

Space and Missile Systems Center



Update on GPS Modernization Efforts

2 June 2015

Brig Gen William T. "Bill" Cooley
Director, GPS Directorate



AEHF = Advanced Extremely High Frequency System, AFSCN = Air Force Satellite Control Network, CCAFS = Cape Canaveral Air Force Station, DMSP = Defense Meteorological Satellite Program, DSCS = Defense Satellite Communications, DSP = Defense Support Program System, EPS = Enhanced Polar System, GEODSS = Ground-based Electro-Optical Deep Space Surveillance System, GPS = Global Positioning System, GSSAP = Geosynchronous Space Situational Awareness Program, JSpOC = Joint Space Operations Center, ORS = Operationally Responsive Space, SBIRS = Space-Based Infrared System, SBSS = Space-Based Surveillance system, SSA = Space Situational Awareness, SST = Space Surveillance Telescope, VAFB = Vandenberg Air Force Base, WGS = Wideband Global Satellite Communications



Global Positioning Systems Directorate

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Mission:

Acquire, deliver and sustain reliable GPS capabilities to America's warfighters, our allies, and civil users



From left to right, a GPS IIA, IIR-M, and IIF satellite

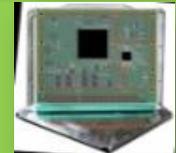


BGen Bill Cooley
Director

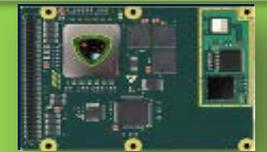


Master Control Station
(located at Schriever AFB, CO)

