Global Differential GPS (GDGPS) System Future

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NASA Headquarters
Presentation Purpose

• Provide Purpose and Status of NASA initiated GDGPS Working Group

• Solicit input from PNT Advisory Board to support data analysis and inform GDGPS Working Group Recommendations
Outline

• GDGPS Overview
• GDGPS Working Group
• Summary and Advice Questions
GDGPS Overview
Global Differential GPS (GDGPS) System

- Designed to improve upon the positioning and timing accuracy provided by operational GPS
- Provides real-time corrections to the GPS broadcast navigation message, enabling global sub-10-centimeter accurate positions
- Estimates the precise orbits and clock states of the GPS satellites
- Create global differential corrections within seconds
- Monitors system stability
- Does the same for most current GNSS systems
The Global Differential GPS (GDGPS) System

Provides real-time GNSS products – continuously – since 2000
Multi-GNSS constellations: GPS, GLONASS, BeiDou, Galileo, QZSS
~5 cm real-time positioning globally

Real-Time Tracking Network (Core is NASA’s network)

Reliable Redundant Data Centers

Measurements

Products, Services

Real-time GNSS Monitoring

Precision Industrial Positioning

Personal Geolocation

Repeat pass positioning support for UAVSAR airborne radar

Time-critical environmental monitoring services (Earthquake monitoring, tsunami prediction, etc.)

Provides near real-time infrastructure for Sentinel-6 weather products, including radio-occultation

Prototype system and testbed for next generation GPS Control Segment (OCX)
Global Tracking Resources Based on NASA’s Global GNSS Network

- 80+ global tracking sites deployed, controlled, operated and maintained by JPL for NASA
  - JPL installs and maintains receiver hardware (UNAVCO subcontract)
  - JPL software edits and streams data every second
  - Monitoring multiple GNSS: GPS, GLONASS, Galileo, BeiDou and QZSS
- Hundreds of additional sites contributed by US and foreign agencies leveraged to increase redundancy and diversity
Global Differential GPS (GDGPS) System
Core Software

Post-processing  Real-time processing

Core GipsyX/RTGx Software
- Data editor
- Orbit integrator and force models
- GNSS signal models
- Geodetic quality Earth models
- Filter (optimized fit forward in time)
- Smoother (optimized fit for all time)

Space geodesy operations software
- Space geodesy products

GDGPS real-time operations software
- GDGPS real-time products
  - Flex Power Monitoring
  - Satellite Signal Monitoring
  - Orbit and Clock updates
  - Signal Editing

GDGPS real-time products

Post-processing

Real-time processing
Global Differential GPS (GDGPS) System Working Group
Global Differential GPS (GDGPGS) System Working Group Establishment

• NASA and JPL were evaluating the future of GDGPGS due to the changing commercial markets, emerging dependencies on the GDGPGS products and software, and an increasing user base that was not contributing to maintaining the baseline capability

• NASA determined that reviewing individual tasks would not provide the necessary knowledge to identify the NASA and national needs of this capability

• The GDGPGS working group was established in May 2020

• Membership:
  • NASA HQ/SCAN
  • NASA HQ/Earth Science Division
  • NASA HQ/NASA Management Office
  • Jet Propulsion Laboratory
Global Differential GPS (GDGPS) System Working Group Purpose

- Establish Capability Baseline necessary for current and future NASA and National needs
- Identify Future Operating Construct
  - Funding source(s) and structure
  - Government/FFRDC or Commercial
- Identify any necessary inter-agency cooperation and methods for codifying the cooperation
Global Differential GPS (GDGPS) System Issues

- End users do not recognize GDGPS dependencies due to no direct interface
- Funding to maintain capability
  - Currently provided by users directly requesting unique products
  - Not all users of the GDGPS products provide funding to support basic capabilities
### Evaluation of Commercial Precise Point Positioning (PPP) Services (work in progress)

