Space and Missile Systems Center

Military GPS User Equipment Modernization

NDIA
20th Annual Systems Engineering Conference

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Global Positioning Systems Directorate
### 1966 Aerospace Corporation “Navigation Satellite Study”

**RANGE AND RANGE DIFFERENCE SYSTEMS**

<table>
<thead>
<tr>
<th>Location of Computation</th>
<th>Computation Performed by User</th>
<th>Computation Performed by Ground Station</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Navigation Radio Link</strong></td>
<td>2 Way</td>
<td>1 Way</td>
</tr>
<tr>
<td><strong>User Equipment</strong></td>
<td>USER</td>
<td>USER</td>
</tr>
<tr>
<td>R = Receiver</td>
<td>R</td>
<td>R</td>
</tr>
<tr>
<td>T = Transmitter</td>
<td>T</td>
<td>T</td>
</tr>
<tr>
<td>X = Crystal Clock</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>A = Atomic Clock</td>
<td>A</td>
<td>A</td>
</tr>
<tr>
<td>C = Computer</td>
<td>C</td>
<td>C</td>
</tr>
<tr>
<td><strong>Applicable Measurements</strong></td>
<td>2 Sats ppa</td>
<td>3 Sats ppp</td>
</tr>
<tr>
<td></td>
<td>3 Sats Δpapa</td>
<td>4 Sats Δpapa</td>
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<td>V</td>
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<tr>
<td><strong>User Active</strong></td>
<td>USER PASSIVE</td>
<td>USER ACTIVE</td>
</tr>
<tr>
<td><strong>User Passive</strong></td>
<td>USER</td>
<td>USER</td>
</tr>
</tbody>
</table>

- **1-way ranges, passive receivers, crystal oscillators**
- **Passive (one-way) reduces UE power and avoids detection**
- **Internal computer spreads the burden for 1,000’s of users and avoids sending measurements**
- **Crystal oscillator minimizes UE SWAP-C and doesn’t hurt accuracy**
- **Autonomous receivers**

\[\text{SWAP-C} = \text{Size, Weight, and Power - Cost}\]

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**The widespread use of GPS and duplication by all other GNSS validate these choices**
GPS Overview

Civil Cooperation
- 3+ 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)

Department of Defense
- Services (Army, Navy, AF, USMC)
- Agencies (NGA & DISA)
- US Naval Observatory
- PNT EXCOM
- GPS Partnership Council

International Cooperation
- 57 Authorized Allied Users
  - 25+ Years of Cooperation

Spectrum
- World Radio Conference
- International Telecommunication Union
- Bilateral Agreements
- Adjacent Band Interference

Department of Transportation
- Federal Aviation Administration

Department of Homeland Security
- U.S. Coast Guard

Maintenance/Security
- All Level I and Level II
  - Worldwide Infrastructure
  - NATO Repair Facility
- Develop & Publish ICDs Annually
  - Public ICWG: Worldwide Involvement
  - Materials Available at: gps.gov/technical/icwg
- 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

35 Satellites / 31 Set Healthy
Baseline Constellation: 24 Satellites

<table>
<thead>
<tr>
<th>Satellite Block</th>
<th>Quantity</th>
<th>Average Age</th>
<th>Oldest</th>
</tr>
</thead>
<tbody>
<tr>
<td>GPS IIR</td>
<td>12</td>
<td>15.7</td>
<td>20.1</td>
</tr>
<tr>
<td>GPS IIR-M</td>
<td>7</td>
<td>10.1</td>
<td>11.9</td>
</tr>
<tr>
<td>GPS IIF</td>
<td>12</td>
<td>3.6</td>
<td>7.3</td>
</tr>
<tr>
<td>Constellation</td>
<td>31</td>
<td>9.7</td>
<td>20.1</td>
</tr>
</tbody>
</table>

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35 Satellites / 31 Set Healthy
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 (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 0**
  - GPS III Launch & Checkout

- **GPS III Contingency Ops (COps)**
  - GPS III Mission on AEP

- **M-Code Early Use (MCEU)**
  - Operational M-Code on AEP

- **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
Military GPS User Equipment (MGUE)

- Commercial market-driven acquisition approach
- Three vendors developing modernized receiver cards
  - Ground form factor
  - Aviation/Maritime form factor
- Current Status
  - L-3 Technologies first to receive security certification Oct 2016
  - Developmental testing ongoing
  - Conducting early integration activities to support Service-nominated Lead Platforms
Military GPS User Equipment
Prototype GPS Receiver Flight Tested on B-2

Prototype Military GPS User Equipment Receiver Card

Prototype Miniaturized Airborne GPS Receiver

4 Successful B-2 Test Flights

Military GPS User Equipment Demonstrated in B-2
MGUE Precision Guided Munitions Test

MGUE INCREMENT 1 FIRST EVER GUIDE-TO-HIT
Looking Ahead: Multi-GNSS
• GPS is the Global Utility
  – Commited to maintaining uninterrupted service
  – “The Gold Standard”
• Modernizing to enhance GPS resiliency by:
  – Upgrading all three segments
  – Moving to M-Code
  – Adding civil signals
• Exploring multi-GNSS potential