Aviation & Maritime



Ground



Modernized GPS User Equipment
(MGUE) Components



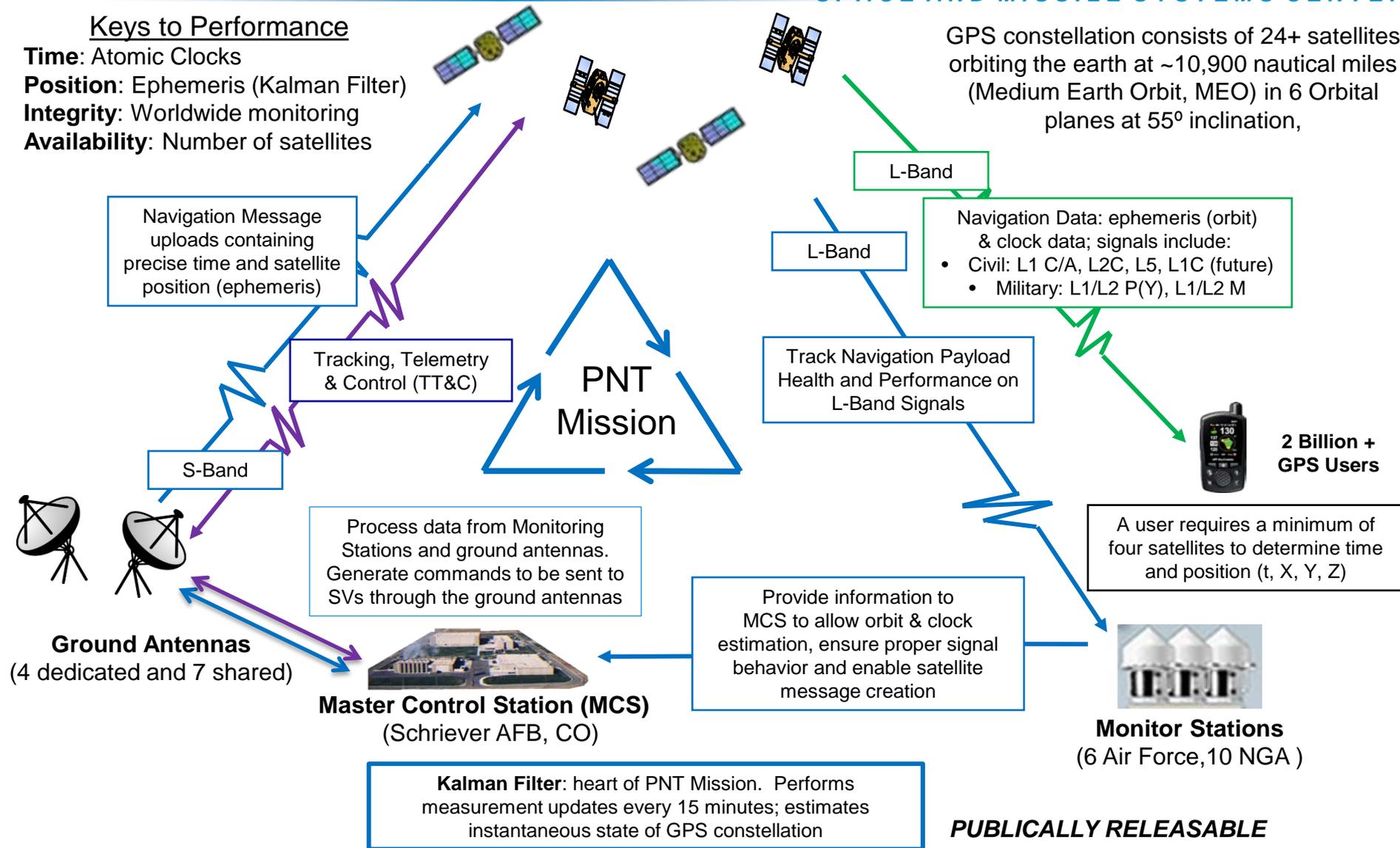
How GPS Works

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Keys to Performance

- Time:** Atomic Clocks
- Position:** Ephemeris (Kalman Filter)
- Integrity:** Worldwide monitoring
- Availability:** Number of satellites

GPS constellation consists of 24+ satellites orbiting the earth at ~10,900 nautical miles (Medium Earth Orbit, MEO) in 6 Orbital planes at 55° inclination,



Kalman Filter: heart of PNT Mission. Performs measurement updates every 15 minutes; estimates instantaneous state of GPS constellation

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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 (2nd Civil Signal)
 - L5 (Aviation Safety of Life)
 - L1C (International)



38 Satellites / 31 Set Healthy
Baseline Constellation: 24 Satellites

Satellite Block	Quantity	Average Age	Oldest
GPS IIA	3	21.5	24.4
GPS IIR	12	13.3	17.7
GPS IIR-M	7	7.7	9.6
GPS IIF	9	1.8	4.9
Constellation	31	9.5	24.4

AS OF 20 APR 15

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
- International Committee On Global Navigation Satellite Systems (GNSS)

International Cooperation

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

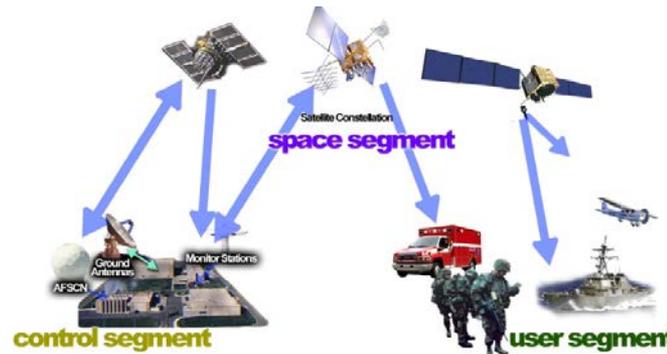


Department of Transportation

- Federal Aviation Administration

Department of Homeland Security

- U.S. Coast Guard



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GPS Modernization Program

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Legacy GPS IIA/IIR

- Single Civil Frequency (L1 C/A)
- P(Y)-Code (L1 & L2)

GPS IIR-M

- 2nd Civil Signal (L2C)
- M-Code (L1M & L2M)

GPS IIF

- 3rd civil signal (L5)
- 2 Rb + 1 Cs Clocks
- 12 year design life

GPS III

- 4th civil signal (L1C)
- 4x better User Range Error than GPS IIF
- Increased availability
- Increased integrity
- 15 year design life



