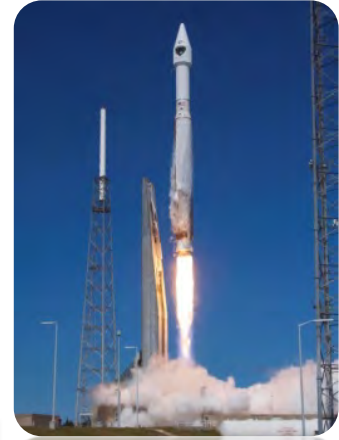
20 Feb 14: IIF-5



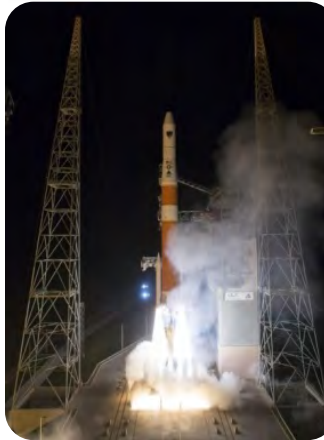
16 May 14: IIF-6



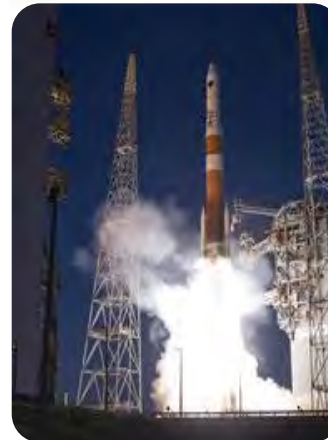
1 Aug 14: IIF-7



29 Oct 14: IIF-8



25 Mar 15: IIF-9



15 Jul 15: IIF-10



31 Oct 15: IIF-11



5 Feb 16: IIF-12

8 IIF Launches in 24 Months – Preparing for 1st GPS III Launch

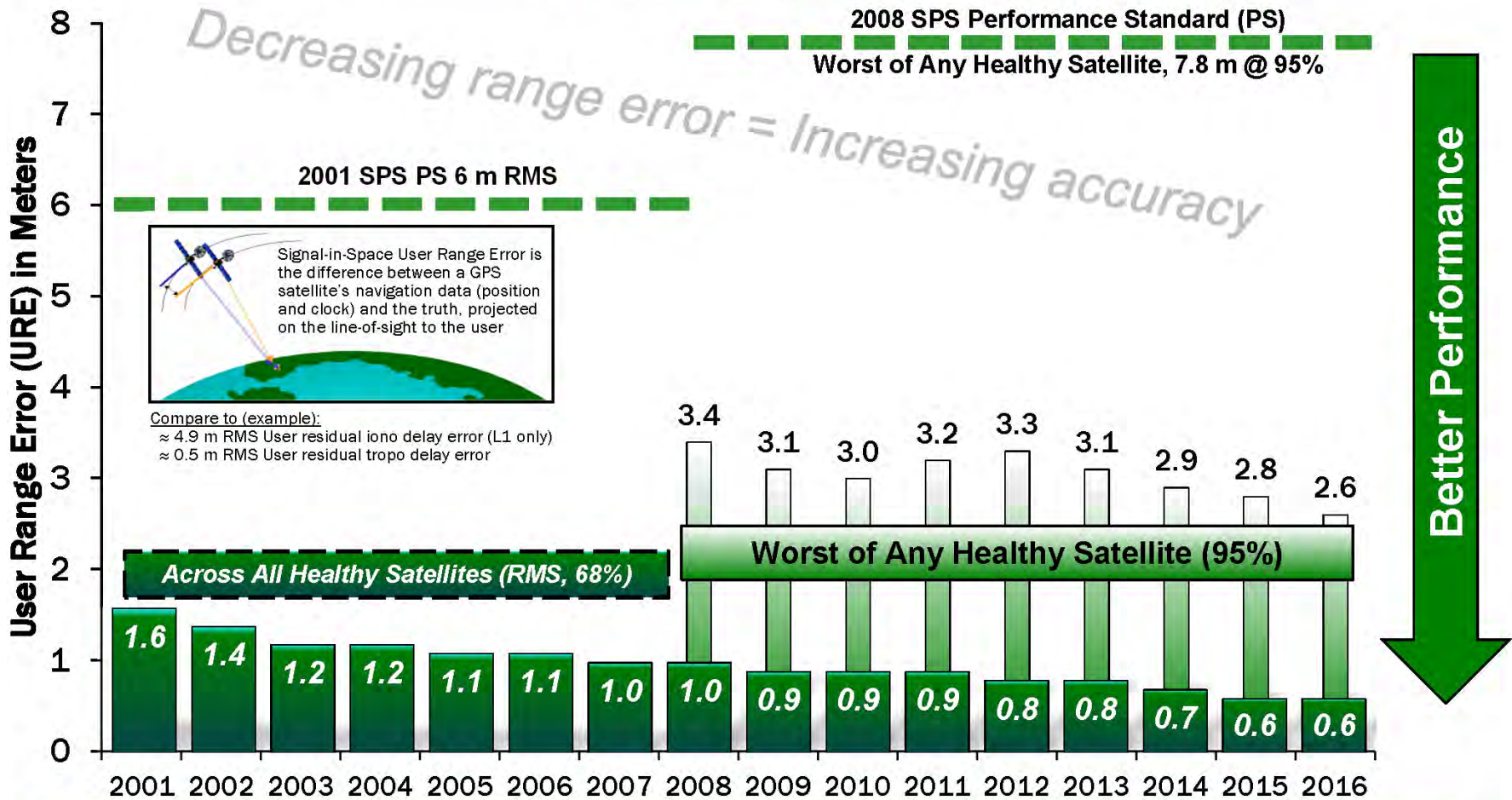
GPS Performance Report Cards



- 2013-2017 performance reports available on gps.gov
- These reports measure GPS performance against GPS Standard Positioning Service (SPS) Performance Standard commitments
- Reports generated by Applied Research Laboratories at the University of Texas at Austin

Performance Standard Metric		2013	2014	2015	2016	2017
SIS Accuracy	URE Accuracy	✓	✓	✓	✓	✓
	UTC OE Accuracy	N/A	N/A	✓	✓	✓
SIS Integrity	Instantaneous URE Integrity	✓	✓	✓	✓	✓
	Instantaneous UTC OE Integrity	N/A	N/A	✓	✓	✓
SIS Continuity	Unscheduled Failure Interruptions	✓	✓	✓	✓	✓
	Status and Problem Reporting	N/A	✗	✓	✗	✗
SIS Availability	Per-Slot Availability	✓	✓	✓	✓	✓
	Constellation Availability	✓	✓	✓	✓	✓
	Operational Satellite Counts	✓	✓	✓	✓	✓
Position/Time Standards	PDOP Availability	✓	✓	✓	✓	✓
	Position Service Availability	✓	✓	✓	✓	✓
	Position Accuracy	✓	✓	✓	✓	✓

Standard Positioning Service (SPS) Signal-in-Space Performance



System accuracy better than published standard

GPS SIS Performance Scoreboard

GPS SIGNAL IN SPACE (SIS) PERFORMANCE (CM)

