



*United States of America
Space-Based Positioning,
Navigation, and Timing (PNT)
Status and Applications*

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23 October 2023



U.S. Laws and Policies

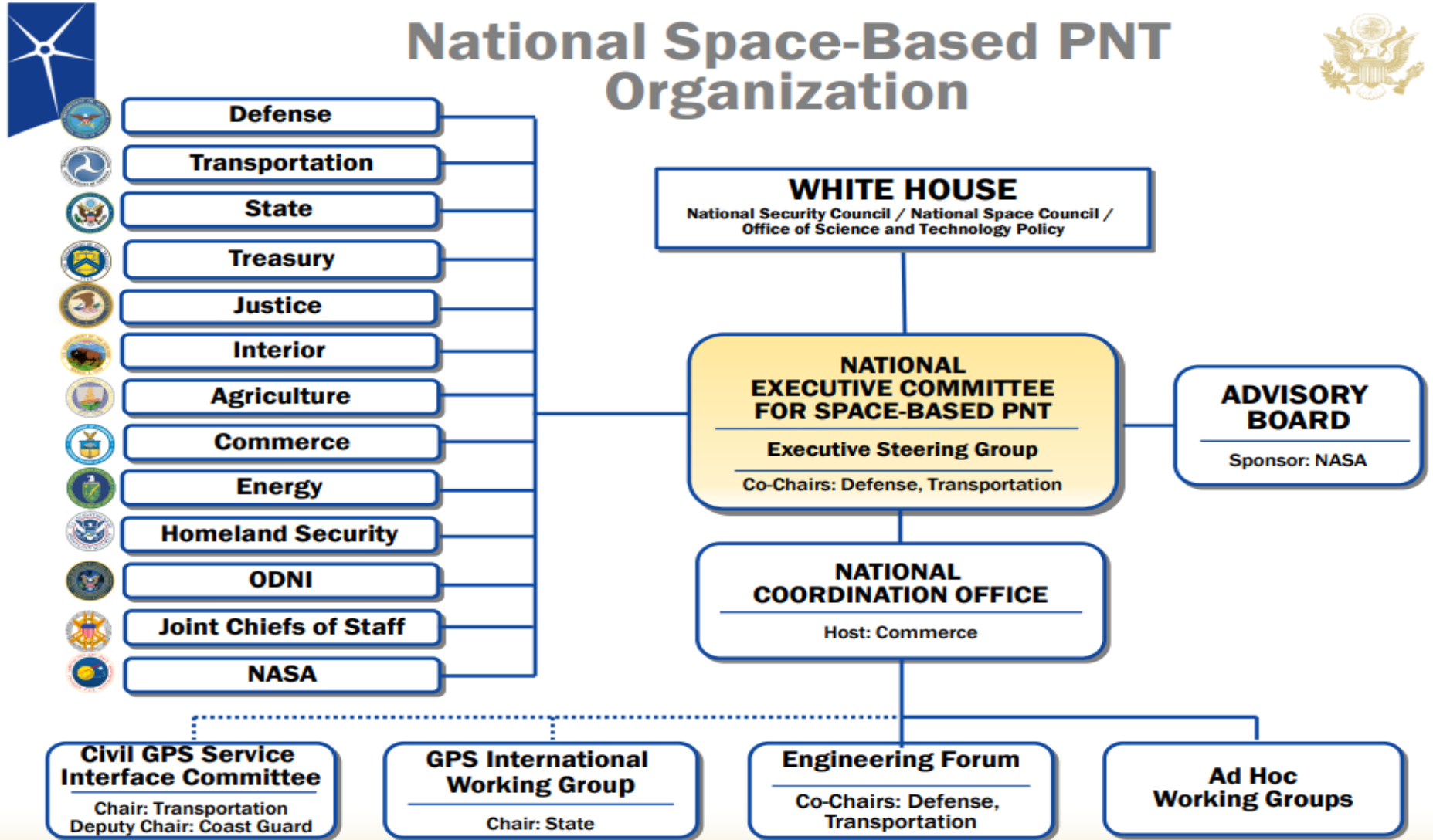


- **10 United States Code 2281 GPS**
 - **Direction to provide civil GPS on a continuous, worldwide basis, free of direct user fees.**
- **49 United States Code 44505**
 - **The Federal Aviation Administration is responsible for safe systems for aviation – supports *International Civil Aviation Organization***
- **51 United States Code 50112**
 - **Promotion of GPS as an international standard, promote cooperation with foreign governments and international partners, and for the protection of the radio spectrum used by GPS**
- **Space Policy Directive 7**
 - **Encourage interoperability with likeminded nations, promote transparency in civil service provision**
 - **Integrate multiple PNT services**
 - **Ensure GNSS non-interference to support mutual security concerns**

