# M-CODE GPS for Precision Guided Munitions

**Presented at the 2015 Precision Strike Annual Review**


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# Topics

- **What is M-Code?**
  - **USAF GPS Directorate** led GPS Modernization Program which includes Military GPS User Equipment (MGUE) such as M-Code GPS Receivers
- **What are we doing in the Precision Guided Munitions (PGM) community?**
  - **USA PEO Ammo** led MGUE Component-level Assessment for PGMs (MCAP) [i.e. TRL5 for PGMs?] and Acceleration of MGUE Increment 2 for PGMs (AM2P) [i.e. TRL6 for PGMs?]
- **What are the next Position, Navigation, and Timing (PNT) challenges for PGMs and what are we doing to address it?**

# What is M-code?

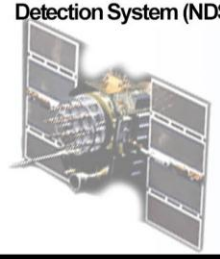
- M-code is a major component of the USAF-led Major Acquisition Category **GPS Modernization Program**
- M-code is a **new military signal** designed to further improve jamming resistance and secure access of the military GPS signals
  - M-code is transmitted in the same general L1 and L2 frequencies used by the previous military code, the P(Y)-code
  - Migrates to a system with spectrally separated military services while adding new civil services
- GPS Modernization Program is comprised of **three segments**: space (satellites), ground control, and user equipment (receivers)
  - Military GPS User Equipment (MGUE)
  - USA PD PNT has on-site presence at the USAF GPS Directorate

# GPS Modernization

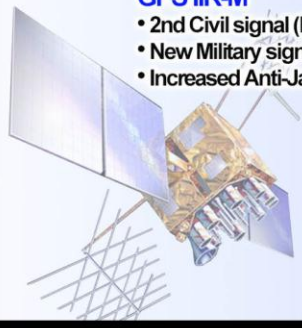


## Space System (Satellites)

**Legacy (GPS IIA/IIR)**
- Basic GPS
- NUDET (Nuclear Detonation) Detection System (NDS)

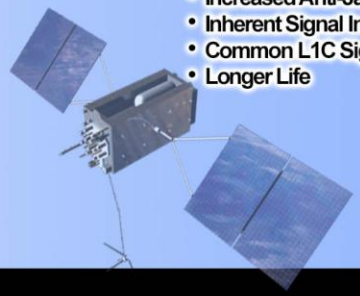


**GPS IIR-M**
- 2nd Civil signal (L2C)
- New Military signal
- Increased Anti-Jam power



**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

## 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

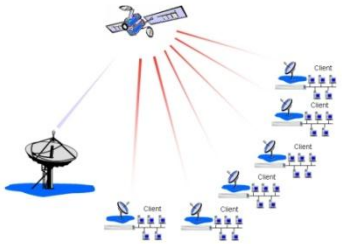
**Modernized**
- M-Code Receivers
- Common GPS Modules
- Increased Access/ Power with M-Code
- Increased Accuracy
- Increased Availability
- Increased Anti-Tamper/ Anti- Spoof
- Increased Acquisition in Jamming