BEST WEEK*

BEST DAY*

WORST DAY*

ENDING

SIS

ENDING

SIS

ENDING

SIS

ROLLING YEAR

20 SEP 17

48.9

14 MAR 18

37.5

1 DEC 17

77.7

BEST WEEK EVER

29 NOV 16

44.1

***ROLLING YEAR**



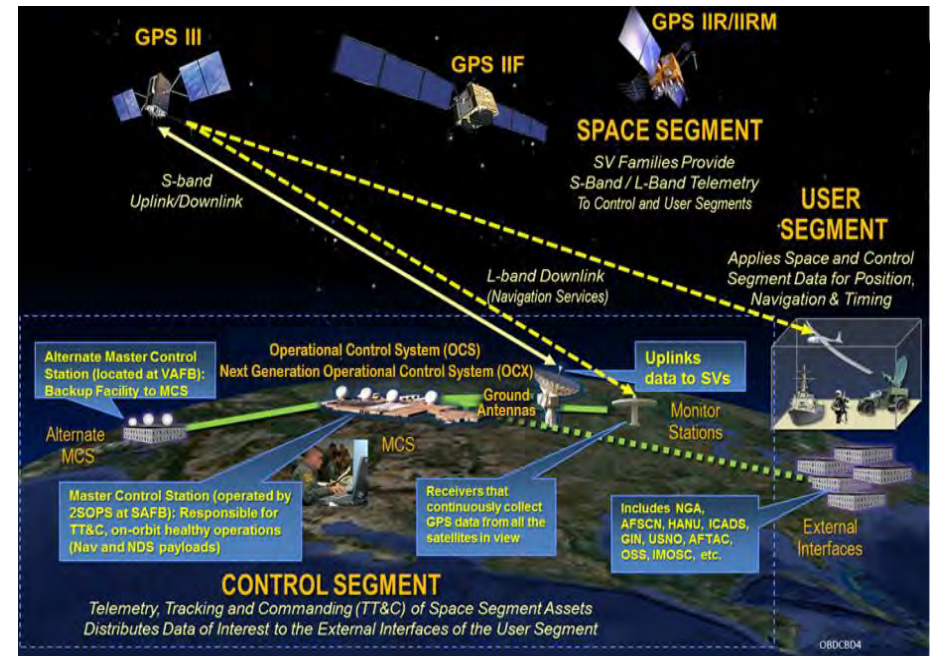
Modernized Civil Signals

- Continuous CNAV message broadcasts (L2C & L5) since April 2014
 - Daily (nominal) uploads
 - Position accuracy not guaranteed during pre-operational deployment
 - L2C message currently set “healthy”
 - L5 message set “unhealthy” until sufficient monitoring capability established
- User-Range Error (URE) CNAV Performance
 - Daily uploads are consistent with or slightly exceed LNAV performance
- Modernized Civil Signal Roadmap to Initial/Full Operational Capability in work



GPS III Contingency Operations (COps)

- Limited operations for GPS III Space Vehicles until OCX Block 1 delivery
 - Provides legacy and modernized civil signal operations
 - Relies on OCX Block 0 for GPS III launch, major anomaly, and disposal capabilities
- Software Development
 - Risk reduction modification to current Operational Control System (OCS)
 - Four incremental software builds
- Current Status:
 - Software development is complete
 - Component Integration Test (CIT) finishes Oct 2018
 - Operational Acceptance: Jan 2020