PNT Policy in the United States



National Space-Based PNT Organization





GPS Constellation

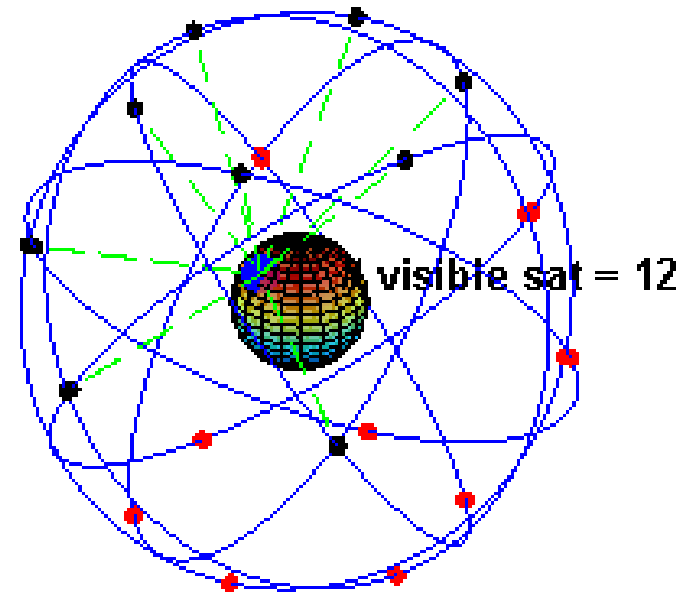


GPS Signal in Space Performance

From 01 Jan 23 to 12 Oct 23

Satellite Block	Quantity	Average Age (yrs)	Oldest (yrs)
GPS IIR	7	21.7	26.1
GPS IIR-M	7	16.1	17.9
GPS IIF	11	9.6	13.3
GPS III	6	2.9	4.7

Average URE*	Best Day URE	Worst Day URE
48.4 cm	34.1 cm (23 Jun 23)	163.7 cm (25 Jan 23)



*All User Range Errors (UREs) are 95% Root Mean Square values

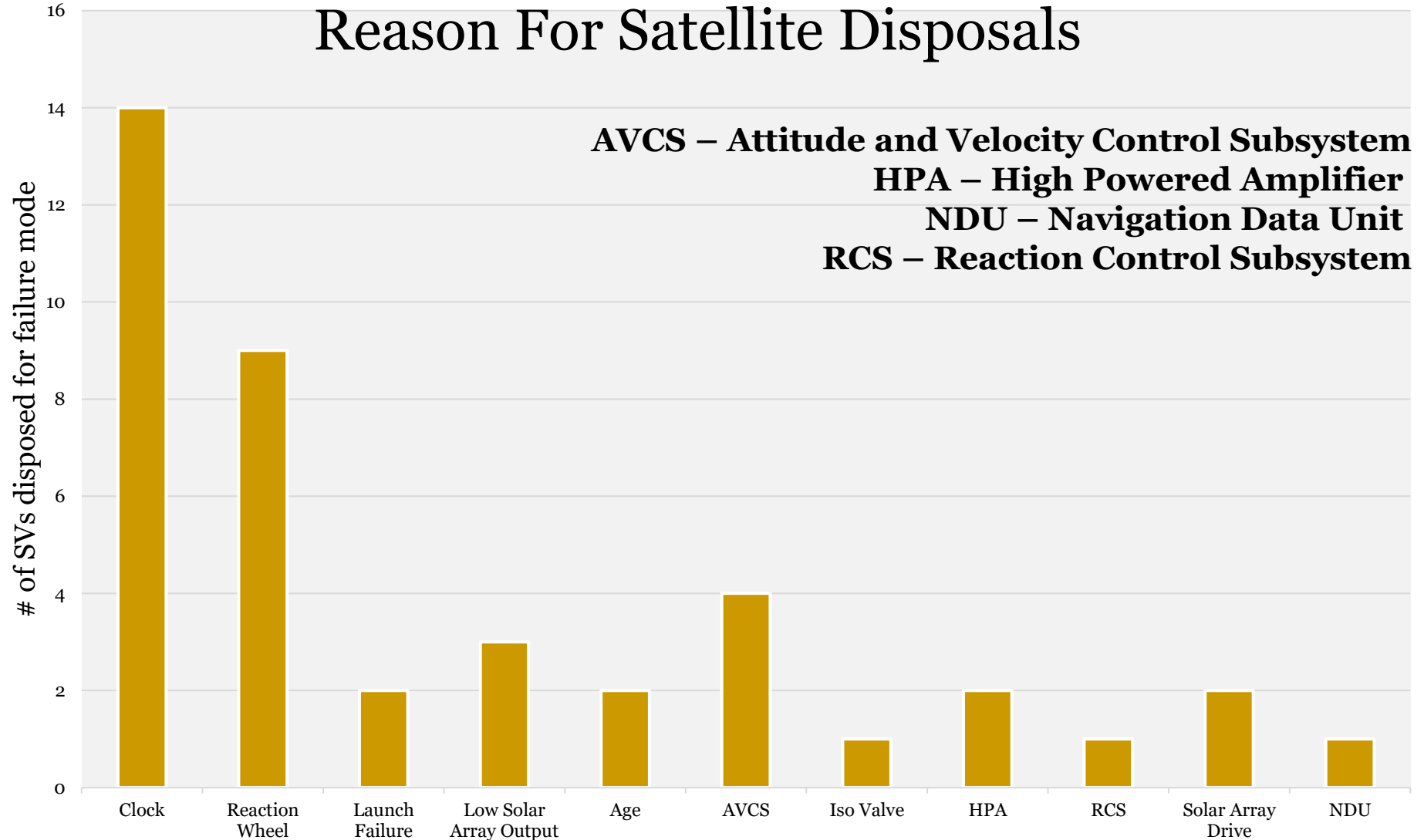
- 6 Additional satellites in test/residual configuration
- GPS Operates in 6 Planes, at an altitude of 20,200 km
 - 12 hour orbit
 - 100% global coverage



