

# Space and Missile Systems Center

## Global Positioning Systems Directorate

GPS Status & Modernization Progress:  
Service, Satellites, Control Segment,  
and Military GPS User Equipment

CGSIC / ION GNSS+

12-16 Sep 2016

Col Steve Whitney, Director

Global Positioning Systems Directorate







# Global Positioning Systems Directorate

*SPACE AND MISSILE SYSTEMS CENTER*



"We are... the Green Monsters!"

**Mission:**

Professionals acquiring, delivering and sustaining reliable GPS capabilities to America's warfighters, our allies, and civil users



**Col Steve Whitney**  
Director



# GPS Overview

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## Civil Cooperation

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



## Department of Defense

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

## Maintenance/Security

- All Level I and Level II
  - Worldwide Infrastructure
  - NATO Repair Facility
- Develop & Publish ICDs Semi-Annually
  - ICWG: Worldwide Involvement
- Update GPS.gov Webpage
- Load Operational Software on over 970,000 SAASM Receivers
- Distribute PRNs for the World
  - 120 for US and 90 for GNSS



## Spectrum

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

**37 Satellites / 31 Set Healthy**  
**Baseline Constellation: 24 Satellites**

Satellite Block	Quantity	Average Age	Oldest
GPS IIR	12	14.7	19.1
GPS IIR-M	7	9.1	10.9
GPS IIF	12	2.6	6.3
Constellation	31	8.7	19.1

AS OF 29 AUG 16

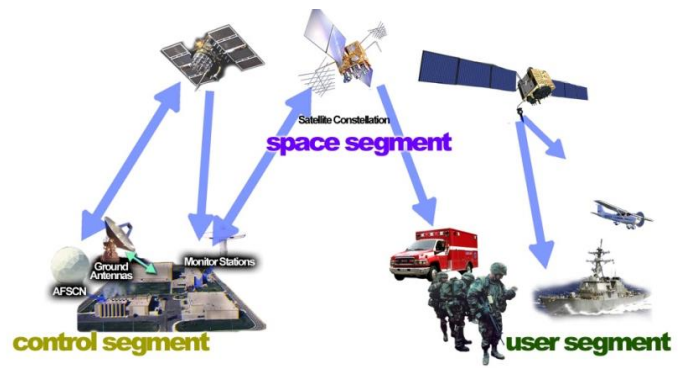


## Department of Transportation

- Federal Aviation Administration

## Department of Homeland Security

- U.S. Coast Guard



## International Cooperation

- 57 Authorized Allied Users
  - 25+ Years of Cooperation
- GNSS
  - Europe - Galileo
  - China - Beidou
  - Russia - GLONASS
  - Japan - QZSS
  - India - IRNSS





# GPS SIS Performance Scoreboard

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## GPS SIGNAL IN SPACE (SIS) PERFORMANCE (CM)

**BEST WEEK**

**BEST DAY**

**WORST DAY**

**ENDING SIS**

**DATE SIS**

**DATE SIS**

**ROLLING YEAR**

**14 APR 16 45.3**

**11 MAY 16 36.5**

**19 DEC 15 70.3**



**BEST WEEK EVER**

**14 APR 16**

**45.3**





# GPS Performance Report Card

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- 2013 report now available on [gps.gov](http://www.gps.gov)
  - <http://www.gps.gov/systems/gps/performance/>
- This report measures GPS performance against GPS SPS PS assertions

