

The Future of High-Accuracy GPS

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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 world-wide 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)
- SBAS: SDCM (Russia)

Constantly Changing

- 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.

GLONASS - Rebuilding

- In December 2011, declared fully operational with 24 healthy satellites in orbit.



GLONASS

	L1	L2	L3	L1, L2	other	Status
“Glonass” (1982)	L1OF, L1SF	L2OF, L2SF	–	–		Done
“Glonass-M” (2003)	L1OF, L1SF	L2OF, L2SF	–	–		Done
“Glonass-K1” (2011)	L1OF, L1SF	L2OF, L2SF	L3OC test	–		Done
“Glonass-K2” (2014)	L1OF, L1SF	L2OF, L2SF	L3OC	L1OC, L1SC, L2SC		2014
“Glonass-KM” (2021-....)	L1OF, L1SF	L2OF, L2SF	L3OC	L1OC, L1SC, L2SC	L1OCM, L2OC, L5OC	Under development after 2015



FDMA signals



CDMA signals

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.

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.

	GPS	GALILEO	GPS+ GALILEO
Satellites	24+3	27+3	51+6
Avg # in View	8	12	20
RAIM Integrity	Fair	Fair	Excellent
Coverage	Good	Good	Excellent

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)



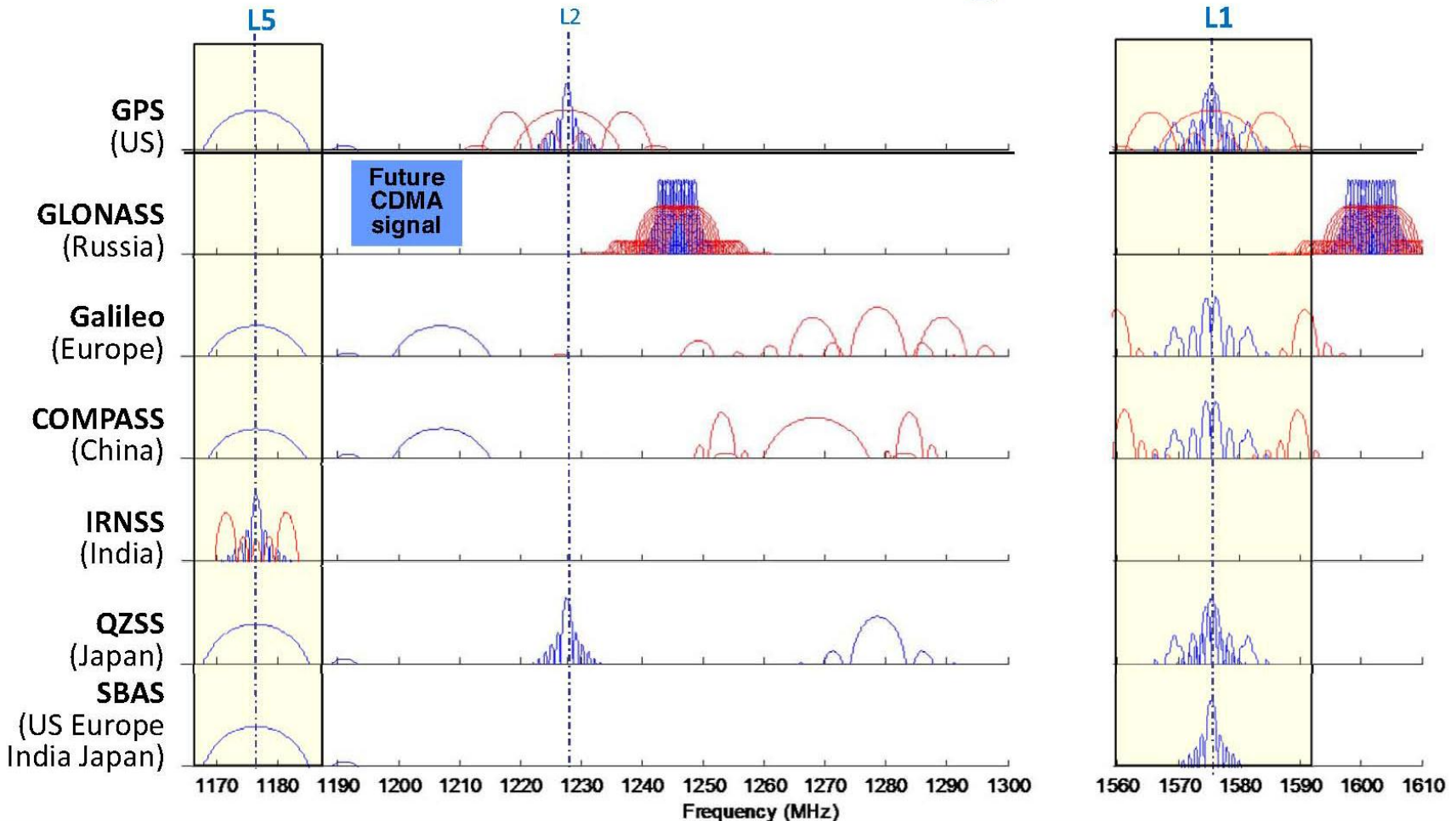
Full Operational Capability
All services, 30 satellites
2019/2020