GPS Constellation Disposal History



Reason For Satellite Disposals

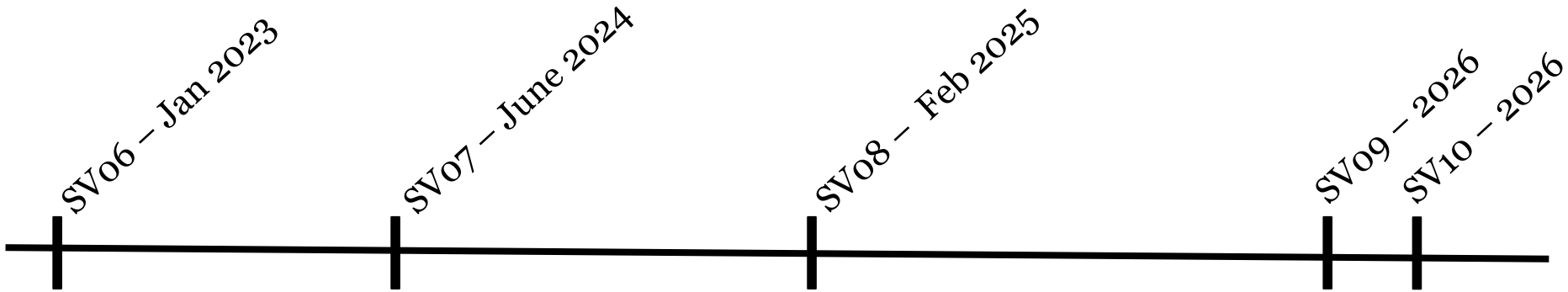




GPS III Launch Schedule

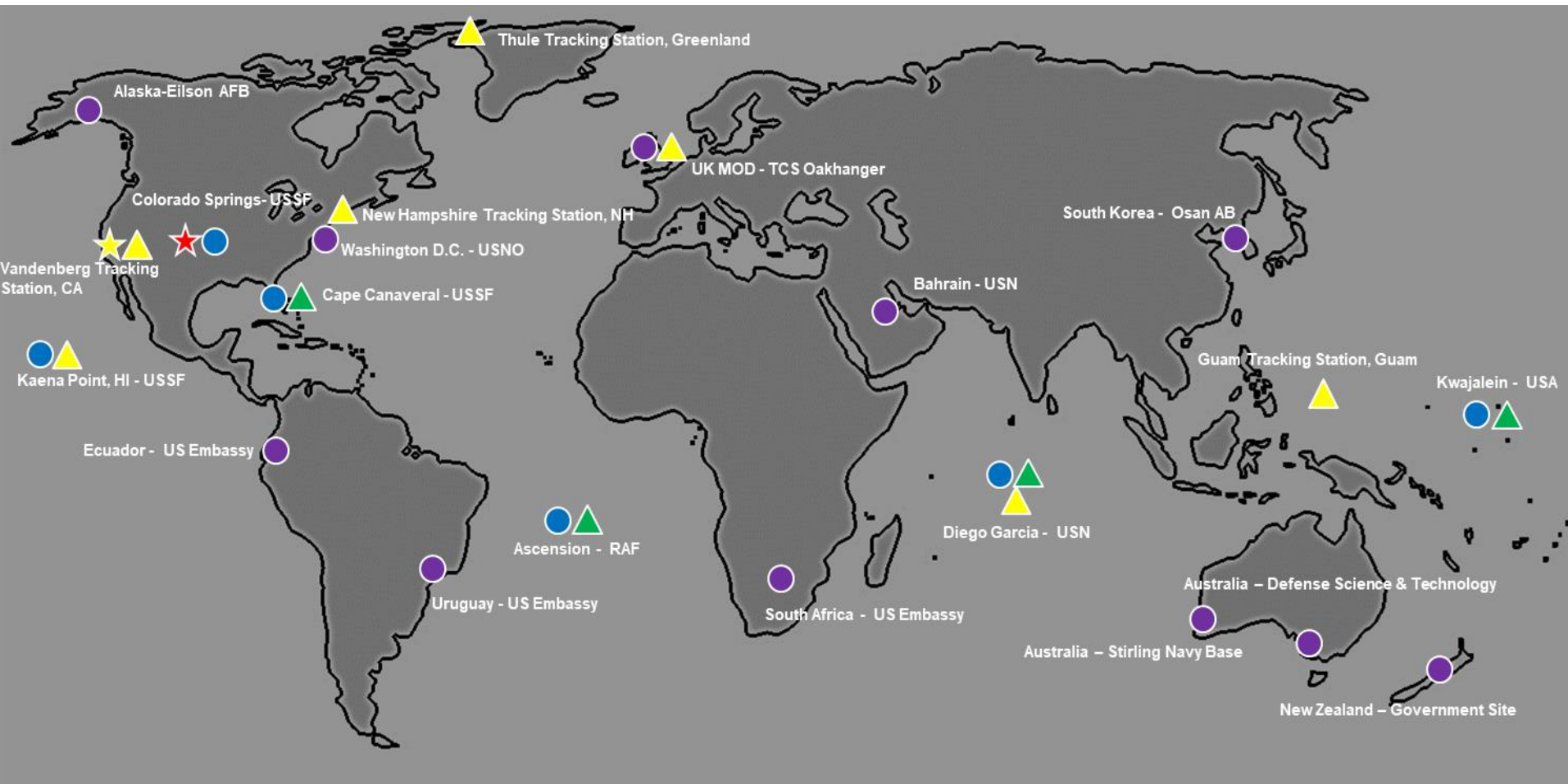


- **The U.S. will launch (4) GPS-III satellites over next 2 years**
- **GPS III-F satellites will begin launch in 2026**





GPS Global Architecture



- ★ Master Control Station (MCS)
- ★ Alternate Master Control Station (AMCS)
- ▲ Ground Antenna
- ▲ Satellite Control Network (SCN) Remote Tracking Station
- Nat. Geospatial Intelligence Agency Monitor Stations
- Space Force Monitor Station

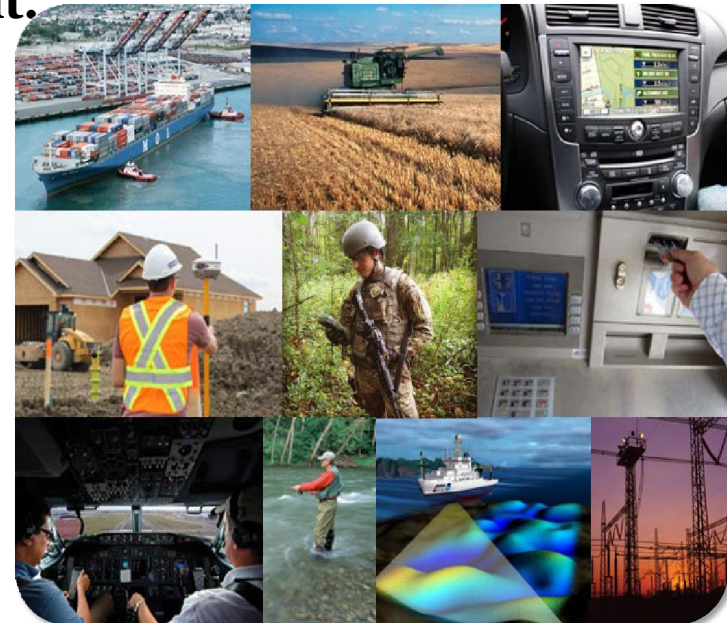


U.S. Military Role with GPS



- **The US Government recognizes how vital the uninterrupted access of Positioning, Navigation, and Timing data is to our modern way of life.**
- **GPS is essential to 14 out of 16 sectors for the United States' critical infrastructure.**
- **The Department of Defense's control of GPS represents the United States' full backing and commitment to the free provision of GPS to the world and the responsibility to protect it.**

- **Ownership ensures rapid reaction capability for threats and timely notification for users**
- **Supports tertiary mission of nuclear detonation detection**
- **The Space Force builds and launches all GPS satellites**





