Update on GPS Modernization Efforts

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Mission: Acquire, deliver and sustain reliable GPS capabilities to America’s warfighters, our allies, and civil users.
How GPS Works

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.

GPS Users: 2 Billion +

A user requires a minimum of four satellites to determine time and position (t, X, Y, Z)

Tracking, Telemetry & Control (TT&C)

Process data from Monitoring Stations and ground antennas. Generate commands to be sent to SVs through the ground antennas

S-Band

L-Band

Ground Antennas
(4 dedicated and 7 shared)

Master Control Station (MCS)
(Schriever AFB, CO)

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

Monitor Stations
(6 Air Force, 10 NGA)

Navigation Data: ephemeris (orbit) & clock data; signals include:
• Civil: L1 C/A, L2C, L5, L1C (future)
• Military: L1/L2 P(Y), L1/L2 M

Navigation Message uploads containing precise time and satellite position (ephemeris)

Provide information to MCS to allow orbit & clock estimation, ensure proper signal behavior and enable satellite message creation

Track Navigation Payload Health and Performance on L-Band Signals

PNT Mission

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.

How GPS Works

Keys to Performance

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

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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

Spectrum
- World Radio Conference
- International Telecommunication Union
- Bilateral Agreements
- Adjacent Band Interference
- International Committee On Global Navigation Satellite Systems (GNSS)

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

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

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AS OF 20 APR 15
GPS Modernization Program

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
Accuracy: Civil Commitments
Standard Positioning Service (SPS) Performance Standard

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

User Range Error (URE) in Meters

- 2001 SPS PS 6 m RMS
- Equivalent RMS Value from 2008 SPS PS (4 m)
- Worst of Any Healthy Satellite (95%)

Across All Healthy Satellites (RMS, 68%)

System accuracy better than published standard

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Accuracy: Military Commitments
Precise Positioning Service (PPS) Performance Standard

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

2007 PPS Performance Standard (PS)
Worst of Any Healthy Satellite, 5.9 m @ 95%

User Range Error (URE) in Meters

Across All Healthy Satellites (RMS, 68%)

System accuracy better than published standard

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Now on The Air: Modernized Civil Signals

- 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!

Modernized Space System: GPS IIF

- 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
Modernized Space System: GPS III

- 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

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Current Control Segment: OCS

- 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
Modernized Control Segment: OCX

- 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

- 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

- 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!