COps is a critical bridge, enabling sustainment of legacy signals for GPS III

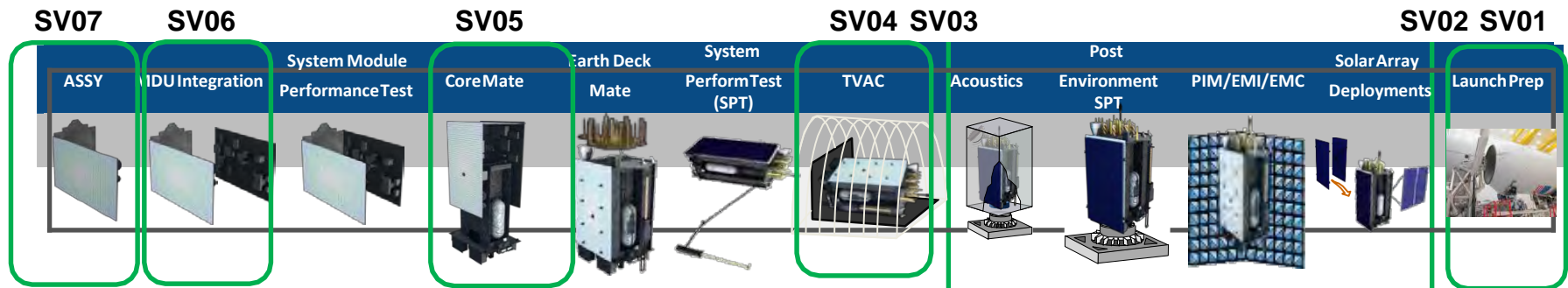
GPS III

- GPS III is newest block of GPS satellites
 - 4 civil signals: L1 C/A, L1C, L2C, L5
 - First satellites to broadcast common L1C signal
 - 4 military signals: L1/L2 P(Y), L1/L2M
- General characteristics
 - Orbit: Six orbit planes at 55 degree inclination
 - Altitude: 10,898 nautical miles
 - Design life: 15 years, 12 years mean mission duration
 - Launch weight: 8,115 lb.
 - On-Orbit weight: 4,764 lb.
 - Size: 97 in wide, 70 in deep, 134 in high



First satellites to broadcast common L1C signal

State of the GPS III Space Vehicles



- SV01 successfully completed post-ship functional testing
- SV02 declared Available For Launch (AFL) on 10 Aug 18. Spacecraft is in short-term storage
- SV03 acoustics testing prep is ongoing
 - Solar array testing in work
 - Shipped to Reverberant Acoustic Laboratory (RAL) on 7 Sep 18
 - Completed Thermal Vacuum (TVAC) on Jun 2018
- SV04 in TVAC Chamber on 30 Aug 18
 - Open door testing to begin on 4 Sep 18
- SV05 core mating is in progress
- SV06 is currently integrating harnesses
- SV07 is currently in Assembly buildup stage



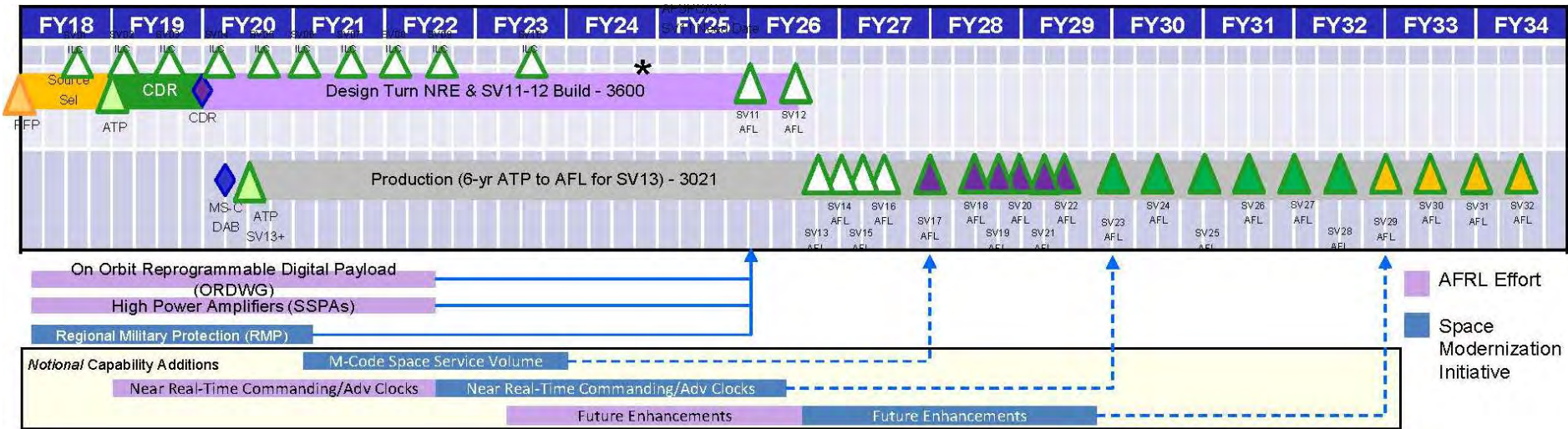
7 SVs in various phases within the single line flow

GPS III SV01 Road To Launch

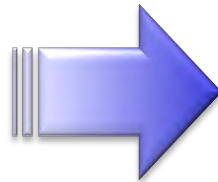


GPS III SV01 enterprise road to launch – A series of firsts!