L5 Signal

The Beginning of a New Era

Current International Signal Plans



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.

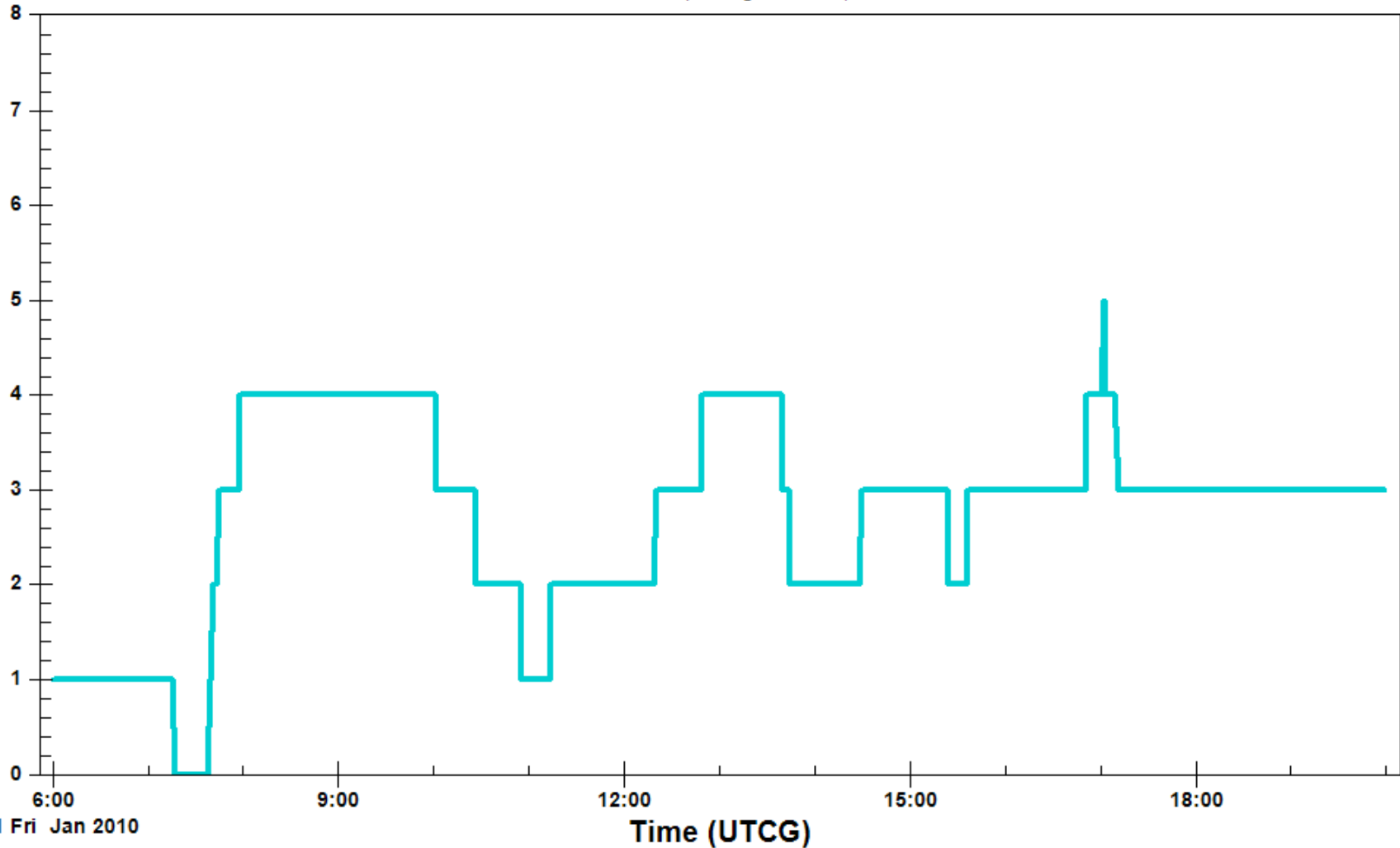
When Will L5 be Available?