<table>
<thead>
<tr>
<th>Parent Company</th>
<th>Provider</th>
<th>Service/s</th>
<th>Users</th>
<th>Coverage</th>
<th>Ref. Network</th>
<th>GDGPS Dependency</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Hexagon AB (Sweden)</strong></td>
<td>Veripos (UK)</td>
<td>Standard</td>
<td>Maritime</td>
<td>Global</td>
<td>GDGIPS</td>
<td>Ref. Data</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Ultra</td>
<td>Maritime</td>
<td>Global</td>
<td>VERIPOS²</td>
<td>Ind. Backup</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Apex</td>
<td>Maritime</td>
<td>Global</td>
<td>VERIPOS²</td>
<td>Ind. Backup</td>
</tr>
<tr>
<td><strong>TerraStar (UK)</strong></td>
<td>TerraStar-X</td>
<td>Agriculture</td>
<td>Regional³</td>
<td>TERRASTAR⁴</td>
<td></td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>TerraStar-C PRO</td>
<td>Land, UAS</td>
<td>Global</td>
<td>TERRASTAR⁴</td>
<td></td>
<td>-</td>
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<tr>
<td></td>
<td>TerraStar-C</td>
<td>Land, UAS</td>
<td>Global</td>
<td>TERRASTAR⁴</td>
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<td>-</td>
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<tr>
<td></td>
<td>TerraStar-L</td>
<td>Land, UAS</td>
<td>Global</td>
<td>TERRASTAR⁴</td>
<td></td>
<td>-</td>
</tr>
<tr>
<td><strong>Deere &amp; Co (USA)</strong></td>
<td>NavCom (Canada)</td>
<td>StarFire Subscription Service: Land Only</td>
<td>Land</td>
<td>Global</td>
<td>Starfire Network⁵</td>
<td>-</td>
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<tr>
<td></td>
<td></td>
<td>StarFire Subscription Service: All Area</td>
<td>Maritime</td>
<td>Global</td>
<td>Starfire Network⁵</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td></td>
<td>StarFire Over IP</td>
<td>All</td>
<td>Internet</td>
<td>Starfire Network⁵</td>
<td>-</td>
</tr>
<tr>
<td><strong>Trimble (USA)</strong></td>
<td>-</td>
<td>Trimble-RTX</td>
<td>Land</td>
<td>Global</td>
<td>Trimble⁶</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td></td>
<td>VRS Services</td>
<td>Land</td>
<td>Selected Areas⁷</td>
<td>Trimble⁶</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td></td>
<td>xfill Premium</td>
<td>Land</td>
<td>Global</td>
<td>Trimble⁶</td>
<td>-</td>
</tr>
<tr>
<td><strong>Fugro (Netherlands)</strong></td>
<td>Fugro-Marinestar</td>
<td>Marinestar Positioning Services</td>
<td>Maritime</td>
<td>Global (&lt;70°N)</td>
<td>Fugro Network</td>
<td>Ind. Backup</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Marinestar Arctic Services⁹</td>
<td>Maritime</td>
<td>Arctic (&gt;70°N)</td>
<td>Fugro Network</td>
<td>Ind. Backup</td>
</tr>
<tr>
<td><strong>UniStrong (China)</strong></td>
<td>Hemisphere GNSS (USA)</td>
<td>Atlas Basic</td>
<td>All</td>
<td>Global</td>
<td>~200 stations¹¹</td>
<td>Divested¹²</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Atlas H10</td>
<td>All</td>
<td>Global</td>
<td>~200 stations¹¹</td>
<td>Divested¹²</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Atlas H30</td>
<td>All</td>
<td>Global</td>
<td>~200 stations¹¹</td>
<td>Divested¹²</td>
</tr>
<tr>
<td><strong>Swift Navigation (USA)</strong></td>
<td>-</td>
<td>Skylark Cloud Corrections Service</td>
<td>Land, UAS</td>
<td>Regional¹³</td>
<td>Skylark Network¹¹</td>
<td>-</td>
</tr>
<tr>
<td><strong>TopCon (Japan)</strong></td>
<td>-</td>
<td>TopNET</td>
<td>Land, UAS</td>
<td>Selected Countries</td>
<td>TopCon GNSS Network¹¹</td>
<td>-</td>
</tr>
<tr>
<td><strong>DLR &amp; Telespazio (Europe)</strong></td>
<td>Spaceopal (Germany)</td>
<td>NAVCAST¹⁵</td>
<td>All</td>
<td>Internet</td>
<td>~100 IGS stations</td>
<td>-</td>
</tr>
</tbody>
</table>

³ Service available only in limited regions.
⁴ Services provide regional coverage.
⁵ Services support multiple networks.
⁶ Trimble services are available for Trimble customers.
⁷ Services provide coverage in selected areas.
⁸ Services provided in collaboration with Marinestar.
⁹ Services provide coverage in Arctic regions.
¹⁰ Services provided in collaboration with Hemisphere.
¹¹ Services support multiple networks.
¹² Services have been divested.
¹³ Services provide regional coverage.
¹⁴ Services provided in collaboration with Telespazio.
¹⁵ Services provide global coverage.
Uniqueness of Global Differential GPS (GDGPS) System Domestic Providers of Similar Positioning Services

<table>
<thead>
<tr>
<th>Attribute</th>
<th>JPL</th>
<th>General Provider Capabilities</th>
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<tbody>
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<td>Constellation:</td>
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<tr>
<td>GPS</td>
<td>Yes</td>
<td>Yes</td>
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<tr>
<td>GLONASS</td>
<td>Yes</td>
<td>Yes</td>
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<tr>
<td>BeiDou</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Galileo</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>QZSS</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Independent of user receiver or software</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Global feed (uniformly valid; use anywhere)</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>No geographical limits</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Access available:</td>
<td></td>
<td></td>
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<tr>
<td>Internet</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Secure Land Line</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Secure VPN</td>
<td>Yes</td>
<td>No</td>
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<td>GPS III models</td>
<td>Yes</td>
<td>No</td>
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<tr>
<td>Attitude Quaternions</td>
<td>Yes</td>
<td>No</td>
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<tr>
<td>RTCM SSR Standard</td>
<td>Yes</td>
<td>No</td>
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<tr>
<td>Licensable Technology</td>
<td>Yes</td>
<td>No</td>
</tr>
</tbody>
</table>

Green indicates not provided commercially

Table 1. Comparison of high accuracy (sub 10 cm) GNSS differential corrections available over Internet
Global Differential GPS (GDGPS) System Working Group Actions

• Data Collection
  • Operational Construct Options
  • Current Status of Commercial Market Place
  • Common Understanding of GDGPS Capability and Current Uses

• Analysis
  • Determine NASA Baseline Capability Needs
  • Identify any differences between NASA and National Capability Needs
  • Identify Operational Construct for Future Capability Maintenance and Upgrades

Current Point:
May 2020
Aug 2020
Nov 2020
Summary and Advice Questions

• GDGPS is becoming a part of National Infrastructure – should it be?

• What is the Current Government user set?

• Are there Future uses that should be taken into consideration?

• Are there Operating constructs that shouldn’t be missed in the evaluation (funding and oversight)?

• Any additional advice or guidance?