# Modernized Military GPS Capability Features

SPACE AND MISSILE SYSTEMS CENTER

## Key Management

Reduced burdens, Improved user autonomy

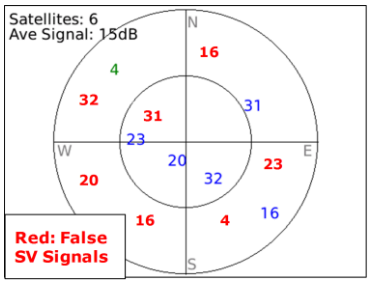


## Jamming Resistance

Initial fix enhanced, Anti-Jam extended

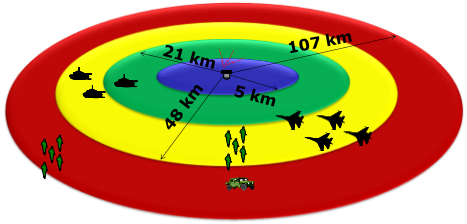

## Anti-Spoof

Detect and reject false signals



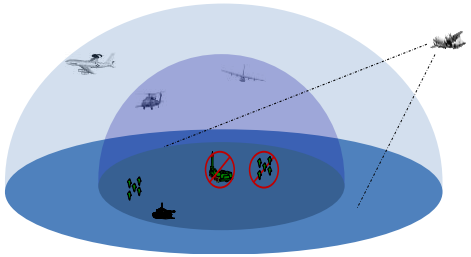

## M-Code Power

Operate closer to jammer, under trees




## Blue Force Electronic Attack

Operate near friendly jamming



## M-Code Cryptography

More secure, more flexible

## External Augmentations

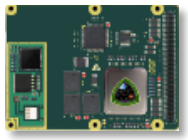
Extend GPS accuracy/ availability in challenged environments

# Military GPS User Equipment (MGUE)



- Building next-generation of military GPS receivers that incorporate M-Code (required in statute by FY17)
- Direction from USD(AT&L) to accelerate MGUE Increment 1
- Requirements approved by JROC Jul 2014
- Successfully completed Preliminary Design Reviews for MGUE Increment 1 contractors Aug-Sep 2014
- Security Certification Underway
- Updated Lead Platforms
  - Army: Raven to DAGR Distributed Device (D3)
  - Air Force: F-15E to B-2 Spirit (B-2)

MAGRa-2K



Ground-Based Card

Aviation/Maritime Card

# What Are We Doing in the PGM Community?

- PGM Programs of Record (PoRs) must determine if they can use MGUE Increment 1 technology versus waiting until Increment 2
- USAF GPS Directorate is sponsoring an ongoing 17-month RDTE effort led by USA PEO Ammo to conduct a MGUE Component-Level Assessment for PGMs (MCAP) [i.e. TRL5 for PGMs?]
- USA PD PNT is similarly sponsoring a complimentary parallel ongoing RDTE effort called Accelerate MGUE Incr 2 for PGMs (AM2P) which leverages MCAP investments [i.e. TRL6 for PGMs?]
- Joint PGM Materiel Development Stakeholders are engaged via an Overarching IPT to reduce subsequent PGM PoR M-Code GPS implementation risk and assist in POM/compliance activities

***PL 111-383 mandates the use of M-Code GPS for FY18+***

# What do PGMs and MGUE Have in Common?

- Common GPS Capability Needs
  - M-Code Access (Security, Power, Anti-Jam, Anti-Spoof, etc)
  - Enhanced Accuracy and Availability
- Common GPS Solutions
  - Production ready suppliers to Primes
  - Increased Competition
- Taxpayer Investment Efficiencies
  - Common technology maturation versus cumulative discrete potentially duplicative PoR non-recurring RDTE investments
  - Economies of Scale across Joint/Foreign Military Sales (FMS) stakeholders

***These common imperatives are reinforced by the approved MGUE Acquisition Decision Memorandum dated 20Feb14***

# Why are PGM Requirements More Difficult?

**PGMs are a Joint Service Problem Set**
**(ex. USA/PGK, USA/GMLRS-AW, USMC/PERM, USN/LRLAP, USAF/SDB-II)**

- PGMs represent a major M-Code GPS market segment
- Three main use-cases (Gun-Launched, Rockets/ Missiles, Air-Dropped)
- Gun-Launched Environment much more severe than the environments for handhelds, avionics, and shipboard receivers

| | Precision Guided Munition (PGM) |
|---|---|
| *Initial Conditions* | Load GPS Ephemeris data prior to launch and reacquire after muzzle exit at high velocity (up to 800 m/s) |
| *Shock Environment* | Extreme (up to 20,000 Gs) |
| *Spin Environment* | High Spin (up to 300 Hz) |
| *Size, Weight, Power (SWP)* | Desired 40mm Diameter |
| *Set-Time Requirement* | Less than 10 seconds |
| *Time To First Fix / Time To Usable Nav* | 7 sec (O = 4 sec) |
| *POR Quantities* | > 100,000 |
| *Durable vs. Consumable* | Consumable |
| *Shelf Life* | 20 Years |