GPS III Acquisition Strategy



- Contract award for competitive production contract for 22 GPS III satellites
- Partnerships with AFRL for technology insertion & path to flight
 - Digital Payloads
 - High Power Amplifiers
 - Advanced Clocks
 - Near Real-Time Commanding/Crosslinks



Ensuring the Gold Standard Today and into the future

Lockheed Martin selected as vendor for GPS IIF on 14 Sept 2018

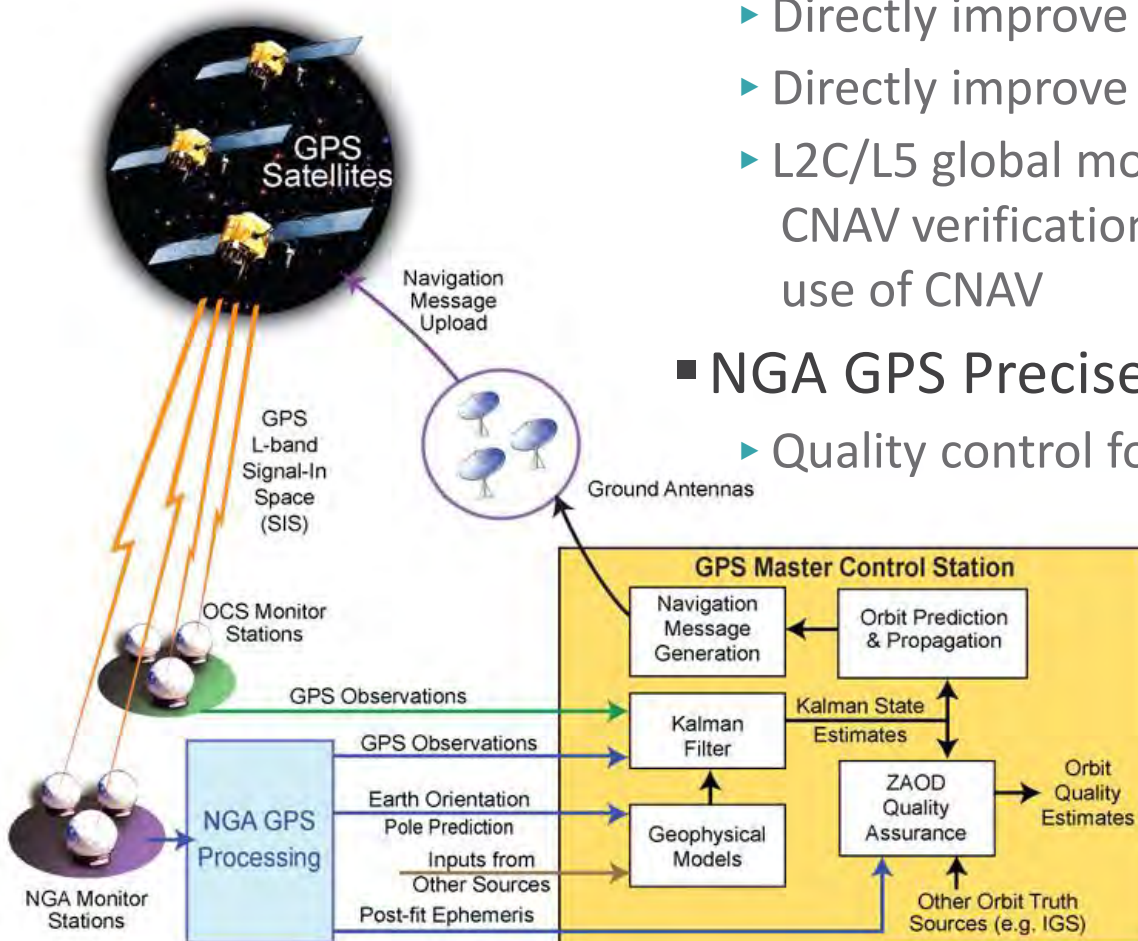
Current GPS Operations and NGA

■ NGA GPS observations

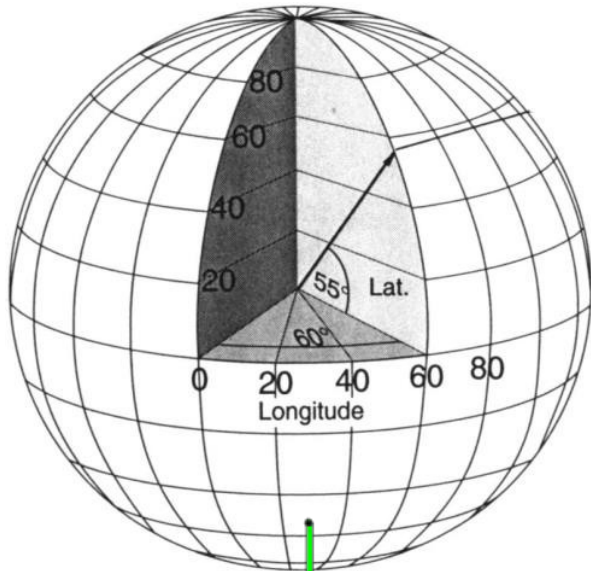
- ▶ 6 USAF GPS and 10 NGA monitor stations
- ▶ Directly improve GPS Broadcast Accuracy
- ▶ Directly improve GPS Integrity Monitoring