Examples of U.S. GPS Dependencies



Critical Infrastructure Sector	Areas Dependent on PNT (Not all inclusive)				
Chemical	Earth Drilling	Pipelines	Industrial Control Systems (ICS)	All Modes of Transpiration	-----
Communications	Wired/Wireless	Internet of Things	Health Care Monitoring	-----	-----
Critical Manufacturing and Defense Industrial base	Supervisory Control Data Acquisition (SCADA)	ICS	Monitoring	Workforce/Asset Tracking	-----
Dams	Power Generation	SCADA	Waterway Surveillance	-----	-----
Energy	Timestamping	Measurement and Monitoring	Control System	Automation	Protection
Financial Services	System Forensics	Food Control	Workforce/Asset tracking	Environmental Protection	Automation
Information Technology	Smart Devices	Cloud Operations	Incident Investigation	Boot/Runtime Security	-----
Transportation	Aviation	Maritime	Pipelines	Rail	Roadway
Water and Wastewater systems	Power Generation	SCADA	Waterway Surveillance	-----	-----



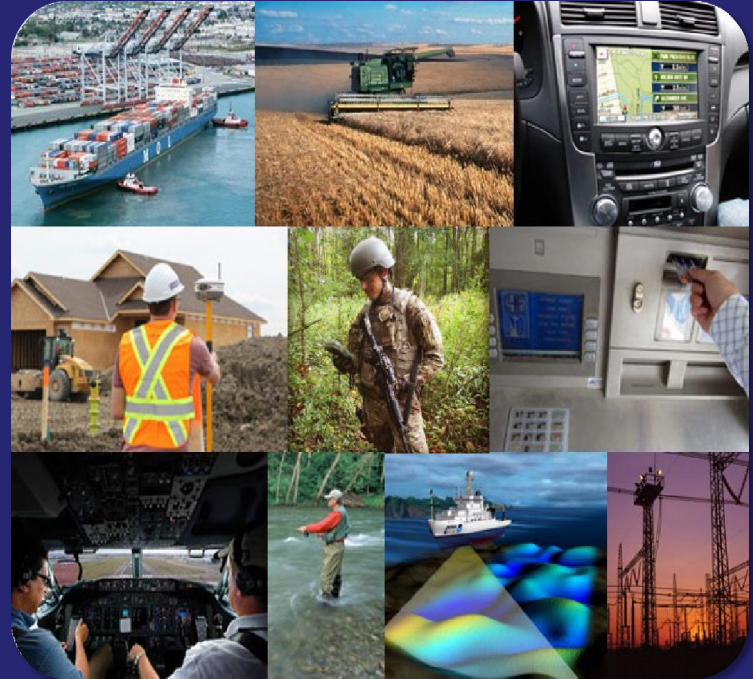
GPS as a Global Utility



GPS is utilized across multiple infrastructures and impacts almost every industry. Some of these industries include:

- Agriculture
- Maritime
- Public Safety
- Recreation
- Space
- Aviation
- Finance
- Telecommunications
- Telematics
- Oil/Gas

US GPS economic benefit ~\$365 billion per year



30 Years of GPS Reliability = Dependability for Environmental Solutions and new Technologies



Telematics



Total Cost of Fleet Operation



Fleet Telematics seen as a 'Productivity Tool' is best placed to support Transport companies to optimise and maximize their fleet better.

Benefits After Effective Deployment of Fleet Management System



10-15%
Increase in
Productivity



10-15%
Overtime
Reduction



20-25%
Reduction in
Fuel Expenses



5-10%
Reduction in
Total Miles



20-30 minutes
Day/Driver
Labour Savings



15-20%
Increase in
Vehicle Utilization



20-30%
Reduction in
Vehicle Idle Time



Public Safety Applications



- Over 30 million emergency calls are responded to per year in the U.S. alone for EMT services, and the response times are dependent on GPS accuracy
- GPS Jamming in Northern Norway (2019-2020) led to severe delays for medical and fire personnel responding to emergencies



Finance Applications



- All financial services use GPS to timestamp financial transactions, match trading orders, and synchronize financial computer systems.
- The U.S. processes \$1.5 quadrillion dollars through SWIFT banking system with GPS timestamped transfers





Petroleum: Oil & Gas Applications



- GPS for oil fleet managers allows them to rapidly verify the location of assets in the field as well as vehicles and/or drivers on the highway.
- Oil companies use telematics by providing enhanced safety for truck drivers and ships
- A 5 trillion-dollar industry, oil/gas would not be as effective today without the use of GPS telematics to steer the fleets.



Agricultural Applications



- GPS enables a controller to keep a machine on course from pass to pass, 95% of the time perfectly parallel in a field.
- Yields increase up to 20%, but waste less fuel, reducing CO₂ emissions
- Precision agriculture has a projected growth rate of 12.8% globally.
- Environmental Benefits:
 - Up to 25% less water
 - Up to 20% less pesticides, herbicides



Maritime Applications



- Marine operations such as search and rescue, underwater surveying, buoy placement, and hazard navigation have been vastly improved with GPS.
- Container management in port facilities have seen a 4-8% decrease in costs, and a 5-10% increase in efficiency.