Table 2.1: Summary of SPS PS Metrics Examined for 2013

SPSPS08 Section	SPS PS Metric	2013 Status
3.4.1 SIS URE Accuracy	≤ 7.8 m 95% Global average URE during normal operations over all AODs	✓+
	≤ 6.0 m 95% Global average URE during normal operations at zero AOD	✓+
	≤ 12.8 m 95% Global average URE during normal operations at any AOD	✓+
	≤ 30 m 99.94% Global average URE during normal operations	✓+
	≤ 30 m 99.79% Worst case single point average URE during normal operations	✓+
3.5.1 SIS Instantaneous URE Integrity	≤ $1 \times 10^{-5}$ Probability over any hour of exceeding the NTE tolerance without a timely alert	✓+
3.6.1 SIS Continuity - Unscheduled Failure Interruptions	≥ 0.9998 Probability over any hour of not losing the SPS SIS availability from the slot due to unscheduled interruption	✓+
3.7.1 SIS Per-Slot Availability	≥ 0.957 Probability that (a.) a slot in the baseline 24-slot will be occupied by a satellite broadcasting a healthy SPS SIS, or (b.) a slot in the expanded configuration will be occupied by a pair of satellites each broadcasting a healthy SIS	✓+
3.7.2 SIS Constellation Availability	≥ 0.98 Probability that at least 21 slots out of the 24 slots will be occupied by a satellite (or pair of satellites for expanded slots) broadcasting a healthy SIS	✓+
	≥ 0.99999 Probability that at least 20 slots out of the 24 slots will be occupied by a satellite (or pair of satellites for expanded slots) broadcasting a healthy SIS	✓+
3.7.3 Operational Satellite Counts	≥ 0.95 Probability that the constellation will have at least 24 operational satellites regardless of whether those operational satellites are located in slots or not	✓+
3.8.1 PDOP Availability	≥ 98% Global PDOP of 6 or less	✓+
	≥ 88% Worst site PDOP of 6 or less	✓+
3.8.2 Position Service Availability	≥ 99% Horizontal, average location	✓+
	≥ 99% Vertical, average location	
	≥ 90% Horizontal, worst-case location	
3.8.3 Position Accuracy	≥ 90% Vertical, worst-case location	✓+
	≤ 9 m 95% Horizontal, global average	
	≤ 15 m 95% Vertical, global average	
	≤ 17 m 95% Horizontal, worst site	
	≤ 37 m 95% Vertical, worst site	

✓+ - Met or Exceeded





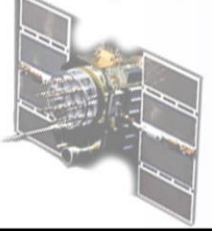
# GPS Modernization

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## Space System (Satellites)

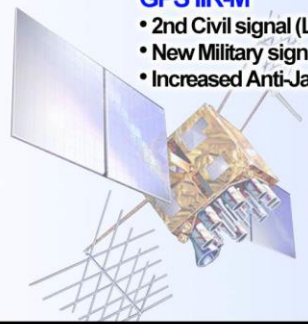
### Legacy (GPS IIA/IIR)

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



### GPS IIR-M

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



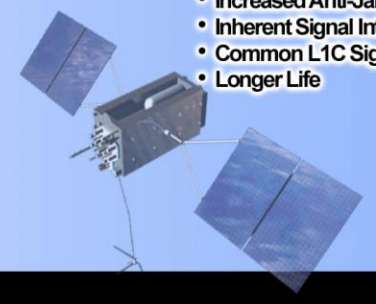
### GPS IIF

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



### GPS III

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



## 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 1

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

### OCX Block 2+

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

### OCX Block 0

- GPS III Launch & Checkout

### GPS III Contingency Ops (COps)

- GPS III Mission

## 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

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20 Feb 14: IIF-5



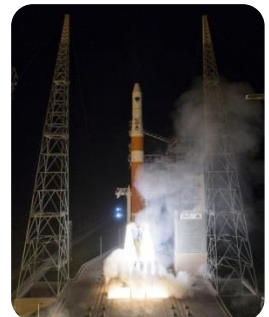
16 May 14: IIF-6



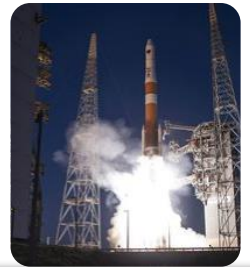
1 Aug 14: IIF-7



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 Launches in 24 Months -- Most aggressive GPS launch schedule since 1993**



# GPS III

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- GPS III is the 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
- SV01-SV08 on contract; SV09 & SV10 negotiated
  - 2 year delay due to technical challenges w/ payload
  - SV09-10 same requirements baseline as SV01-08 but with no NDS payload
- Current Status
  - SV01 In Testing Flow
    - Baseline thermal vacuum testing completed 23 Dec 15
    - Electromagnetic Interference (EMI) test completed 14 May 16
  - SV02/03 In Assembly & Integration
  - SV04 thru 08 in box level assembly