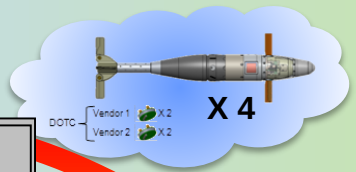
***Gun-Launched PGMs have some of the most demanding requirements***

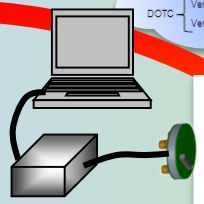
# Acceleration of MGUE Inc 2 for PGMs (AM2P)

***Reduces risk and promotes competition for PGM Programs of Record***

MCAP

**PGM MGUE Integration Risk**



- Performance
- Live Acquisition
- Temperature
- Vibration
- Spin, High-G
- EMI/EMC
- Instrumented Flight Test
- AJ Testing (MGUE Reqts)

**D**efense **O**rdinance **T**echnology **C**onsortium (DOTC)

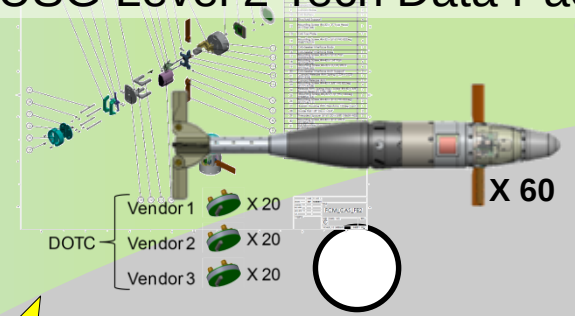
Vendor 1 X 20

Vendor 2 X 20