Legacy Operational Control Segment (AEP / LADO)

- Mainframe system
- Command & Control
- Signal monitoring
- Launch and disposal

Next Generation Operational Control System (OCX)

OCX Block 0

- Launch & On-Orbit Checkout of GPS III

OCX Block 1

- Replaces AEP for constellation C2
- M-Code
- Robust cyber security
- New civil signals & monitoring
- Improved accuracy

Modernized GPS User Equipment (MGUE)

- Provides M-code access for military users
- Increased anti-jam/anti-spoof capabilities

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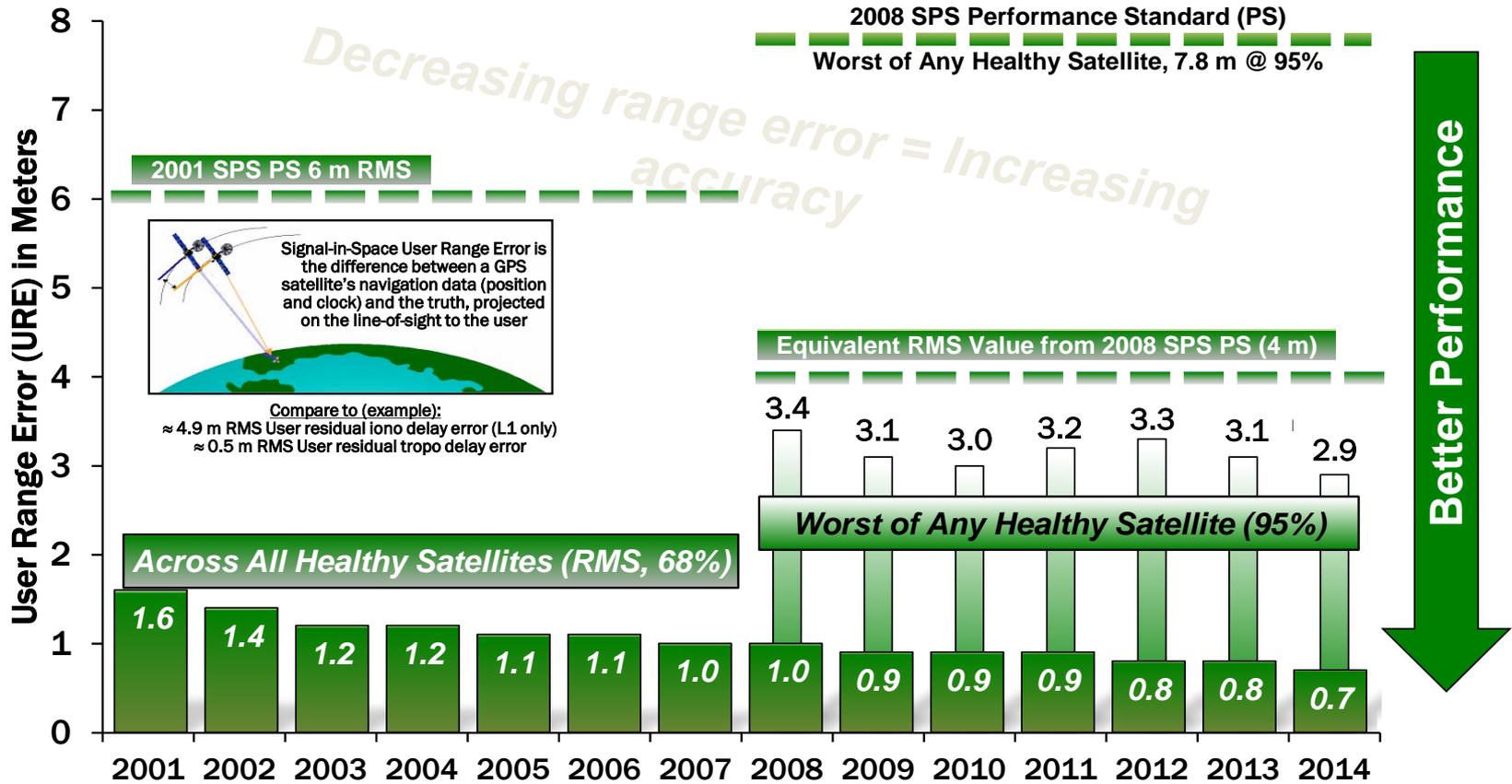


