

Space and Missile Systems Center

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Global Positioning System Update to PNT Advisory Board

28 June 2017

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Global Positioning Systems Directorate



GPS - Critical National Asset



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- Vital to International Security, Economic Growth, and Public Safety
 - 1+ Billion civil & commercial users worldwide; 57 Authorized Allied Users
- Extends across all domains -- air, land, sea, space, cyberspace
 - Effects transcend national and military boundaries
- Develop & Publish Interface Control Documents
 - Worldwide Involvement in annual GPS Public Interface Control Working Groups





GPS Impacts



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Timing

- Synchronization of cell and data networks
- Time-stamps for transactions (ATMs)
- Grid performance (power utilities)

Aviation

- Fuel-efficient routes
- Safe landing approaches

Agriculture

- Increased crop yield
- Reduced fertilizer and fuel

Marine

- Reductions in port costs
- Search and rescue capabilities
- Efficient open-sea navigation

Positive GPS impacts are everywhere!

3.3 Million U.S. Jobs and \$67.6B economic benefits are directly attributable to GPS*

Public Safety/Disaster Relief

- Integral to emergency response
- Improved earthquake and other natural disaster detection

Recreation

- A staple in outdoor recreational equipment for running, hiking, fishing, biking, and many more!

Space

- Reduces satellite costs by providing timing/position

*Economic Benefits of Commercial GPS (June 2011, Pham)

(NASA satellite Jason-2 pictured)

Building the Future of Military Space

UNCLASSIFIED



GPS Threats & Mitigation



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- Our adversaries understand how US space capabilities enable the speed, precision, effectiveness, and freedom of actions the US joint force relies on for global projection and application of military power
 - Their arsenals are developing quickly and in a diversified way
 - Given our adversaries rapid weapon development, and prepositioning of terrestrial and on-orbit forces, the USAF must prepare to fight and operate through a war that extends into space
- **Cyber**
 - Updates on going to existing GPS Operational Control System (OCS) to improve cyber security posture and monitoring
 - Next Generation Operational Control System (OCX) includes robust information assurance, cyber security and signal monitoring requirements
- **Jamming & Spoofing**
 - Military GPS User Equipment (MGUE) Increment 1 capabilities focus heavily on improvements to jamming resistance and anti-spoof
 - Additional MGUE modifications to increase resiliency
- **Kinetic**
 - Satellite constellation size/reliability provides resiliency
 - System capable of operations without ground segment for several days



GPS Resiliency Considerations



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- GPS Architecture Contains Some Inherently Resilient Characteristics
 - DoD's largest satellite constellation
 - Proven high reliability
 - Can operate without the ground segment for several days
 - Robust and diverse user equipment inventory
 - Decades of experience countering jamming and spoofing
 - Encrypted military signals; GPS IIR-M & IIF satellites "Flex Power" boost
 - Cybersecurity improvements on existing control segment
- Multiple Resiliency Enhancements Currently Being Fielded
 - New civil signals (L2C, L5, L1C & new message types)
 - New MGUE signal processing techniques & modern cryptography
 - GPS III Space Vehicle (SV) boosted M-Code
 - Cybersecurity further strengthened in OCX
- Potential Future Capabilities
 - High power regional signal, reprogrammable digital payload, advanced signals initiatives and Multi-GNSS



GPS Modernization

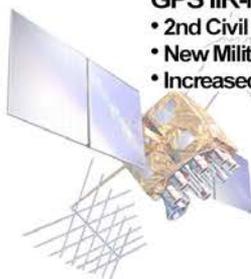


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Space System (Satellites)

Legacy (GPS IIA/IIR)

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

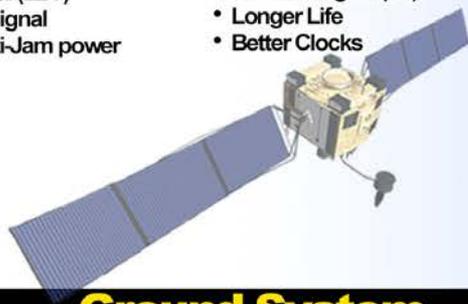


GPS IIR-M

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

GPS IIF

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



GPS III (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 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 on AEP