- ▶ L2C/L5 global monitoring (~2014) supports USAF CNAV verification and enabled pre-operational use of CNAV

■ NGA GPS Precise Ephemeris

- ▶ Quality control for GPS operations

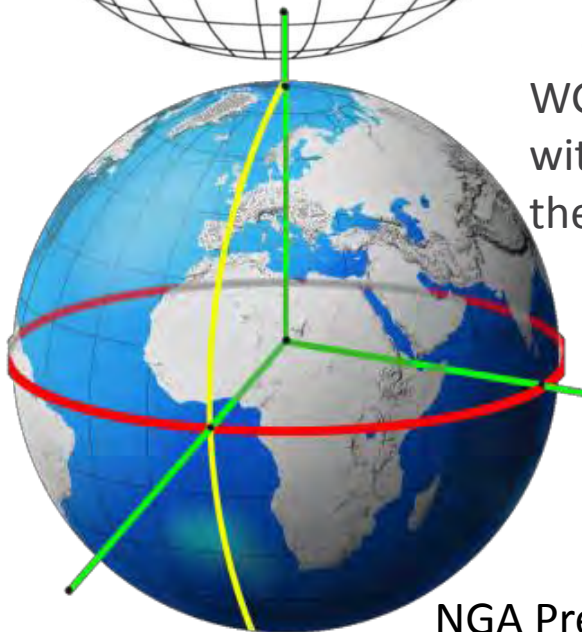


World Geodetic System 1984 (WGS 84)



Origin for ALL modern Geospatial Data is at Earth's Center of Mass

WGS-84 is known in 3-D with uncertainty smaller than the size of a postage Stamp



Recent WGS 84 Frame Realizations

Realization	Absolute Accuracy	Date
Original (TRANSIT)	1-2 m	Jan 1987
G730	10 cm	Jun 1994
G873	5 cm	Jun 1997
G1150	2 cm	Jan 2002
G1674	1 cm	Feb 2012
G1762*	1 cm	Oct 2013
GXXXX **	1 cm	Oct 2018