**GPS III SV01 Available For Launch Dec 2016**

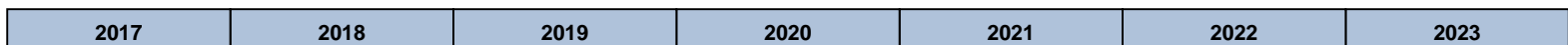




# GPS III SV 11+

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- Build on the legacy of the GPS IIF and GPS III programs
  - Drive down costs, maintain production readiness to achieve 2023 need date
- Plan to compete GPS III SV 11+ Follow-on Production
  - Promote competition and reduce risk for production GPS space vehicles
- Two-phase approach
  - Phase 1: Production Readiness Feasibility Assessment
    - Gain insight into contractor SV & navigation payload production maturity & risk
    - The Boeing Company, Lockheed Martin Space Systems Company, and Northrop Grumman Aerospace Systems awarded contracts on 9 May 16
  - Phase 2: Production Competition
    - Full and open competition for up to 22 production ready GPS III SVs



GPS III SV11+ Acq Decision

Contract Award Late FY18

SV 11 Delivery FY23



# GPS Next Generation Operational Control System (OCX)

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- Next-generation C2 and cyber-defense for GPS
  - Worldwide, 24 hr/day, all weather, position, velocity and time source for military & civilian users
  - Improved PNT performance
  - Robust information assurance and cyber security
  - Modern civil signals & monitoring
  - Support to Military Code (M-Code) navigation warfare
- Incremental Development
  - OCX Block 0: launch & checkout for GPS III
  - OCX Block 1: operate & manage GPS constellation, replaces AEP, adds modern features
  - OCX Block 2: operate advanced M-Code features and Civil Signal Performance Monitoring
- Current Status: Working through program challenges
  - Quarterly Reviews with OSD AT&L, SECAF, and Raytheon CEO
  - SECAF Declared Nunn-McCurdy Breach on 30 Jun 16
  - Nunn-McCurdy Review in progress, requires decision by 13 Oct 16



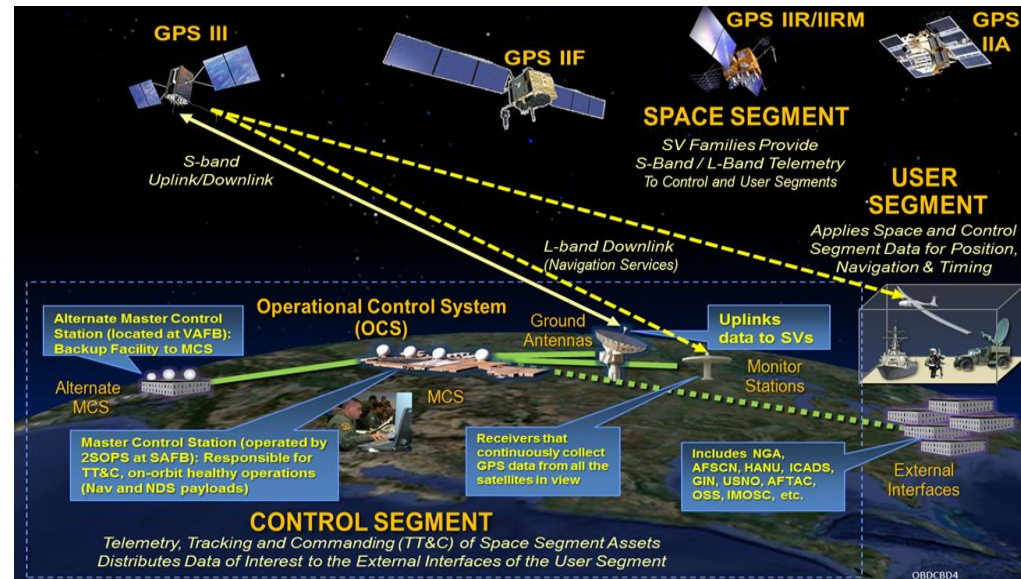




# Contingency Operations (COps)

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- Contingency Operations (COps) provides limited operations of GPS IIIs until OCX Block 1 delivery
  - Legacy signal operations
  - Test-only support for modernized signals
  - RTO projected Apr 2019
- Schedule supports current mission need date of Sep 2019 to sustain on-orbit legacy signal capability
- COPS relies on OCX Block 0 for GPS III launch, major anomaly, and disposal capabilities
- Completed PDR in May 2016