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

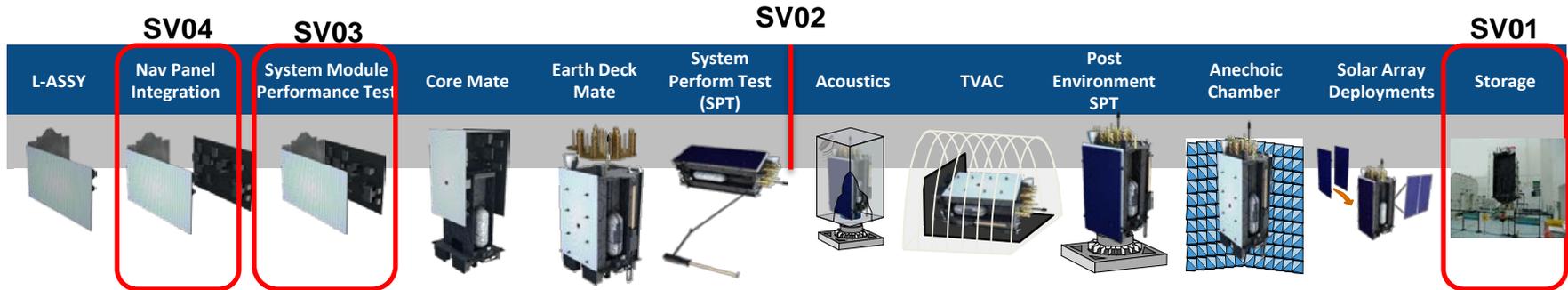




State of GPS III Vehicles



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- SV01 placed into short term storage on 28 Feb 17
 - LAE R&R and Regression Testing in mid to late Jul
- SV02 is currently preparing for Acoustics
 - Acoustics Test & Alignments start in Jul 2017
 - LAE R&R and Regression Testing in late Jul to mid Aug
 - Thermal Vacuum in late Aug; ECD Mid Dec 2017
- SV03 conducting Initial Power Turn on Testing
 - SPT starting Jun 2017; ECD Jul 2017
 - Core Mate scheduled for late Jul 2017
- SV04 is currently in System Module buildup stage



R&R – Remove and Replace
 LAE – Liquid Apogee Engine
 TVAC – Thermal Vacuum
 SPT – System Performance Test
 SV – Space Vehicle

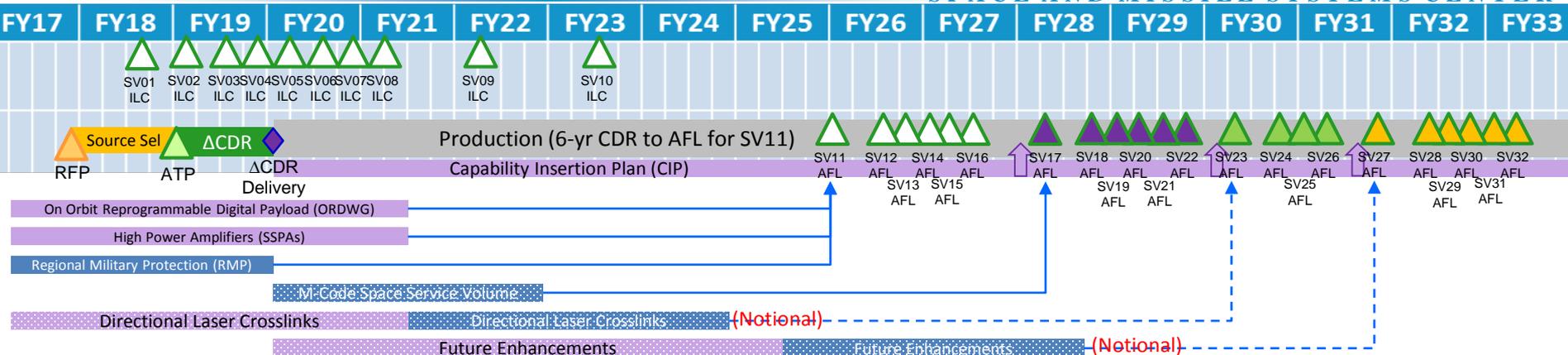
GPS III Has 4 SVs in Various Phases Within The Single Line Flow