WGS 84 defined in NGA.STND.0036

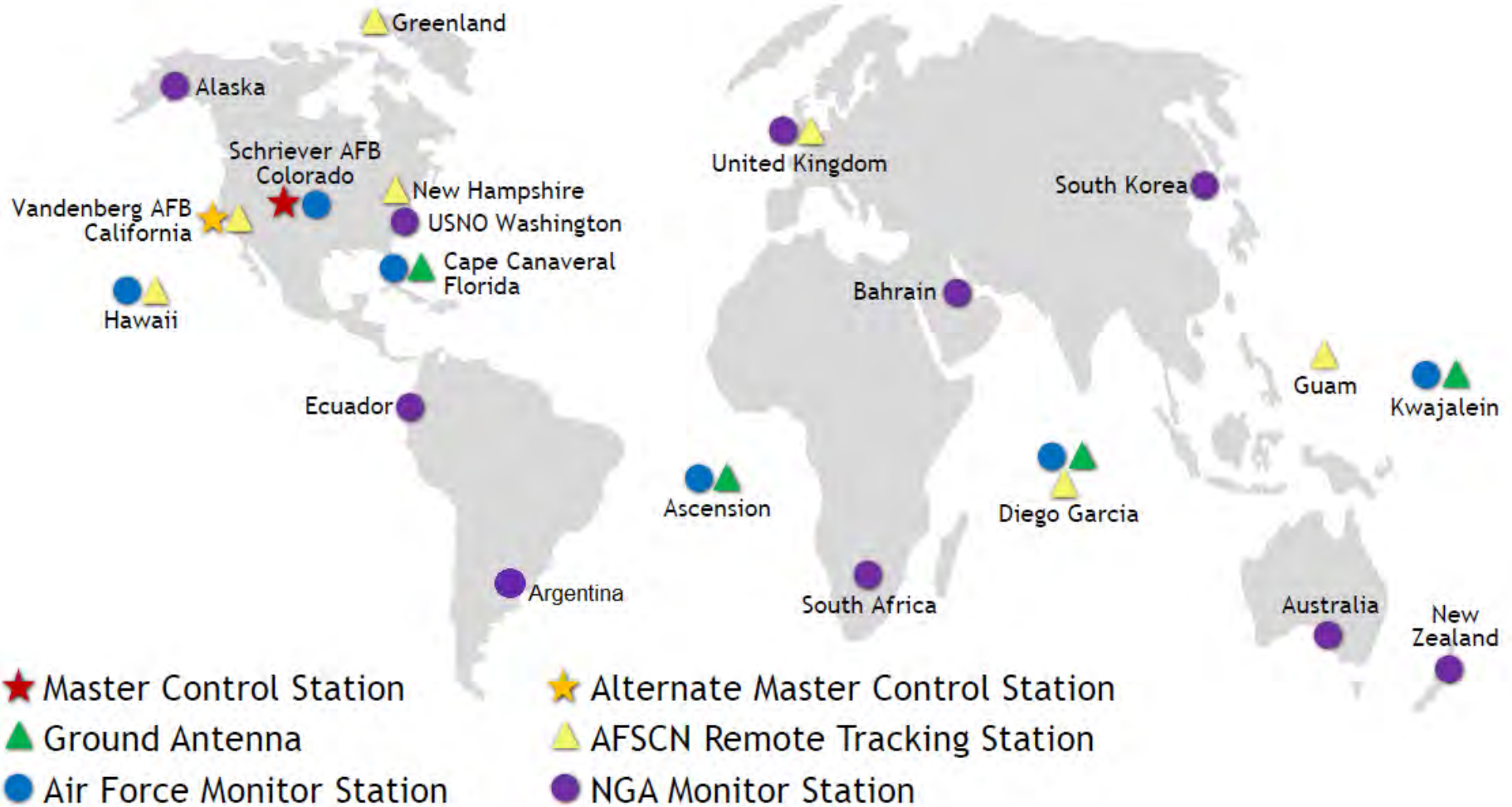
* Aligned to ITRF08

** Aligned to ITRF14



NGA Predecessor Agencies – Developed the First (1958) Global Reference Frame and Geophysical Models for Modern Geospatial Information

NGA & USAF GPS Monitor Stations - OCX



- NGA and USAF have separate, but complimentary GPS missions
 - Operated & maintained independently; NGA & USAF receivers & antennas are different
- **OCX**
 - **NGA and USAF equipment collocated at each monitor station**
 - **All 17 stations will have both an USAF OCX receiver/antenna and NGA receiver/antenna**

GPS Next Generation Operational Control System (OCX)

