The Future of High-Accuracy GPS

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**Presented at:** Esri International User Conference  
San Diego, CA  
July 26, 2012
GNSS technology in the **next** 5 years is going to advance significantly more than the **past** 5 years.
Outline

- What is GNSS?
- GPS Status
- GLONASS Status
- Galileo Status
- What is the L5 Signal?
- Trends
- Gotchas
- Questions
GNSS is the new GPS

- GNSS = Global Navigation Satellite Systems

- “GNSS refers collectively to the worldwide positioning, navigation, and timing (PNT) determination capability available from one or more satellite constellations.”
# GNSS is the new GPS

## ACTIVE GNSS:
- GPS (USA)
- GLONASS (Russia)

**SBAS:**
- WAAS (North America), MSAS (Japan)
- EGNOS (Europe), Fugro/Omnistar, Veripos
- QZSS (Japan)
- DGPS/NDGPS
- RTK Networks

## PLANNED GNSS:
- Galileo (Europe)
- Compass/BeiDou (China)

**SBAS:**
- GAGAN (India)
- SDCM (Russia)
Not only is GNSS receiver technology constantly evolving, so is the GNSS infrastructure (satellites, signals and control).

This is one of the reasons that the GNSS industry is so dynamic and will be for the foreseeable future.

These changes will affect the way that GNSS mapping and surveying users perform their work.
Current GPS Status
GPS Status

- There are currently 31 operational GPS satellites in a 24 + 3 configuration.
- 22 x GPS Block IIA/IIR. L1 C/A, L1/L2 P(Y)
- 7 x GPS Block IIR-M. L1 C/A, L1/L2 P(Y), L2C
- 2 x GPS Block II-F. L1 C/A, L1/L2 P(Y), L2C, L5
- **L2C** = More robust iono correction for high precision positioning. No need for cross-correlation (semi-codeless).
- **L5** = Similar to L2C, but stronger signal @ 1176
GLONASS
Russia’s Satellite Navigation System
GLONASS

- Common feature in high-end surveying receivers.
- Emerging in mapping/consumer receivers.
- Complementary to GPS.
- Doesn’t improve accuracy (other than improving PDOP). Improves productivity.
- Fundamentally different radio design than GPS and Galileo. CDMA vs. FDMA.
In December 2011, declared fully operational with 24 healthy satellites in orbit.
## GLONASS

<table>
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<tr>
<th></th>
<th>L1</th>
<th>L2</th>
<th>L3</th>
<th>L1, L2</th>
<th>other</th>
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<td>L2OF, L2SF</td>
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<td>L2SC</td>
<td>L5OC</td>
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<td>“Glonass-KM”</td>
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<td>L2SC</td>
<td>L5OC</td>
<td>after 2015</td>
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**FDMA signals**

**CDMA signals**

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GLONASS

- 21 operational satellites.
- Russia has an aggressive launch schedule.
- A valuable augmentation to GPS. Not used as a stand-alone system yet.
- Valuable to high-precision users (RTK, sub-meter) because it increases productivity.
- 5-8 satellites are added when using GLONASS.
With the GPS 24+3 initiative and aggressive GLONASS launch schedule, GPS/GLONASS users are seeing a substantial improvement in satellite availability.

Some new mapping-grade receivers and consumer GNSS chips with GLONASS are being introduced.
Galileo
Europe’s Satellite Navigation System
Galileo

- Galileo is real! Two sats in orbit (IOV).
- Two more scheduled for launch in 2012.
- 18 total scheduled for launch by 2015.
- 30 total scheduled for launch by 2020.
- Currently dual launch. Feb. 2012 contract issued to modify the Ariane 5 launcher to accommodate four Galileo satellites.
- No L2 support.
Galileo

- GPS+Galileo = 20 average satellites in view.