GPS III Space Vehicles 01 – 32 Approach



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- GPS III acquisition defined as 32 space vehicles with upgrade approach to meet evolving threat
- SV01+
 - +5dB Boosted M-Code Earth Coverage signals
 - International Compatible civilian signals (L1C, L5)
- SV11+
 - +18 dB Regional Military Protection (RMP) of M-Code signals
 - Energized Charged Particle (ECP) sensor for increased Space Situational Awareness
 - Search and Rescue (SAR) GPS payload to transition Personnel Recovery (PR) mission to DoD assets
 - Redesigned NUDET Detection System (NDS) for obsolescence and reduced size/weight
- SV17+, SV23+, SV27+
 - Potential Enhanced M-Code Space Service Volume (SSV) for freedom of action in space
 - Partnership w/ AFSPC/A5 & AFRL on new technology to increase resiliency and evolve to mitigate threats



GPS Next-Generation Operational Control System (OCX)



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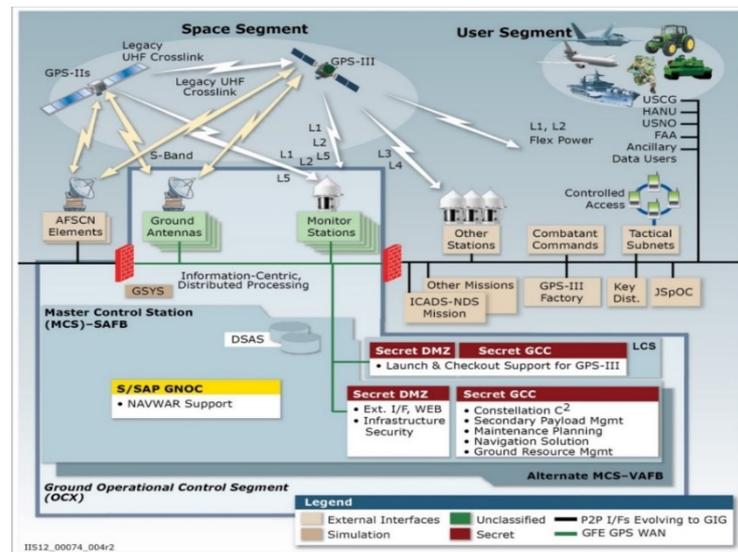
- Next-Generation C2 and cyber-defense for GPS
 - Worldwide, 24 hr/day, all weather, position, velocity and time source for military/civilian users
 - Improved PNT performance
 - Robust information assurance and cyber security
 - Modern civil signals & monitoring
 - Support Military Code (M-Code) navigation warfare

- Incremental Development

- OCX Block 0: launch & checkout for GPS III
- OCX Blocks 1 & 2: operate & manage GPS constellation, adds modern features, operate advanced M-Code features and Civil Signal Performance Monitoring

- Current Status: Working through program challenges

- Program replanned to implement process improvements, including increased automation in software development, platform deployment and an improved software approach
- Quarterly Reviews with OSD AT&L, SECAF, and Raytheon CEO