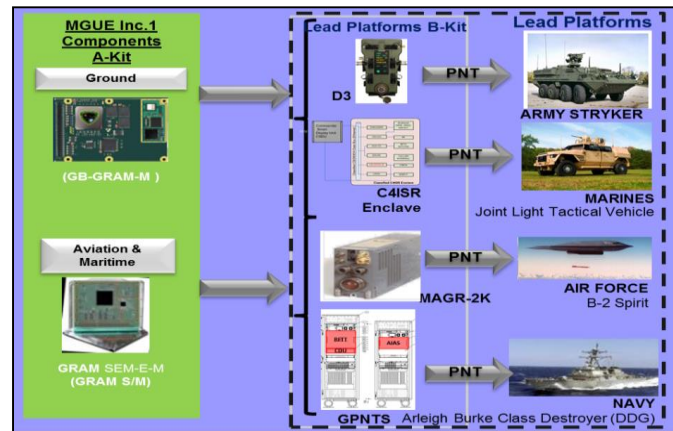
**COps is a critical bridge enabling sustainment of Legacy signals for GPS III**



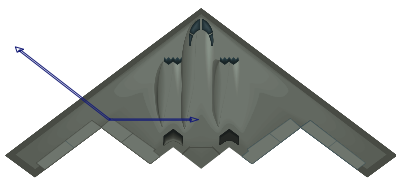
# Military GPS User Equipment (MGUE)

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- Commercial market-driven acquisition approach
  - Three vendors developing modernized receiver cards
- Conducting early integration activities to support Service-nominated Lead Platforms
  - Nov 2015: Delivered first prototype MAGR2K-M to support B-2 integration & test
  - Dec 2015: Successful tracking of Y-Code by prototype MAGR2K-M in B-2 Software Integration Lab (SIL)
  - Apr 2016: Successful integration and M-Code track: modernized Embedded GPS Inertial System (EGI)
  - Jun 2016: MGUE Final Test Articles (FTAs) provided to Navy DDG Destroyer Lead Platform program
  - Aug 2016: B-2 Integration with new antenna in the B-2 SIL; tracking M-Code
- Draft MGUE Increment 2 Capability Development Document (CDD) in coordination: Space Receiver, Handheld, Precision Guided Munitions



MAGR2K-M



JLTV



D3



PGM





# GPS Director's Perspectives

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- GPS is the Global Utility
  - Committed to maintaining uninterrupted service – “the Gold Standard”
- Embracing Gen Hyten's Space Enterprise Vision by continuing to enhance PNT resiliency
  - Includes examination of multi-GNSS receivers
- Appreciate the need for alternative PNT sources, and challenge the community (labs, industry, others) to propose & explore solutions
- Next-Generation Operational Control System (OCX) addressing cost and schedule challenges
  - Looking at opportunities to provide operational modernized signal capabilities prior to OCX



# The men and women of the GPS Directorate



ACQUISITION PROFESSIONALS DELIVERING THE GOLD STANDARD IN SPACE-BASED PNT AND NDS SERVICES





# Back-Up

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# Constellation Snapshot

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## 4 Generations of Operational Satellites

- Block IIA - 6 Residual
  - 7.5 year design life
  - Launched 1990-1997
- Block IIR - 12 Operational
  - 7.5 year design life  
(oldest operational satellite will be 19 years old in Jul)
  - Launched 1997-2004
- Block IIR-M - 7 Operational, 1 Residual
  - 7.5 year design life
  - Launched 2005-2009
  - Added 2nd civil navigation signal (L2C)
- Block IIF - 12 Operational
  - 12 year design life
  - Launched 2010-2016
  - Added 3rd civil navigation signal (L5)