<table>
<thead>
<tr>
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<th>GPS</th>
<th>GALILEO</th>
<th>GPS+ GALILEO</th>
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<tr>
<td>Satellites</td>
<td>24+3</td>
<td>27+3</td>
<td>51+6</td>
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<td>Avg # in View</td>
<td>8</td>
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<td>RAIM Integrity</td>
<td>Fair</td>
<td>Fair</td>
<td>Excellent</td>
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<tr>
<td>Coverage</td>
<td>Good</td>
<td>Good</td>
<td>Excellent</td>
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</table>
Galileo is implemented step-wise

- **Galileo System Testbed v1**
  - Validation of critical algorithms
  - 2003

- **Galileo System Testbed v2**
  - 2 initial test satellites
  - 2005

- **In-Orbit Validation**
  - 4 IOV satellites plus ground segment
  - 2011/2012

- **Initial Operational Capability**
  - Early Services for OS, SAR, PRS
  - 2014 (OS/SAR) – 2016 (PRS)

- **Full Operational Capability**
  - All services, 30 satellites
  - 2019/2020
L5 Signal
The Beginning of a New Era
Current International Signal Plans

- GPS (US)
- GLONASS (Russia)
- Galileo (Europe)
- COMPASS (China)
- IRNSS (India)
- QZSS (Japan)
- SBAS (US Europe India Japan)

Future CDMA signal

Source: Federal Aviation Administration
L5 Signal

• May 2010 marked a new era of GPS with the launch of the first GPS satellite equipped to broadcast L5.

• According to the U.S. Gov’t, a full constellation of 24 GPS satellites broadcasting L5 (and all legacy signals) will be in orbit by 2020.

• Europe’s Galileo could accelerate a full L5 constellation as soon as 2015.
L5 Signal

- L5 = broadcast signal four times more powerful than L2C, frequency further separated from L1 which enhances mitigating the effect of the ionosphere.
- L5 designed for safety-of-life apps (eg. aviation) and frequency (1176.45 MHz) is in the highly protected aeronautical navigation band.
- Both GPS and Galileo support L5.
When Will L5 be Available?

- GPS won’t have a full constellation of satellites broadcasting L1/L5 until 2020.
- Galileo could accelerate that by five years if they keep their projected schedule.
- If GPS has 12 satellites broadcasting L1/L5 by 2015 and Galileo has 18 satellites broadcasting L1/L5 by 2015, there would essentially be a full constellation.
When Will L5 be Available?

Number Of Galileo Satellites
Portland (15 Deg Elevation)

Time (UTC)
When Will L5 be Available?

Number Of Galileo & GPS IIF Satellites
Portland (15 deg Elevation)
When Will L5 be Available?

Plot of 12 GPS IIF Satellites, 19 GPS legacy satellites, and 18 Galileo satellites
15° elevation mask
When Will L5 be Available?

Europe’s Galileo system can accelerate the adoption of inexpensive, high-precision GNSS receivers by as much as five years.
What is Special about L5?

- Open signal.
- Broadcast strength is \(~4x\) more powerful than L2C.
- Longer code and error-correcting techniques for more robust tracking in difficult environments.
- Supported by other global GNSS and SBAS.
- Located in highly-protected aeronautical band.
What is Special about L5?

Improvement of L5 over L1 for Code Tracking

GPS World Innovation: The WAAS L5 Signal
Richard B. Langley, Hyunho Rho

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The Falling Cost of High-Precision Data

• Manpower requirements are shrinking as productivity increases.
• The skill and time required to collect high-accuracy data is falling.
• Projects are completed more quickly.
• Legacy budgeting strategies for collecting high-precision data are becoming obsolete.
Trends

• The new L5 signal will result in very low-cost dual frequency (L1/L5) receivers capable of cm-level horizontal/vertical precision.
• The value of high-precision data (horizontal and vertical) will reduce substantially.
• A business built around the concept of locating points is headed for an economic storm.
Trends

• Sensor integration will allow precise positioning in places where it’s difficult to achieve today (e.g. accelerometer, gyro, laser rangefinding, etc.)
• Trending from measurement skills to data management and analysis skills.
• Trending from relying solely on your own data to incorporating data from external sources (e.g. using crowd-sourced data).
Gotchas

• The ability of organizations to collect high-precision data inexpensively will expose accuracy errors in legacy data and maps.

• The understanding of geodetic concepts and geodetic skills will become increasingly important.

• Accuracy is addictive.
LightSquared

- LightSquared is in Chapter 11 bankruptcy, embroiled in investor and SEC lawsuits.
- FCC has not rendered a ruling and likely won’t before the 2012 presidential election.
- Still no practical engineering solution for GPS receivers to co-exist with LightSquared’s proposed system.
- Spectrum battle is not over.
Questions?
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