- 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 GPS IIF Satellites

Portland (15 deg Elevation)



1 Fri Jan 2010

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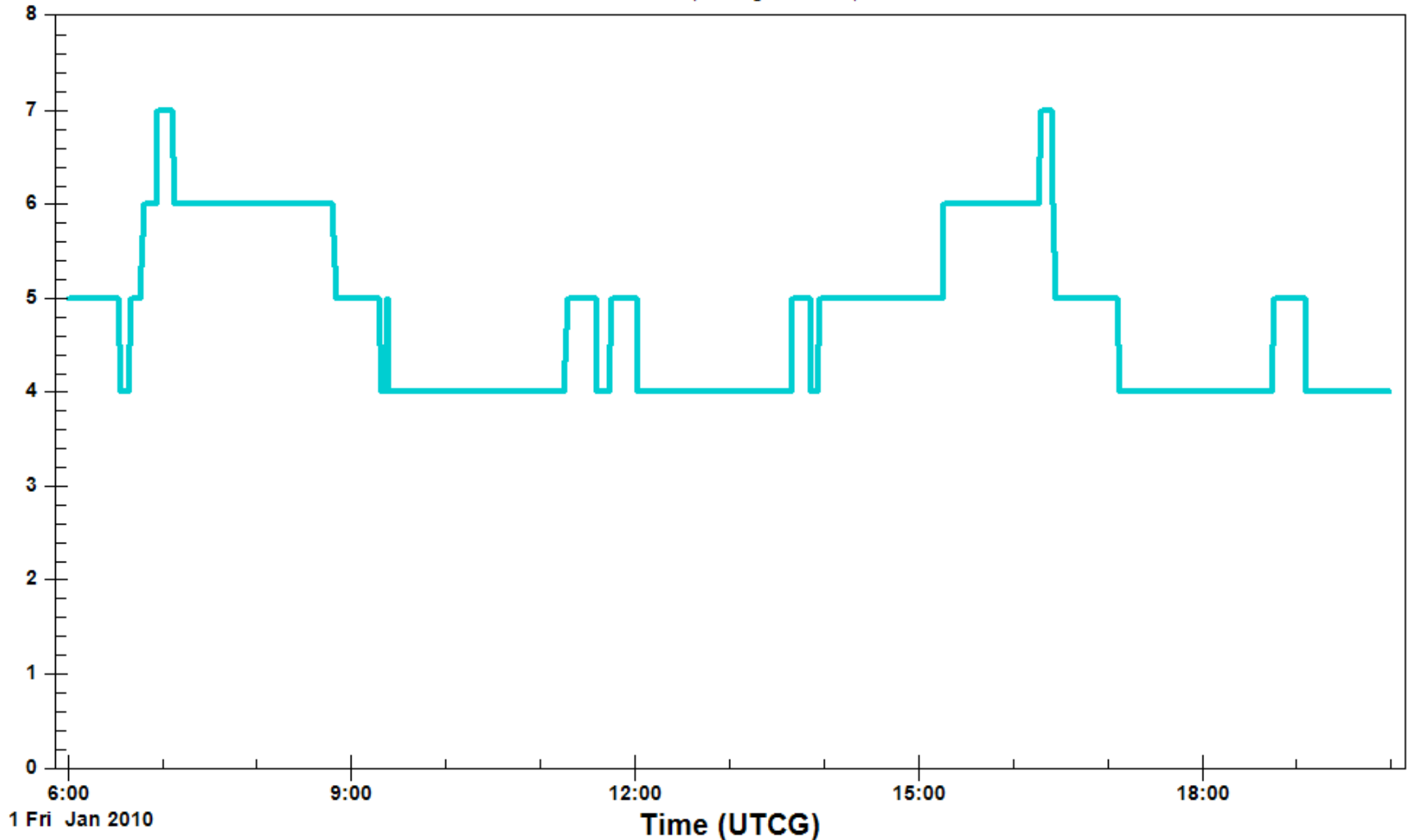
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When Will L5 be Available?