Vendor 3 X 20

TRL 5

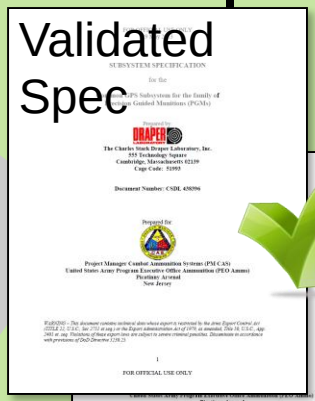
USG Level 2 Tech Data Package



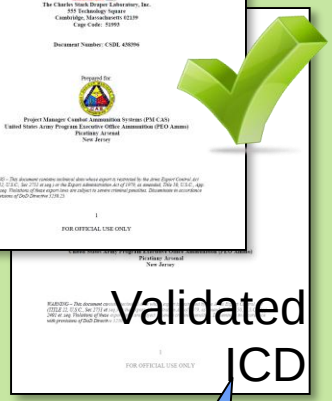

**Conduct M-Code GPS component testing**

**Live Fire GPS-In-The-Loop Testing in a PGM Platform**

Validated Spec

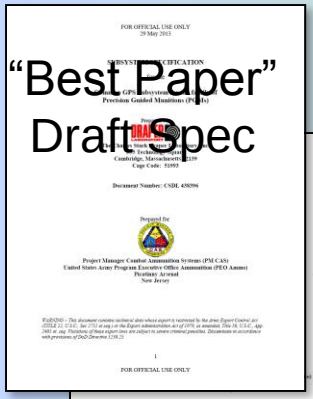


Validated ICD



**Total 34 mo**

"Best Paper" Draft Spec

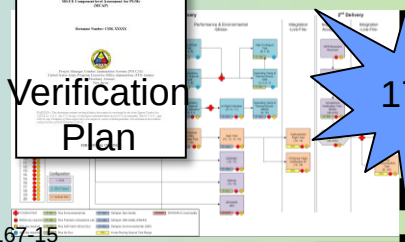


Draft ICD



**M-Code GPS prototype hardware**

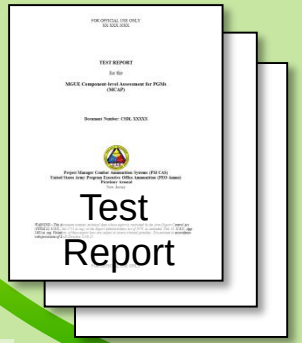
Verification Plan



17 mo

Component Test Report & Updated Spec & ICD

Test Report



TRL 6+