\*Current as of 12 Jul 16



Block IIA Satellite – Designed & Built by Rockwell International



Block IIR/IIR-M Satellite – Designed & Built by Lockheed Martin



Block IIF Satellite – Designed & Built by Boeing

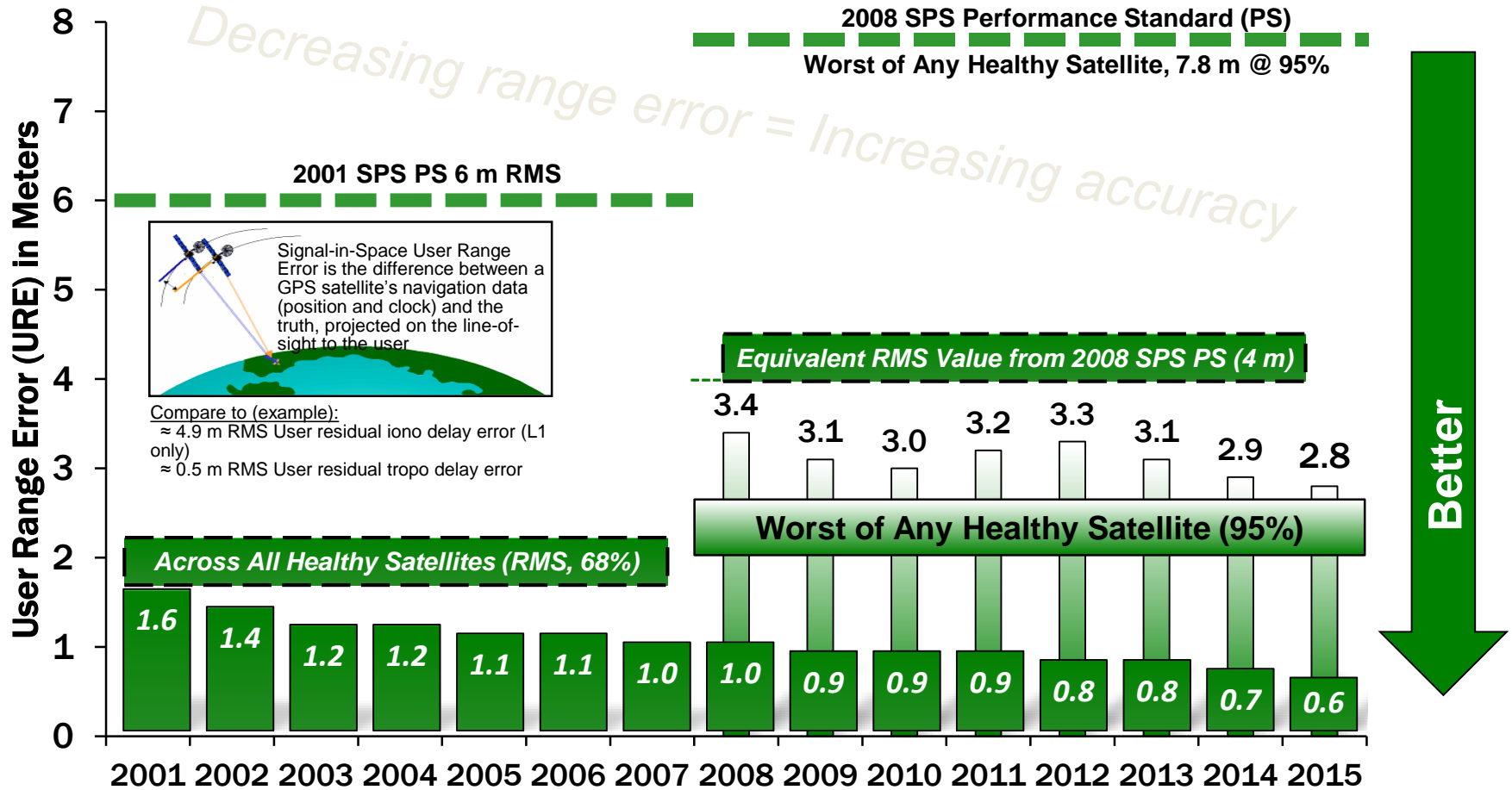


# Accuracy: Civil Commitments

## Standard Positioning Service (SPS) Performance Standard

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



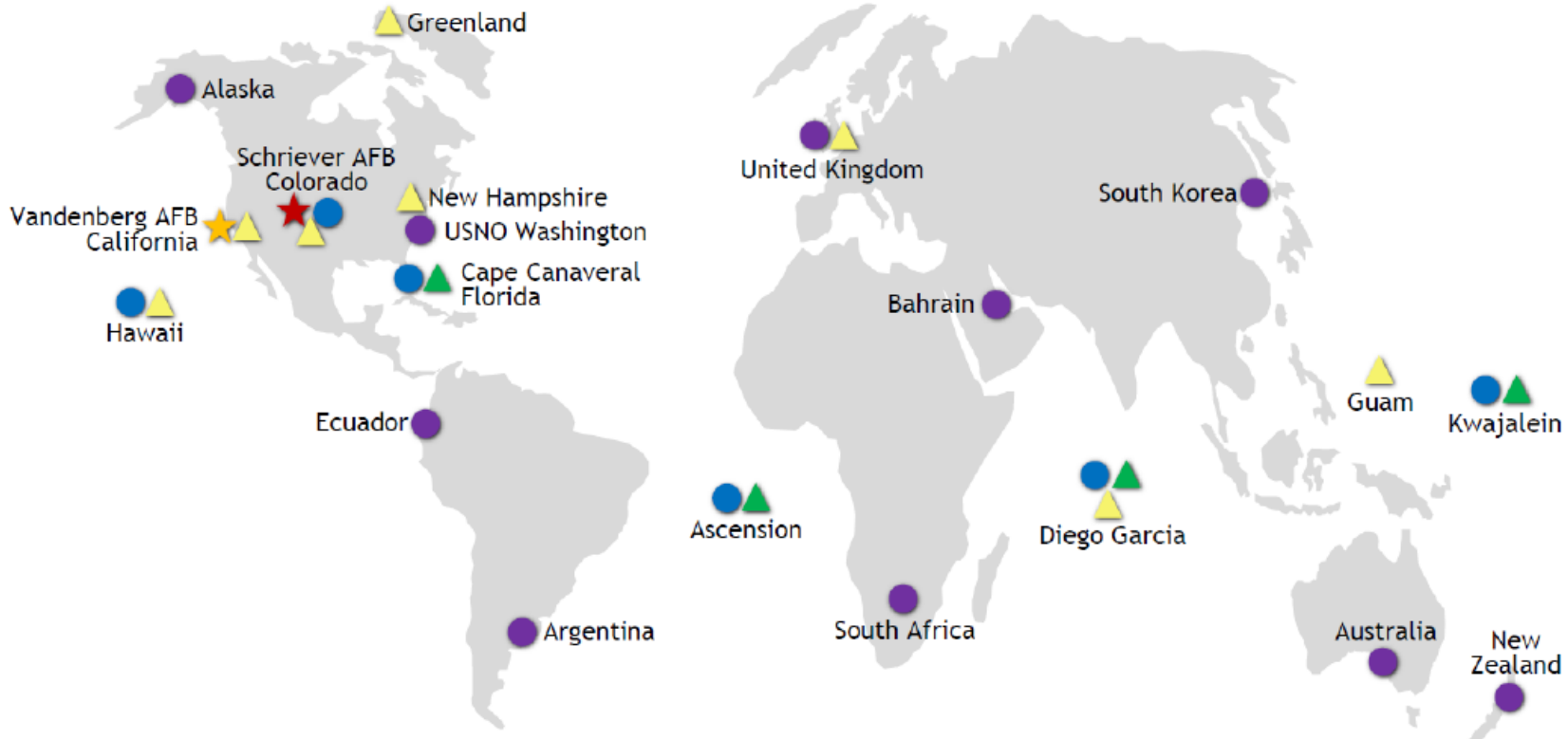
**System accuracy better than published standard**





# Ground Segment

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- ★ Master Control Station
- ▲ Ground Antenna
- Air Force Monitor Station
- ★ Alternate Master Control Station
- ▲ AFSCN Remote Tracking Station
- NGA Monitor Station



# UTC0 Anomaly

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- GPS MCS uploaded incorrect UTC0 parameters to part of the GPS constellation.
  - Occurred from 25-26 Jan, ~14 hour window, 15 SVs affected.
  - Once identified and confirmed, fix uploaded to all affected SVs within 1.5 hours
- SMC/GP and 2SOPS have already implemented a software update to resolve core upload issue.
- SMC/GP also exploring:
  - Addition to the SPS PS, “resilience considerations for handling GPS data.”
  - Increased UTC0 parameter monitoring and exploring additional options
  - Follow-on software update to provide additional protections against UTC0 issues