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Global Navigation Satellite System (GNSS) FAQs for Mapping and GIS

What is a Global Navigation Satellite System (GNSS)?

A global navigation satellite system (GNSS) is a system that allows you to calculate your location anywhere in the world using satellite signals. Every GNSS is made up of three segments: a space segment, a control segment; and a user segment. The space segment consists of a constellation of satellites broadcasting positioning information, the control segment consists of ground stations that monitor and control the satellite orbits and broadcast, and the user segment consists of people from many disciplines equipped with receivers that can pick up the broadcast signals and use this information to calculate their position on the earth.

What GNSS systems exist?

There are four GNSS systems in existence or early deployment at the time of writing. These are:

- The Global Positioning System (GPS) operated by the United States government.
- The GLObal NAvigation Satellite System (GLONASS) operated by the Russian government.
- The Galileo navigation satellite system (Galileo) to be operated by the European Union.
- The Compass navigation satellite system (Compass) to be operated by the Chinese government.

Each GNSS system broadcasts multiple signals for military and/or civilian positioning. Other complementary augmentation or regional navigation systems exist or are proposed. For GPS these include Satellite-Based Augmentation Systems (SBAS) such as the Wide Area Augmentation System (WAAS) in the US, the European Geostationary Navigation Overlay system (EGNOS) in Europe and MTSAT Satellite Augmentation System (MSAS) in Japan.

At the time of writing, the Compass system consists of a single Compass-M1 satellite, the first of 35 proposed satellites. While the signal may be tracked and analysed, the system specification has not been publicly documented[1]. Because of this, the Compass system will not be further discussed in this FAQs document. This FAQs document focuses on the GPS, GLONASS and Galileo systems, outlining the theoretical and practical capabilities of each system and highlighting the differences between them.

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What benefits do GNSS systems offer?

GNSS systems enable you to know your position very quickly and accurately, at any time of day or night and in any weather, anywhere in the world. Moreover, most GNSS services are free to anyone with a GNSS receiver. When fully operational, all GNSS systems can deliver this information. However, at this time only GPS is fully operational 24 hours a day, 7 days a week around the globe.

Due to this status, GPS has a comprehensive network of differential correction infrastructure and a well established community that supports and develops user applications. The system has been embraced by users worldwide for applications ranging from recreational uses such as hiking, fishing, geocaching, and personal training; everyday uses such as in-car vehicle navigation; or location-based services and industrial uses such as timing, agriculture, surveying, and construction. GPS receivers are affordable and accessible to consumers and professionals while being truly global in their application. For the GIS community, GPS is a familiar tool for mapping and geospatial data capture.

Though used in Russia for many years, GLONASS is yet to establish a similar global community or a comprehensive network of differential correction infrastructure.

What is the operational status of the different GNSS systems?

Of the three systems, only GPS is fully deployed, and its 30 operational satellites far exceed the minimum of 24 satellites required to maintain global 24 hour a day, 7 days a week coverage. The extra satellites provide additional reliability and redundancy.

Although GLONASS has been in existence almost as long as GPS, the ability to launch and maintain a full constellation has been plagued by relatively short life of satellites, failed satellite launches and economic recession. These factors have led to a lower number of satellites in orbit and an incomplete constellation as at time of writing. However, renewed political commitment to GLONASS in Russia has recently seen increased investment in the constellation[2].

In comparison, Galileo is in its infancy, having just a single test satellite in orbit.

The table below describes the key status parameters for each GNSS system as at January 2008.

	GPS	GLONASS	Galileo
Operational status	Fully operational with global coverage	Operational with partial global coverage	Test broadcast Frequency secured
Total satellites in constellation (Total usable satellites)	31 (30)	16 (13)	1(0)
Publically available signals	L1 carrier and Coarse Acquisition (C/A) code L2 carrier and L2C code (L2C only available on Block IIR-M satellites) L5 carrier and code (only available on Block IIF satellites)	G1 carrier and code G2 carrier and code Third civil signal planned New L1 and L5 interoperable signals proposed[3]	E1-E2 (L1) carrier and code E5a and b (L5) carrier and code

In active development	Yes	Yes	Yes
Blocks in current constellation	Block IIA/IIR and IIR-M satellites	GLONASS and GLONASS-M satellites	GIOVE (Galileo In-Orbit Validation Element)
Recent launch activity	IIR15-M, 25 Sept 06 IIR16-M, 17 Nov 06 IIR17-M 17 Oct 07 IIR18-M 20 Dec 07	715, 716, 717, 25 Dec 06 718,719,720, 26 Oct 07 721, 722, 723, 25 Dec 07	GIOVE-A, 28 Dec 05
Recent decommissioning activity	II-9, 14 Mar 07 IIA-10 unusable till further notice	711, 794 & 789, 11 Jan 08 792 & 798, 12 Jan 08	N/A
Scheduled launches	IIR19-M, Mar 08 IIR20-M, Jun 08 IIF1, Aug 08 IIR21-M, Sept 08	M15,/M16/M17, Sept 08 K1/K2, Oct 08	GIOVE-B, Apr 08 GIOVE A2, Nov 08

For the latest status visit the following websites:

- For GPS status, go to the US Coast Guard navigation center website http://navcen.uscg.gov/gps
- For GLONASS status, go to the Russian space agency website www.glonass-ianc.rsa.ru
- For Galileo status, go to the European Space agency website www.esa.int/esaNA/galileo
- For satellite launch schedules, go to www.satelliteonthenet.co.uk

What are the main differences between the GNSS systems?