Accuracy: Civil Commitments

Standard Positioning Service (SPS) Performance Standard

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



System accuracy better than published standard



Accuracy: Military Commitments

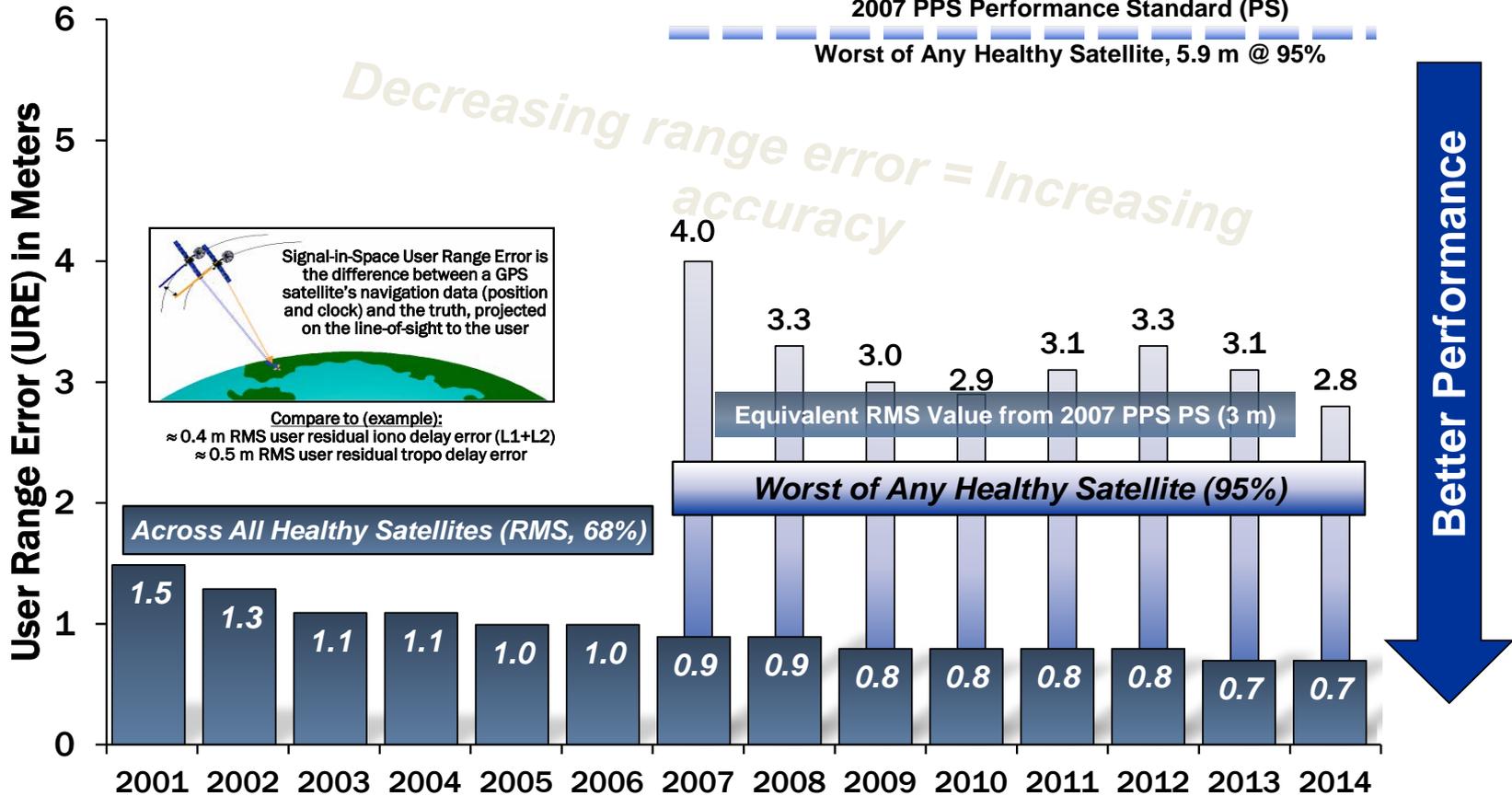
Precise Positioning Service (PPS) Performance Standard