Number Of Galileo Satellites

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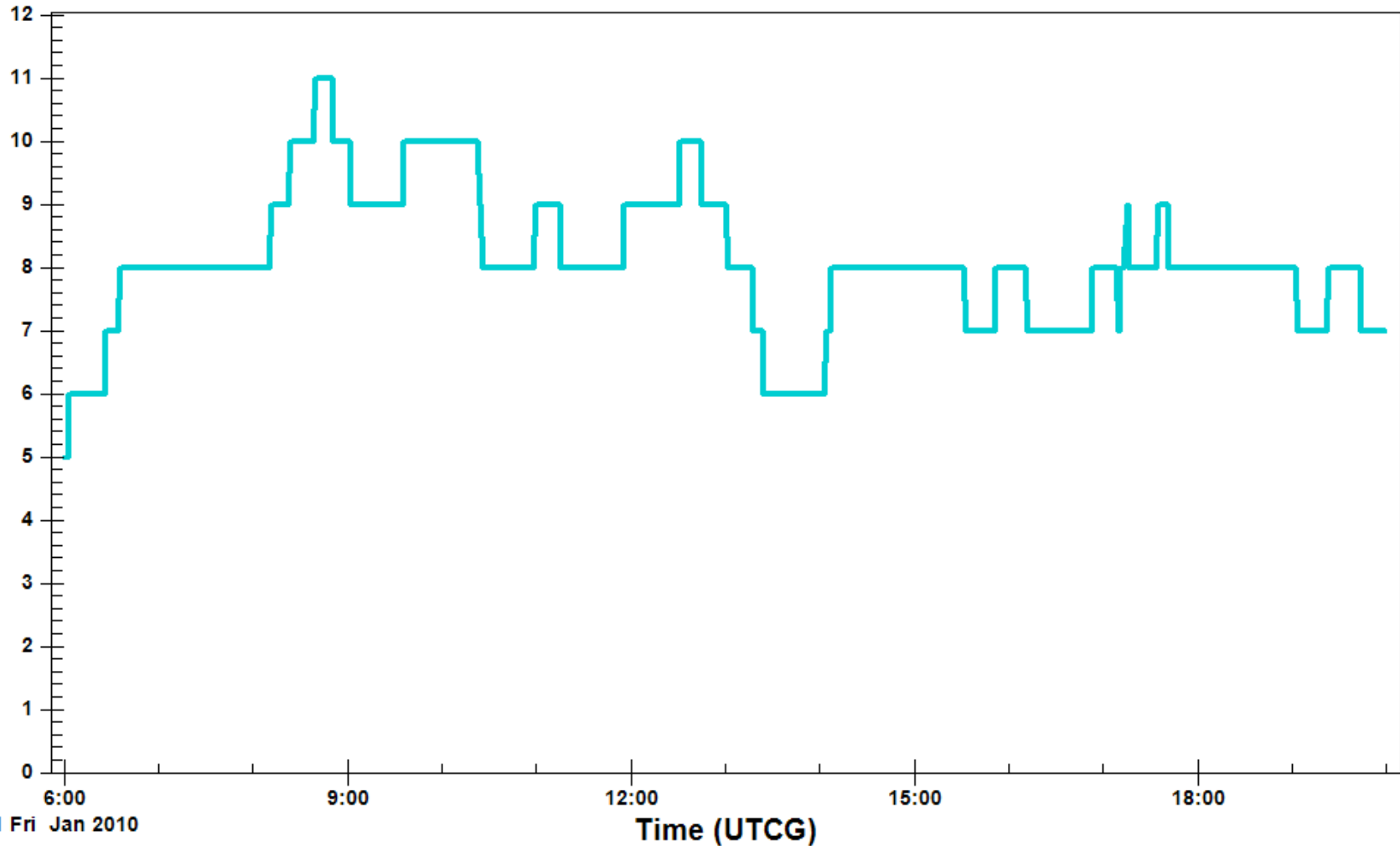
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When Will L5 be Available?