OCX Core Requirements



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Technical Challenges

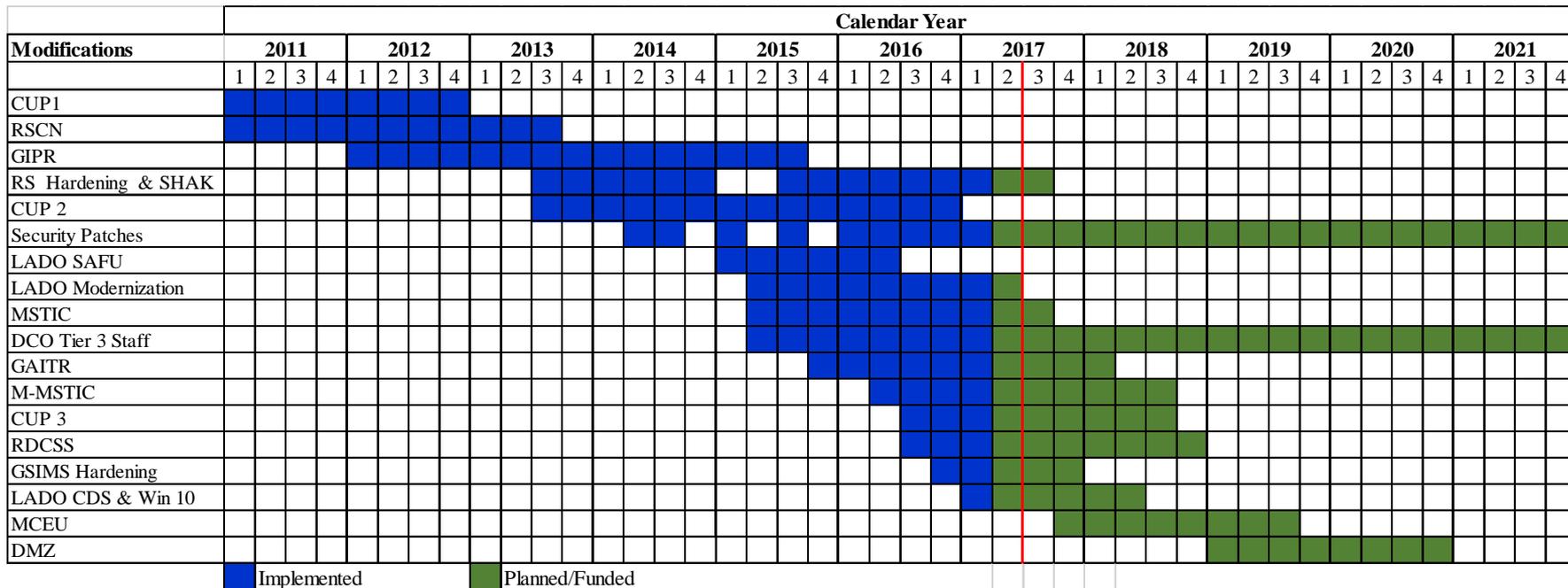
	Area	Attributes	OCS Current	OCX PDR (Jun 2011)
M-Code →	Operational Navigation Signals	L1 / L2: C/A, P(Y)	Yes	Yes
		M-Code	No	Yes
		L1C, L2C, L5	No	Yes
	Services	Modernized Signal Monitoring (OMSRE)	No	Yes
		Military & Civil Navigation Related Messaging	No	Yes
	NAVWAR (Anti-jam)	Flexible power	Yes	Yes
		Integrated Situational Awareness	No	Yes
Integrity Monitoring →	Architecture	Flexible, Scalable, Adaptable, Evolvable	No	Yes
		Integrity Infrastructure	No	Yes
Net-Centric Migration/New Interfaces		No	Yes	
Modern Key Management		No	Yes	
Advanced Software and Architecture Standards		No	Yes	
Advanced Information Assurance		No	Yes	
Operate over 32 satellites		No	Yes	
External Interfaces →	Performance	Navigation Solution Performance Improvement	No	Yes
Info Assurance →				
PNT Performance →	SV Family Support	GPS IIR, IIR/M	Yes	Yes
		GPS IIF	Yes	Yes
		GPS III	No	Yes



GPS Enterprise Sustainment Roadmap



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2011-2021: ~\$130M executed/planned on OCS Cyber Upgrades