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Precise Positioning Service (PPS) Signal-in-Space Performance

2007 PPS Performance Standard (PS)

Worst of Any Healthy Satellite, 5.9 m @ 95%



System accuracy better than published standard



Now on The Air: Modernized Civil Signals

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- The U.S. initiated CNAV message broadcast (L2C & L5) on 28 Apr 14
 - Daily uploads (nominal procedure for satellite operations) began on 31 Dec 14
 - L2C message currently set “healthy”
 - L5 message set “unhealthy” until sufficient monitoring capability established
 - Position accuracy not guaranteed during pre-operational deployment
- User Range Error (URE) CNAV Performance Post
 - Daily uploads consistent with or exceed legacy navigation performance*
 - Inter-signal corrections enable single point positioning competitive with P(Y) receivers
- Full potential of signals require receiver manufactures’ adoption
 - Challenge: Industry taking advantage of these signals moves capabilities forward!



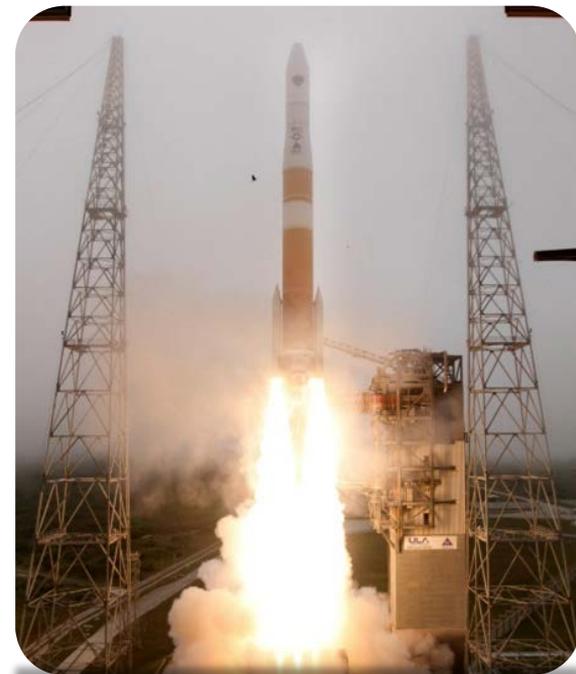
* Data from “Performance Evaluation of the Early CNAV Navigation Message”, Pstreigenberger, O. Montenbruck, U. Hessels; Study conducted in Europe.



Modernized Space System: GPS IIF

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- Nine total GPS IIFs on-orbit
- Four GPS IIF launches in 2014!
- Three additional GPS IIFs in the pipeline
 - SV-9 & 12 are in storage; SV-11 at Cape
- Prime: The Boeing Company
- Upcoming launch dates:
 - GPS IIF-10 (SV-11) : 15 Jul 15
 - GPS IIF-11 (SV-12): 30 Oct 15
 - GPS IIF-12 (SV-9): NET 3 Feb 16



25 Mar 15: IIF-9



Modernized Space System: 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
- SV-1 – SV-8 on contract; SV-9 & 10 approved
- Navigation payload panel delivered 1 Nov 14
- Updated Mission Data Unit delivered 9 Mar 15
- SV-1 System Module Core Mate completed 9 Apr 15
- SV level thermal vacuum scheduled for Fall 2015
- SV-1 available for launch Aug 2016



Lockheed Martin (Waterton, CO) – Prime



Current Control Segment: OCS

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- Current system Operational Control Segment (OCS)
 - Flying the GPS constellation with both the Architecture Evolution Plan (AEP) and the Launch & Early Orbit, Anomaly Resolution, and Disposal Operations (LADO) software systems
 - Cyber security / information assurance enhancements in progress
 - Prime: Lockheed Martin