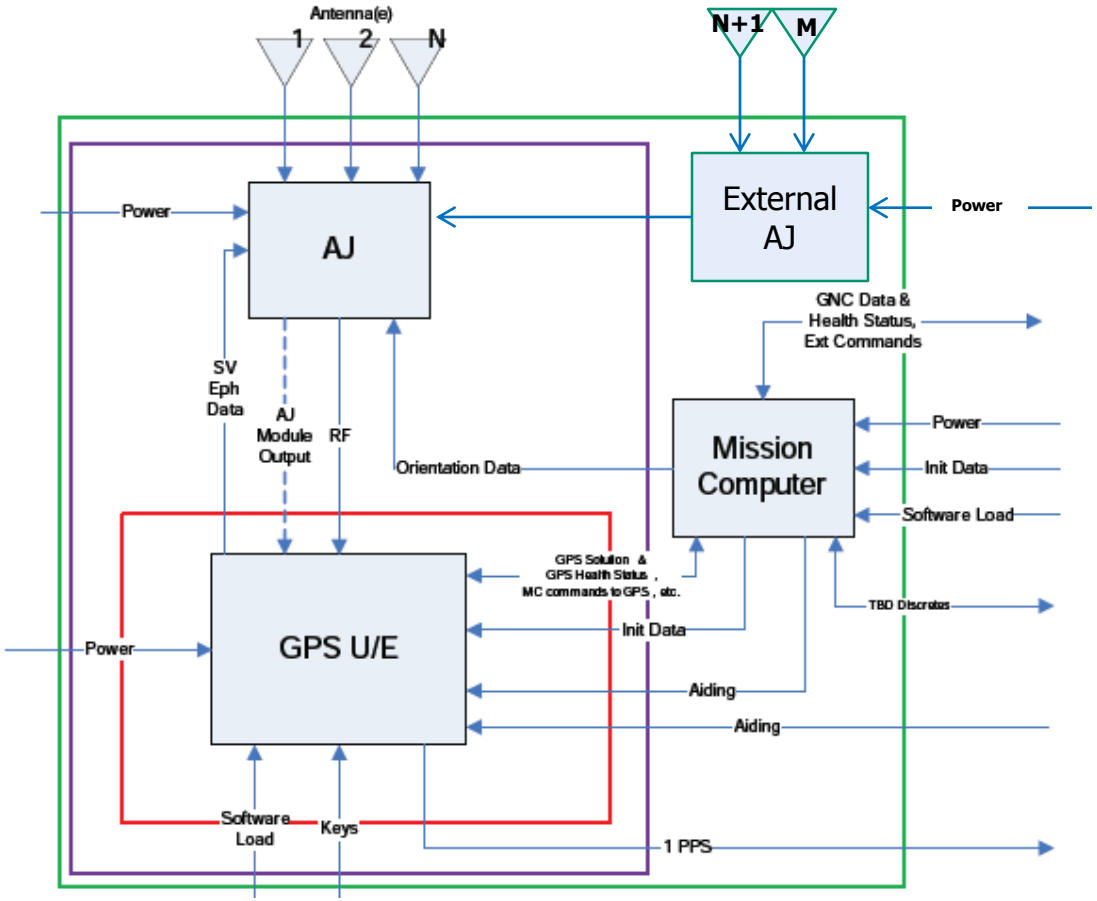
31 mo

Revised "Best Paper" Spec/ICD Validation and MGUE Assessment UFR Effort

May 2014 | Oct 2014 | Sept 2015 | Apr 2017

# Joint Common GPS Specification and Interface Control Document (ICD) for PGMs

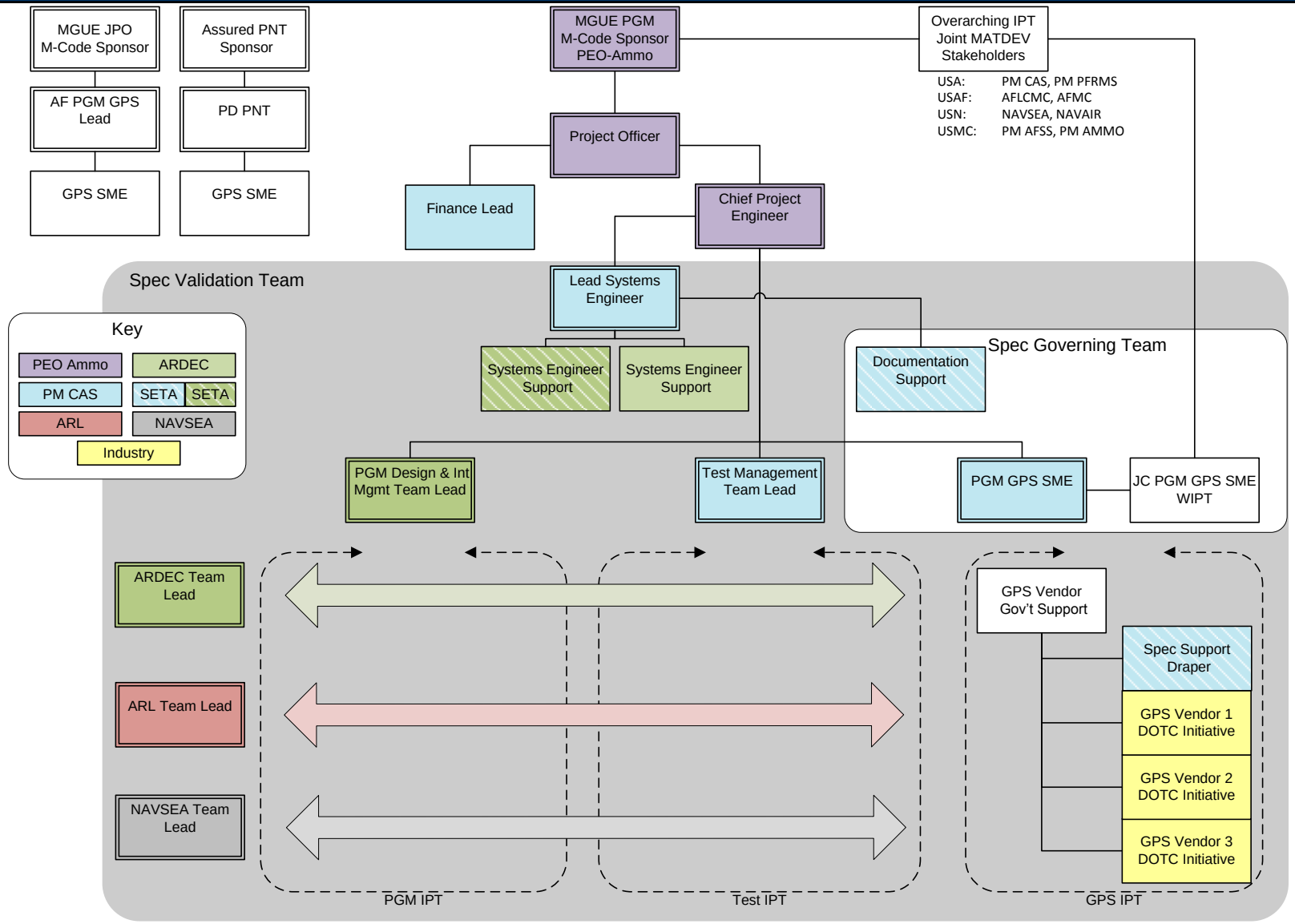
- Generic projectile guidance system architecture functional block diagram
  - GPS U/E only
  - GPS + AJ electronics
  - Guidance & Navigation System + Off Board AJ
- System boundary defines included functionality and interfaces
  - Trade study identified benefits/detriments of each approach