- Next-generation C2 and cyber-defense for GPS
 - Worldwide, 24 hr/day, all weather, Positioning, Navigation, and Timing (PNT) source for military and civilian users
 - Robust information assurance and cyber security
 - Modern civil signals and monitoring
 - Support to Military Code (M-Code) navigation warfare
- Incremental Development
 - OCX Block 0: Launch and Checkout System (LCS) for GPS III
 - OCX Blocks 1 and 2: Operate and manage modernized GPS constellation, add modern features and signals, and provide Civil Signal Performance Monitoring
- Current Status
 - LCS is ready to support GPS III SV01 launch in Dec 2018
 - Third successful integrated launch rehearsal between GPS III and OCX Block 0 completed Jun 2018
 - Cybersecurity testing events in Apr 2018 and May 2018 validated GPS III LCS cybersecurity requirements and identified no new vulnerabilities
 - Block 1 development continues to meet milestones
 - Final iteration Critical Design Review (iCDR) completed 7 Sep 18
 - Final iteration of coding scheduled to complete second quarter 2019; next step is 2.5 years of system testing
 - Ready to Transition to Operations: Apr 2022



GPS Instrument Approach Procedures

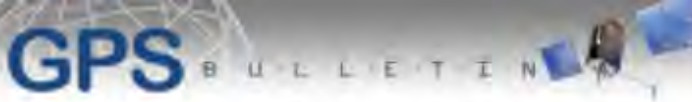
- In 2007, 87 Economies had GPS Instrument Approach Procedures
 - 1st 13 years of GPS aviation use
- In 2017, 164+ (of 193 ICAO Economies) published GPS Instrument Approach Procedures
 - Approximately twice the number of Economies as in 2007
- In 2017, U.S. published 15,379 Instrument Approach Procedures
 - Total GPS, SBAS, and GBAS Instrument Approach Procedures

U.S. Policy and GPS Summary

- U.S. supports free access to civilian GNSS signals and all necessary public domain documentation to enable open competition and market growth
- GPS is a critical component of global infrastructure and is compatible with other GNSS systems and is interoperable at the user level
 - Acquired and operated by U.S. Air Force on behalf of USG
 - Guided at an economy level as multi-use asset
 - Recognize need for robust multi-sensor PNT
- U.S. continues to enhance GPS resiliency by:
 - Addressing near-term needs, Identifying opportunities for resiliency improvements, and Maturing technical needs for future use
- Exploring and expanding multi-GNSS potential
- Modernization milestones: New GPS III Follow-on contract and Dec 2018 first GPS III launch

***GPS: Continuous improvement,
predictable, dependable positioning performance***

GPS Information, Presentations, etc.



GPS BULLETIN
Information for Policymakers from the National Coordination Office for Space-Based Positioning, Navigation, and Timing (PNT)
March 29, 2017

Update on Fiscal Year 2017 GPS Appropriations

On March 9, the House passed H.R. 1301, the revised Department of Defense appropriations bill. The measure would increase overall FY 2017 funding for the GPS program above President Obama's request.

Program Line Item	President's Request	H.R. 1301
Space Procurement: GPS III Satellites	\$34.059M	\$34.059M
Development: GPS III Satellites	\$141.888M	\$171.888M
Development: Next Generation Operational Control System (OCX)	\$393.268M	\$393.268M
Development: Military GPS User Equipment (MGUE)	\$278.147M	\$309.047M
TOTAL	\$847.362M	\$908.032M

[View full details at GPS.gov](#)

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 - Anyone can subscribe or get back issues

Thank You!

Ken Alexander

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www.gps.gov

GPS Act Reintroduced

In February, Sen. Ron Wyden (D-OR) and Rep. Jason Chaffetz (R-UT) reintroduced the Geolocation Privacy and Surveillance Act (“GPS Act,” S. 395 and H.R. 1062). The legislation seeks to provide clarity for government agencies, commercial service providers, and the public regarding the legal procedures and protections that apply to electronic devices that can be used to

GPS: Accessible, Accurate, Interoperable