Number Of Galileo & GPS IIF Satellites

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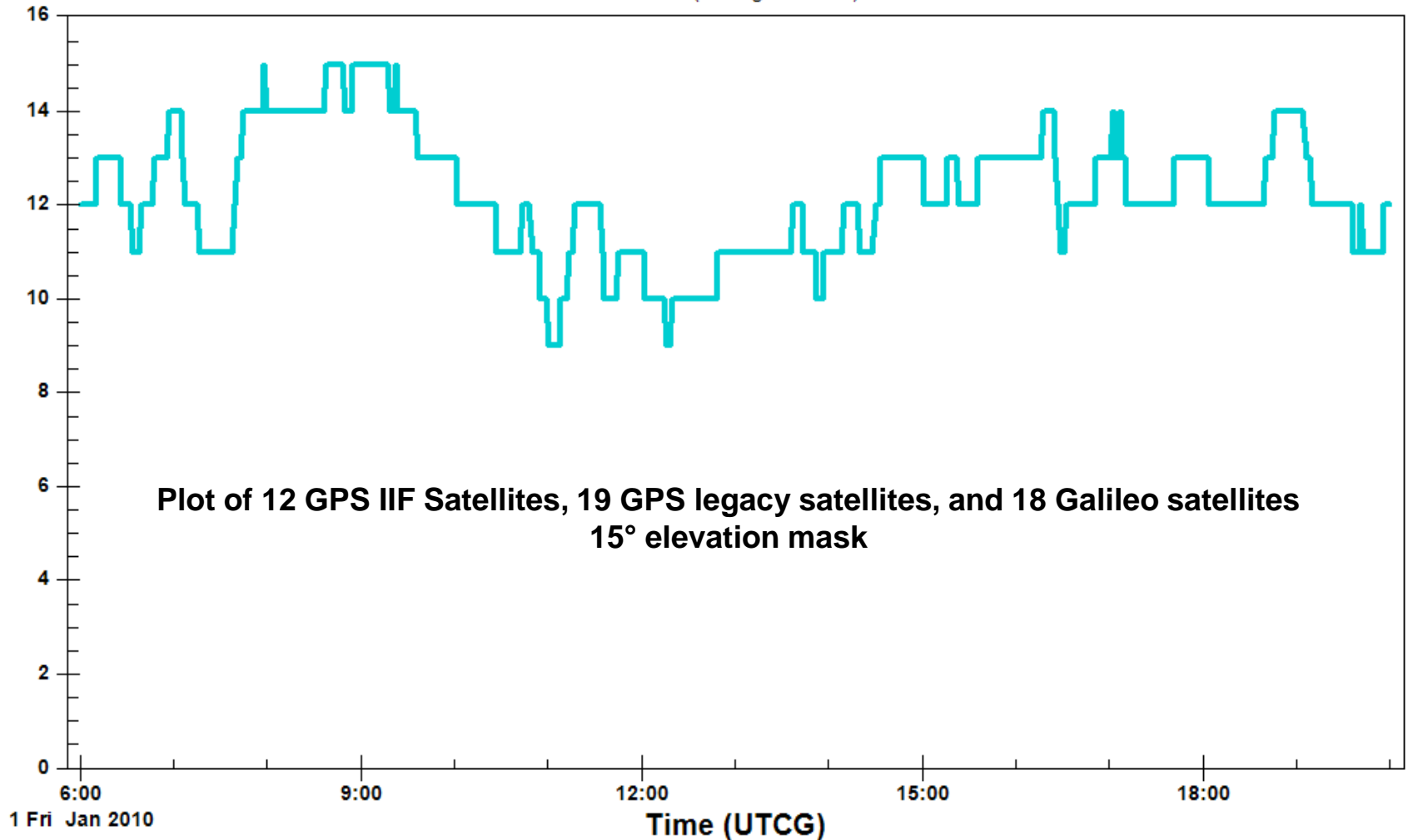
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When Will L5 be Available?