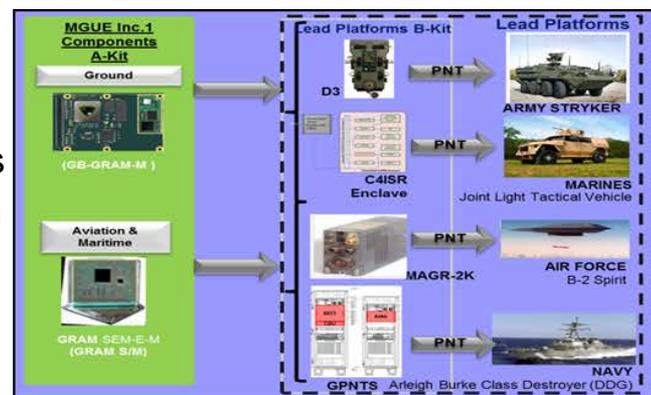


Military GPS User Equipment (MGUE)



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- MGUE Inc 1 is a joint service program developing M-Code capable military GPS receivers
 - Provides reliable, accurate positioning, navigation, and timing
 - Market driven approach; 3 vendors developing M-Code receivers
 - Oct 2016: L-3 first DoD contractor to receive security certification
 - Jan 2017: MGUE Increment 1 received Milestone B approval
- Conducting integration into Service Lead Platforms
 - Nov 2015: Delivered 1st prototype to B-2 Bomber program
 - Jun 2016: MGUE Final Test Articles (FTAs) provided to Navy DDG Aegis-class Destroyer program
 - Mar 2017: MGUE Inc 1 demonstrated on guided flight test of Army PGM
 - Jun 2017: Conducted first flight with the prototype MAGR2K-M on B-2
- Draft MGUE Increment 2 Capability Development Document in coord: Space Receiver, Handheld, Precision Guided Munitions



MAGR2K-M



JLTV



D3



PGM



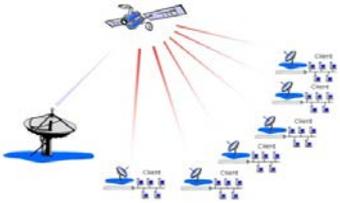
M-Code Capability Advances



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Key Management

Reduced burdens,
Improved user autonomy



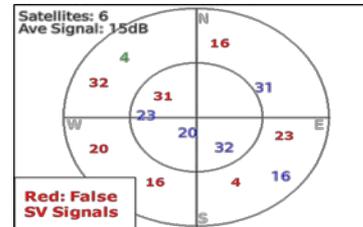
Jamming Resistance

Initial fix enhanced,
Anti-Jam extended



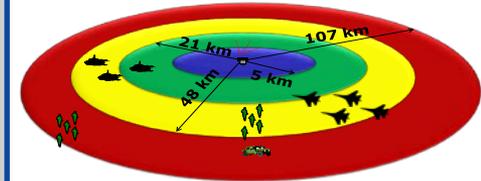
Anti-Spoof

Detect and reject
false signals



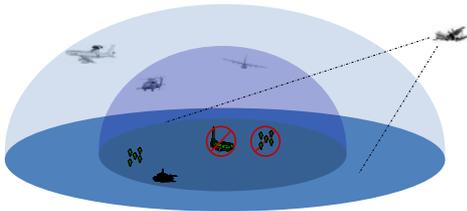
M-Code Power

Operate closer to jammer,
under trees



Blue Force Electronic Attack

Operate near
friendly jamming



M-Code Cryptography

More secure,
more flexible



External Augmentations

Extend GPS accuracy/availability
in challenged environments





Summary



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- Modernized GPS brings significant added capability to Joint Fight:
 - GPS III: Increased anti-jam capabilities through increased signal power
 - MGUE: Upping anti-jam/spoof capabilities with advanced algorithms & M-Code
 - OCX: Improved network cyber security & expanded capabilities





Backups



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GPS OV-1



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