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

**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

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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)
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 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

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

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

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

- **PGM MGUE Integration Risk**
  - Vendor 1: X 20
  - Vendor 2: X 20
  - Vendor 3: X 20

- **MCAP**
  - DOTC

- **Validation**
  - Vendor 2
  - Vendor 3
  - Vendor 3

- **USG Level 2 Tech Data Package**
  - X 60

- **Validation**
  - Spec

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

- **Conduct M-Code GPS**
  - Component testing
  - TRL 5

- **M-Code GPS**
  - Prototype hardware

- **Draft Spec**
  - "Best Paper"

- **Draft ICD**

- **Component Test**
  - Report & Updated Spec & ICD

- **Verification Plan**

- **Test Report**

- **Total**
  - 34 mo

- **Defense Ordinance Technology Consortium (DOTC)**

- **USG Level 2 Tech Data Package**
  - Vendor 1
  - Vendor 2
  - Vendor 3

- **Validation Spec**

- **TRL 6+**

- **31 mo**

- **May 2014**
- **Oct 2014**
- **Sept 2015**
- **Apr 2017**

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- **Validated**
  - ICD
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

MGUE JPO M-Code Sponsor
AF PGM GPS Lead
PD PNT
GPS SME

Assured PNT Sponsor

Overarching IPT
Joint MATDEV Stakeholders
GPS Vendor 3
DOTC Initiative
GPS Vendor 2
DOTC Initiative
GPS Vendor

DOTC Initiative

Gov't Support

ARDEC Team Lead

ARL Team Lead

NAVSEA Team Lead

Specifications Validation Team

Key

MGUE PGM M-Code Sponsor
PEO-Ammo

Project Officer

Finance Lead

Chief Project Engineer

Lead Systems Engineer

Systems Engineer Support

Systems Engineer Support

PGM Design & Int Mgmt Team Lead

Test Management Team Lead

PGM GPS SME

Spec Governing Team

Documentation Support

GPC PGM GPS SME WIPT

JC PGM GPS SME

GPS Vendor Gov't Support

Spec Support Draper

GPS Vendor 1 DOTC Initiative

GPS Vendor 2 DOTC Initiative

GPS Vendor 3 DOTC Initiative

ARDEC

PEO Ammo

PM CAS

SETA

SETA

NAVSEA

ARDEC

PM CAS SETA

PEO Ammo

PM CAS

SETA

NAVSEA

ARDEC

PM CAS SETA

Design & Int Mgmt Team Lead

Test Management Team Lead

PGM IPT

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

Non-parochial GPS component performance testing leveraging USG labs

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Unclassified
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)

**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.

**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.
P2T Demonstration and Optimization
Reduces Performance Risk associated with Interoperability of Pseudolites with PGM Programs of Record

P2T Demonstration

Pseudolite PGM Interoperability Risk

Defense Ordinance Technology Consortium (DOTC)

Vendor 1

Vendor 2

X 20

X 20

Risk Assessment for Pseudolite Interoperability with Legacy Receivers

Initial Pseudolite Compatibility Risk Assessment

Software Requirements Specification

Pseudolite Receiver

Prototype Hardware

Live Fire Testing

Lab Testing

P2T Optimization

Optimization Test & Evaluation

TRL 6+

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

TRL 5

Contractor to deliver test set interface software and hardware for receiver

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

Software Requirements Specification

Pseudolite / PGM Recommendations of Trade Studies to Mitigate Risk

Pseudolite / PGM Lessons Learned

Test Report, Lessons Learned, & Recommendations

PGM can meet CEP requirements w jammers in Pseudolite only and GPS + Pseudolite environment

PGM can meet CEP requirements w jammers in Pseudolite only and GPS + Pseudolite environment

PGM can meet CEP requirements w jammers in Pseudolite only and GPS + Pseudolite environment
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.