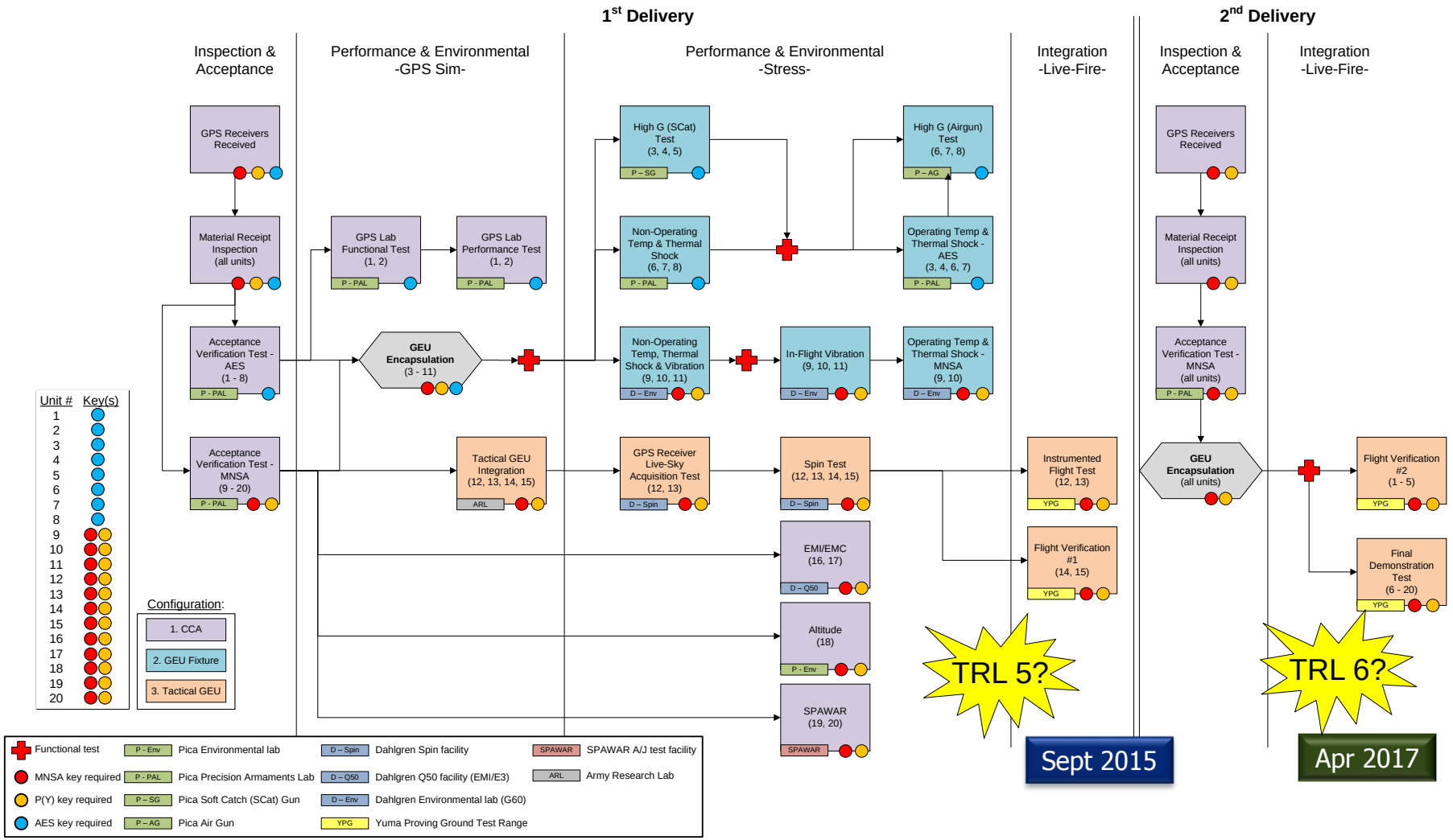

**Joint Common GPS Specification and ICD Scope defined by Purple Box**

***Promotes a Common GPS Supplier Paradigm for Joint PGMs***

# IPT-Based Organizational Structure



# Validating the Joint Common GPS Spec/ICD for PGMs and Determining MGUE Technology Maturity



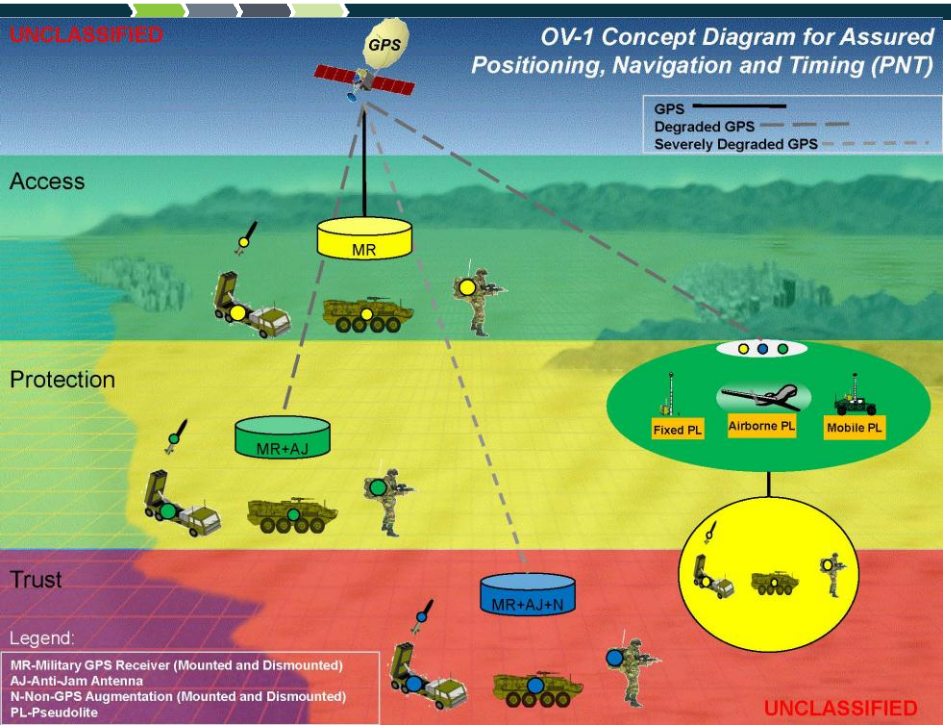

***Non-parochial GPS component performance testing leveraging USG labs***

# What Are the Next PNT Challenges for PGMs and What Are We Doing to Address it?

- **USA PEO Ammo** is closely collaborating with **USA PD PNT**
  - Assured Positioning, Navigation, and Timing (A-PNT)
  - PNT System-of-Systems Architecture
  - Pseudolite-PGM Technology (P2T) Demonstration
  - Optimization of Pseudolite-PGM Interoperability (Proposed)
- **USA PEO Ammo** is coordinating with **OUSD(AT&L)LW&M** on Joint PGM PoR compliance with Public Law 111-383
  - What unplanned non-recurring RDTE funding is required?
  - What on-the-shelf PGMs should be retrofitted?
  - What Joint PGM PoRs in production beyond FY17 require temporary SECDEF waivers and for how long?