- Most of the world's cargo transits via commercial shipping
 - Greater efficiency = reduced CO₂ output
 - Houston, Texas (2022) increased its volume 34%, but did not create a backlog of idling ships or trucks



Aviation Applications



- Helps improve flight efficiency by allowing aircraft to fly user preferred direct routes waypoint to waypoint without depending on ground infrastructure.
- GPS driven networks installed on aircraft saved an estimated 5.3 billion liters of fuel and 12.7 billion kilograms of carbon emissions during 2020 alone.
- Commercial crashes have been significantly reduced in the last 20 years with accidents being cut upwards of 75%.





Wide Area Augmentation System Current Status



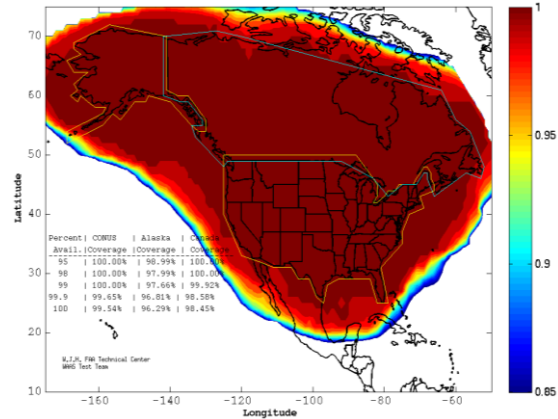
- Provides high availability aviation service in North America
- Developing Dual Frequency WAAS
 - Enable high WAAS vertical service in ionospheric disturbances
- Procedures
 - 4,127 Localizer Performance with Vertical Guidance (LPV) approaches in the National Airspace
 - 1,116 provide CAT I (67m) equivalent performance

• Equipage

- General Aviation:
 - Over 131,000 equipped aircraft in the NAS
 - All classes of aircraft / all phases of flight
- Commercial Aviation:
 - Avionics currently available for Boeing 737-600/700/800 and Airbus A220 & A350



Typical WAAS LPV Coverage





GPS Future: New Civil Signals



- **New: L1C Signal**
 - Enable interoperability
 - Common civil signal for GPS and Galileo
 - Japan's Quasi-Zenith Satellite System (QZSS) and China's BeiDou system are adopting L1C-like signals
 - Improve GPS reception in cities and other challenging environments
- **New: L2C Signal**
 - When combined with L1 C/A in a dual-frequency receiver, L2C enables ionospheric correction, which can increase accuracy
 - Dual-frequency GPS receivers may achieve the same accuracy as the military user
- **Improved: L5 – Safety of Life Signal**
 - Safety-of-life transportation and other high-performance applications
 - Improved signal structure for enhanced performance
 - Higher transmitted power than L1/L2 signal (~3 dB, or 2× as powerful)
 - Wider bandwidth provides a 10× processing gain for the receiver
 - Signal in protected International Telecommunications Union and Aeronautical Radionavigation Services (RNSS) band



GPS Future: The IIRF Program



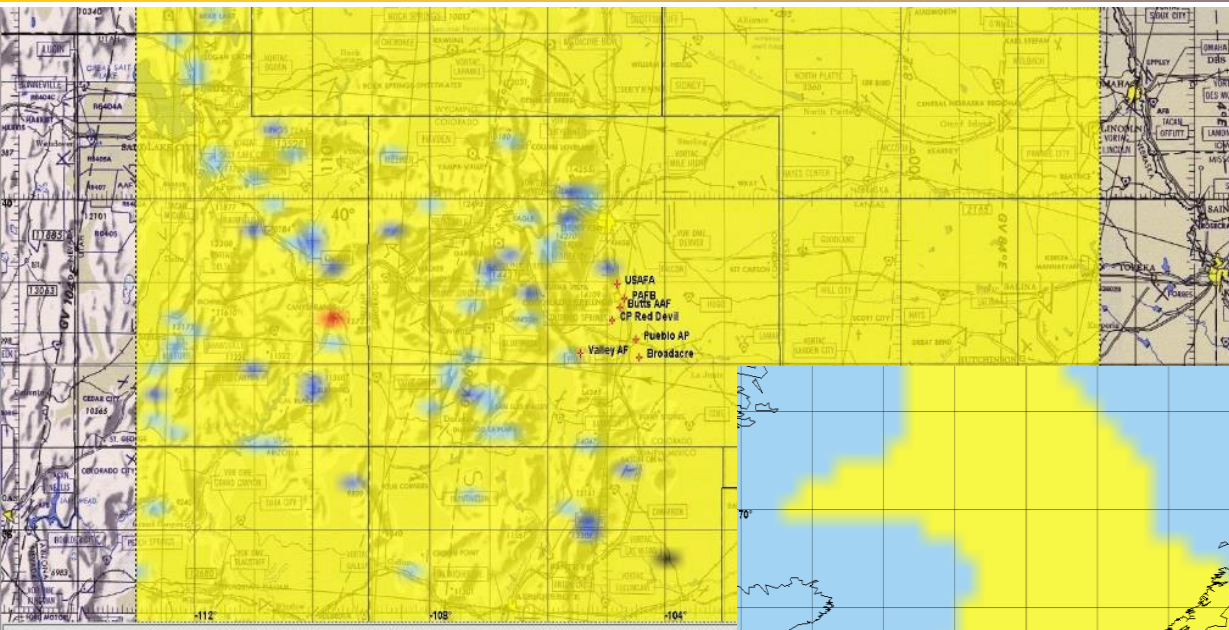
- **Continues GPS III modernization efforts, provides backwards compatibility and includes:**
 - **Regional Military Protection (RMP) for boosted M-code signal**
 - **M-code power increased by 8x in localized area to give resiliency in disadvantaged areas**
 - **Re-designed Nuclear Detection suite**
 - **Canadian-built search and rescue (SAR) payload**
 - **Up to 85% faster detect and locate of distress signals**