Monitor Station



Ground Antenna



2SOPS Ground Control
(Schriever AFB)



Modernized Control Segment: OCX

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- Next Generation Operational Control System
 - Modernized command & control system
 - GPS III command & control
 - M-Code
 - Robust cyber security infrastructure
 - Modern civil signals & monitoring
 - Improved PNT performance
 - Prime: Raytheon (Aurora, CO)
 - OCX Block 0: launch & checkout for GPS III
 - Currently in test; delivery expected May 2016
 - Successfully completed four launch exercises
 - OCX Block 1: replaces AEP, adds modern features
 - Currently in design, delivery expected 2019
 - OCX Block 2: adds advanced NAVWAR and Civil Signal Performance Monitoring capabilities
 - Delivery expected in 2020

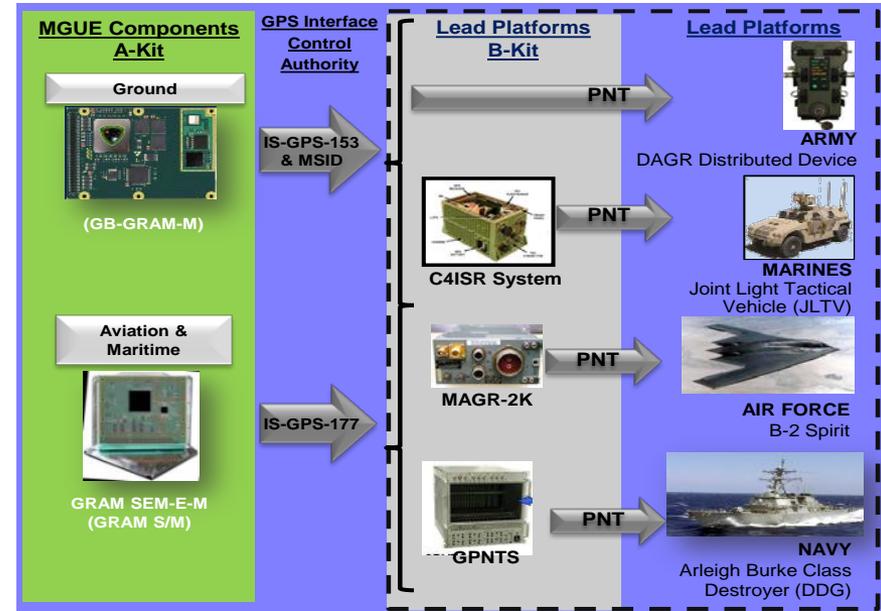




Modernized User Equipment: MGUE

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- Military GPS User Equipment (MGUE) is using a commercial market driven acquisition approach
- Accelerated from TD phase into testing and lead platform integration
- Increment 1 program's 2366b certification is pending
- Successful Preliminary Design Reviews (PDRs) for all 3 MGUE Inc 1 contractors
 - Rockwell Collins (Cedar Rapids IA): 06 Aug 14
 - L-3 Communications (Anaheim, CA): 04 Sep 14
 - Raytheon (El Segundo, CA): 17 Sep 14
- Security Certification Underway
- Integrating Service Lead Platforms
 - Air Force: B-2 Spirit (B-2)
 - Army: DAGR Distributed Device (D3) / Stryker
 - Marines: Joint Light Tactical Vehicle (JLTV)
 - Navy: Arleigh Burke Class Guided Missile Destroyer (DDG)





GPS Director's Focus

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- Delivering new signals to military and civilian users (M-Code, L2C, L5)
- Accelerating Military GPS User Equipment (MGUE)
- GPS III production, following 2-year delay, due to Navigation Panel issues
 - Thermal Vacuum test (Fall '15) final development hurdle
- Next Generation Ground (OCX) program challenges continue
 - Cybersecurity & systems engineering issues drove schedule and cost overruns
 - Contractor working closely with Gov't to deliver, but challenges remain



Team GPS thanks you for your support!