# Assured Positioning, Navigation and Timing (A-PNT)

Chart provided by USA PD PNT




## Payoff:

- Assured PNT capability for soldiers & combat systems.
- Ability to obtain and trust PNT information critical to complex combat operations.
- Ability to avoid or prevent unnecessary or accidental injury or destruction.
- Ability to seamlessly use advanced weapon systems and tactics.

## Purpose:

The purpose of the A-PNT capability is to provide Army forces with unhindered access to trusted Positioning, Navigation, and Timing (PNT) under all conditions.

## Products:

Assured PNT contains four (4) subprograms:

**1) Mounted PNT**- robust integrated multi-sensor system for vehicular applications. Maintains an accurate PNT solution and distributes it to all users on the platform.

**2) Dismounted PNT –** low-SWAP multi-sensor PNT system for the soldier.

**3) Pseudolites** – Area protection for large numbers of users. Augments GPS with terrestrial transmission of a GPS-like navigation signal that can be used by military GPS receivers with the necessary software.

**4) Anti-Jam Antennas** - Point protection for critical users. Enables GPS signal acquisition and tracking in challenged environments.

# P2T Demonstration and Optimization

## *Reduces Performance Risk associated with Interoperability of Pseudolites with PGM Programs of Record*

P2T Demonstration

P2T Optimization

**Pseudolite PGM Interoperability Risk**

Defense Ordinance Technology Consortium (DOTC)

Vendor 1 X 20

Vendor 2 X 20

X 20

Pseudolite / PGM Recommendations of Trade Studies to Mitigate Risk

Pseudolite / PGM Lessons Learned

Pseudolite / PGM Interoperability Test Report

**Test Report, Lessons Learned, & Recommendations**

Project Manager Combat Ammunition Systems

Sept 5, 2016

**Optimization Test & Evaluation**

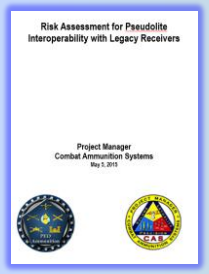
TRL 6+

**Contractor to deliver test set interface software and hardware for receiver**

**Live Fire Testing**

TRL 5

**Lab Testing**

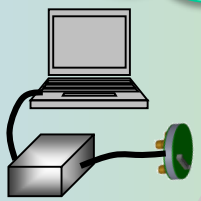


Risk Assessment for Pseudolite Interoperability with Legacy Receivers

Project Manager Combat Ammunition Systems

May 5, 2015

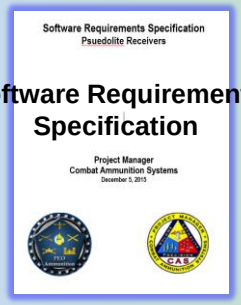
**Initial Pseudolite Compatibility Risk Assessment**



**Pseudolite Receiver Prototype Hardware**

Modeling & Simulation, Lab, and Live Fire Testing to optimize performance and mitigate identified risks

Goal: PGK can meet CEP requirements w jammers in Pseudolite only and GPS + Pseudolite environment



Software Requirements Specification

Psuedolite Receivers

Project Manager Combat Ammunition Systems

December 5, 2015

**Software Requirements Specification**

Year 1

Year 2

# Summary

- M-Code GPS is mandated by Public Law 111-383 for all Joint PGM PoRs in production beyond FY17 and may also be a good idea for many on-the-shelf Joint PGMs
- USA PEO Ammo, as the defacto Assured PNT entry point for Joint PGM Lethality community, is coordinating with OSD, USAF GPS Directorate, USA PD PNT, and Joint PGM PoRs
- USA PEO Ammo is leading multiple ongoing efforts to assess the maturity of MGUE Incr1 technology and integration risk for subsequent use by Joint PGM PoRs
- Future Assured PNT capabilities are being evaluated and optimized for interoperability with Joint PGMs