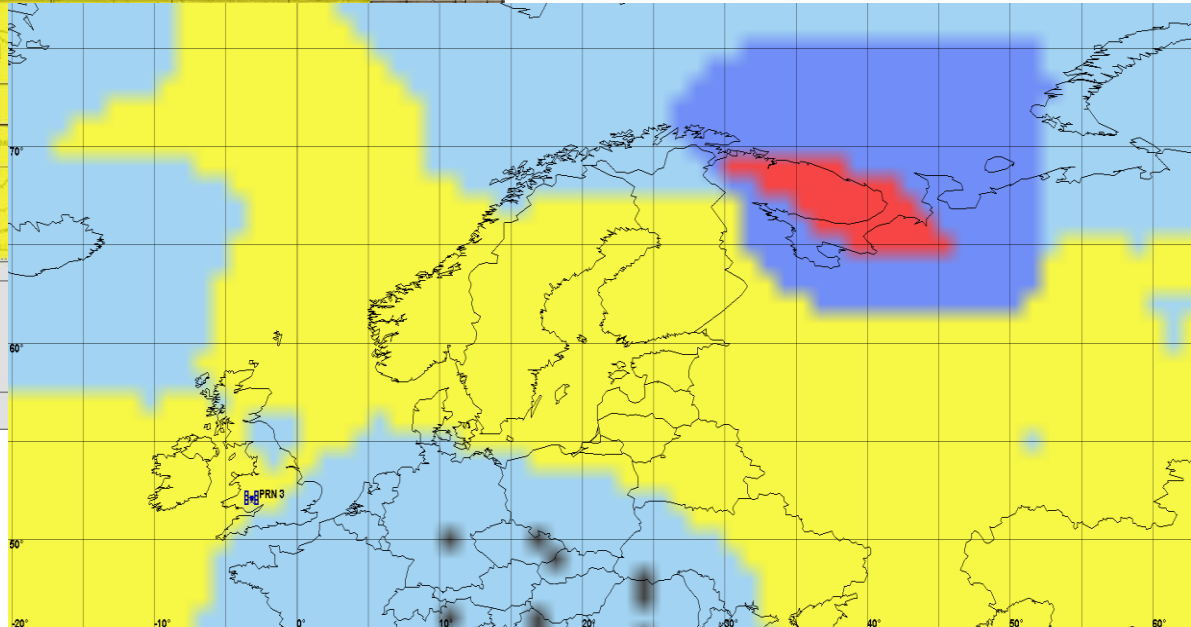
- **Key Upgrade: Laser Retro reflector Array (LRA)**
 - **SV 11 and SV 12 will have 907 kg greater mass than GPS III**
 - **SV 13 – 20 will have a new evolved “combat bus” – size not set**
 - **Critical to allow for future upgrades**



Sample Analysis Support Products

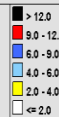


Contour Legend
Metric: PDOP Max
Start Time: 23 Jul 2022 00:00:00Z Altitude: 5 ft AGL
End Time: 23 Jul 2022 23:00:00Z Number of Channels: 4
Almanac Filename: current.a4 Latitude Increment: 00° 09' 10.8" Mask Angle: 5°
SOF File: 2022_195_222300_v02 Longitude Increment: 000° 20' 06" Terrain Blockage Type: FTM
PSF File: 2022_201_000000_v02
Production Date: 07/22/2022 18:21:24
No Outages