Number Of Galileo & GPS Legacy & IIF Satellites

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When Will L5 be Available?

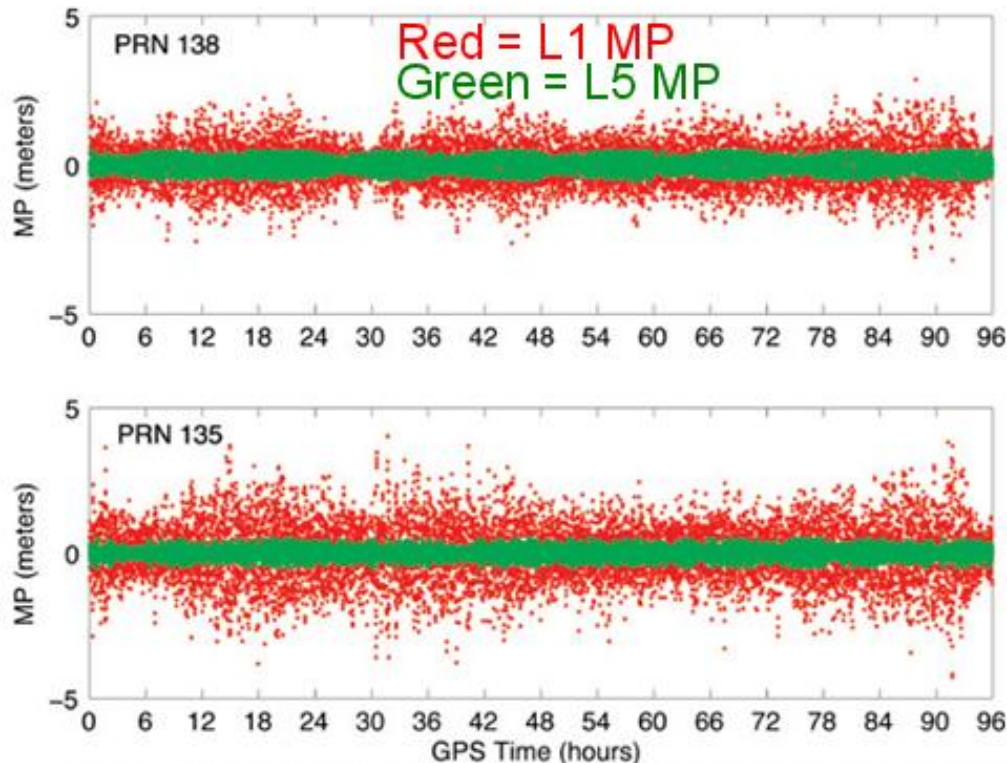
Europe's Galileo system can accelerate the adoption of inexpensive, high-precision GNSS receivers by as much as five years

What is Special about L5?

- Open signal.
- Broadcast strength is $\sim 4x$ 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

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 (eg. 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 (eg. 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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