Contour Legend
Metric: PDOP Max
Start Time: 16 Nov 2022 00:00:00Z Altitude: 0 ft HAE
End Time: 16 Nov 2022 23:59:00Z Number of Channels: 4
Almanac Filename: current.a4 Latitude Increment: 01° 00' 00" Mask Angle: 5°
SOF File: 2022_320_202900_v02 Longitude Increment: 001° 14' 13.2" Terrain Blockage Type: FTM
PAF File: 2022_320_v03
Production Date: 11/23/2022 16:18:40

PRN:15 Outage: 16 Nov 2022 11:18:00 to 16 Nov 2022 20:19:59 PRN:18 Outage: 16 Nov 2022 00:00:00 to Until Further Notice
PRN:26 Outage: 16 Nov 2022 00:00:00 to Until Further Notice





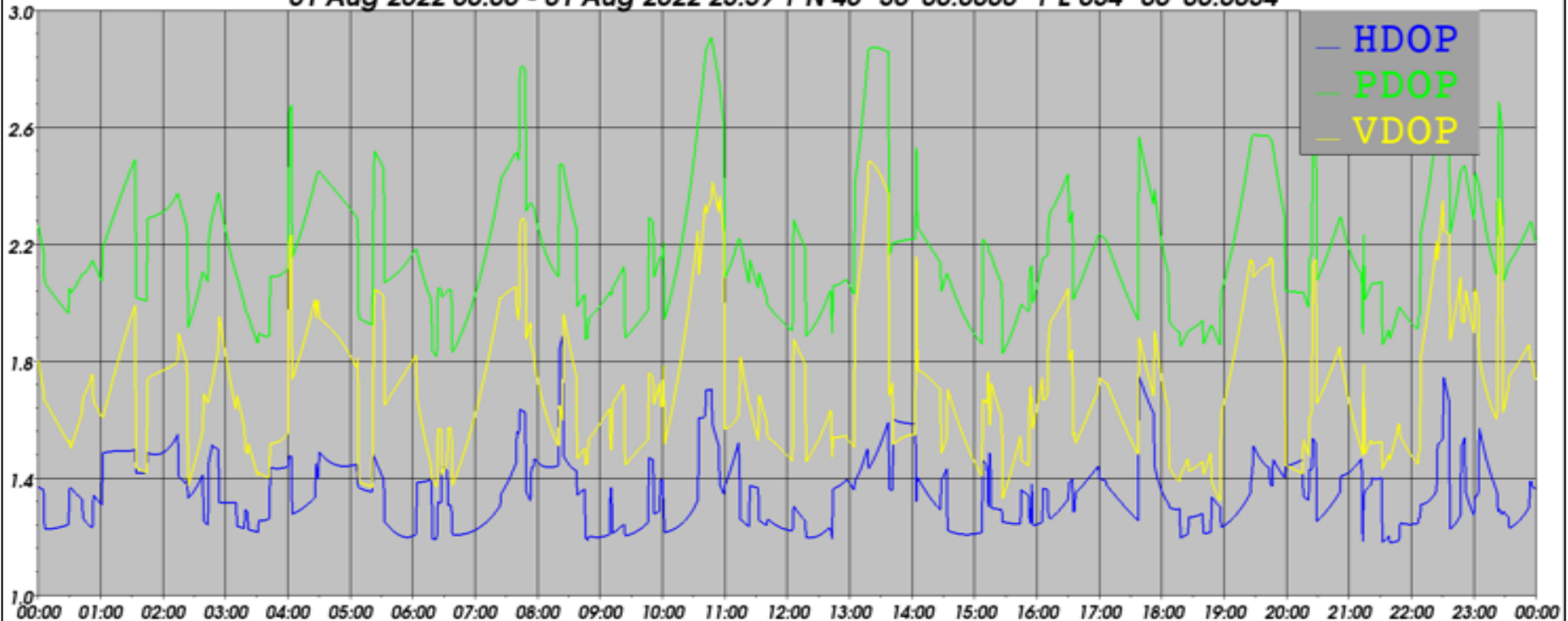
Sample Analysis Support Products



UNCLASSIFIED

Dilution of Precision (DOP) Spike Chart

GPS Accuracy Prediction
01 Aug 2022 00:00 - 01 Aug 2022 23:59 | N 48° 30' 00.0000" | E 034° 00' 00.0034"



Product Generated on Thu Jul 28 23:16:40 2022	Outages:		
Terrain: Off	Altitude: 5 (ft) AGL	Number of Channels: 4	Receiver Mask Angle: 5 (deg)

UNCLASSIFIED



Thank you!

Product Request (Any Governmental Organization) E-mail:

GPSOperationsCenter@us.af.mil

US Coast Guard Navigation Center: [+1-703-313-5900](tel:+17033135900)

1973-2023: Honoring 50 Years of GPS Program

1993-2023: Celebrating 30 Years of GPS Full Operations

2003-2023: Celebrating 20 Years of WAAS Commissioning