All GNSS systems have been designed for the purpose of providing global navigation and surveying capabilities to end users. However significant differences exist in the system architectures of GPS and GLONASS. This is because GPS and GLONASS were designed during the Cold War as competing systems, whereas Galileo has been designed since that time during a period of international cooperation. Recently, as part of a program of cooperation in GNSS development, GLONASS has proposed new signals that better inter-operate with GPS and Galileo[3].

The different signal and design elements that make up each GNSS system are:

	GPS	GLONASS	Galileo
L1 frequency (or equivalent)	1575.42 MHz	G1 @ 1602.5625 to 1615.5 MHz New signal proposed	E1 1575.42 MHz
L2 frequency (or equivalent)	1227.6 MHz	G2 @ 1240 to 1260 MHz	E5b @ 1207.14 MHz E6 @ 1278.75 MHz
L5 frequency (or equivalent)	1176.45 MHz	Proposed	E5a @ 1176.45 MHz
Architecture	CDMA	FDMA (new L1 and L5 signals proposed to use CDMA for interoperability)[3]	CDMA
Datum	WGS84	PZ-90.02	WGS84
Time	UTC (USNO)	UTC (SU)	International Atomic Time (TAI)
Control Segment	Global	Russia only	Global (proposed)

Each system broadcasts multiple signals on a range of frequencies. However, GPS and Galileo satellites broadcast different codes on the same frequency whereas GLONASS satellites broadcast the same codes on different frequencies. In addition, key elements of positioning, such as time and reference frame, vary between the GPS and GLONASS systems but are comparable between GPS and Galileo. These issues directly impact the receiver design and cost.

In each system the control segment includes a network of ground stations that monitor satellites and provide a master control station with orbit information. Because the GLONASS control segment is limited to Russia only, GLONASS satellites are unmonitored for a period in every orbit, resulting in lower system integrity.

Which GNSS system is right for my application?

In terms of satellite signal availability, every application will benefit from the reliable broadcast of healthy signals with full global coverage 24 hours a day, 7 days a week. Of the three GNSS systems available, only GPS currently offers full global coverage 24 hours a day, 7 days a week, therefore a usable GNSS receiver should at a minimum offer GPS support. Outside of Russia it is difficult to find a GNSS receiver that does not support GPS.

Within each GNSS system, different signals and parts of signals offer different levels of accuracy. For example, L1 or G1 code corrections generally offer submeter positioning, whereas L1 or G1 carrier corrections can deliver postprocessed centimeter-accurate positions. With the right infrastructure, dual-frequency GPS or GLONASS can offer centimeter accuracy in real time.

However, the overall design and engineering of the receiver is as important as the GNSS system that it utilizes. Factors such as ruggedness, battery life, size, screen visibility, operating system, application software, support, and reliability can be critical to the success of a project and should take precedence in a purchase decision, provided that minimum positioning accuracy requirements are met. Overall, Trimble recommends that you refer to proven accuracy performance and published test results for the equipment, rather than selecting a receiver based on the GNSS system it uses.

What is dual-frequency?

Sometimes described as L1/L2, a dual-frequency receiver uses two different frequency signals from the same GNSS system for its positioning. Use of dual-frequency signals is generally confined to professional GPS systems. This is because the lower accuracy requirements of consumer applications do not require dual-frequency tracking. The most common dual-frequency receivers are L1/L2 GPS receivers, although L1/L2/G1/G2 GPS/GLONASS receivers are becoming available for geodetic research and surveying applications.

What are the benefits of dual-frequency?

Radio signals travel at different speeds through the ionosphere. The speed at which the signals travel depends on their frequency. By measuring the range of two different frequencies from the *same* satellite, ionospheric errors can be estimated and removed. In addition, the two wavelengths can be combined to more quickly provide range measurements, giving faster initialization for high accuracy. Using two frequencies from *different* satellites, such as might occur in dual-constellation receivers, does not give these same benefits.

What is dual-constellation?

Sometimes called GPS/GLONASS, GPS+, or simply GNSS, a dual-constellation receiver uses two similar frequency signals from two different GNSS systems for its positioning. The most common dual-constellation receivers are GPS/GLONASS receivers. These receivers use signals from GLONASS satellites to augment the positioning from the GPS satellites.

What are the benefits of augmenting GPS with GLONASS?

For real-time surveying (RTK) applications, adding GLONASS satellites can provide benefits in initialization time and signal reliability. Because submeter mapping applications and postprocessing do not require initialization, benefits are limited to incremental improvement in constellation geometries (DOP), and the number of satellites available for tracking in harsh environments.

Geometry improvements are possible due to a greater number of satellites being available for use with dual-constellation receivers. To retain these benefits throughout the process of differential correction (which is required to achieve the manufacturer’s accuracy specifications), both the base and roving receiver must have dual-constellation support. In today’s GPS/GLONASS dual-constellation receivers, these benefits are of a sufficiently small magnitude that they may be outweighed by well-designed GPS receivers that take a higher quality GPS constellation-based measurement.

Productivity improvements are only gained by tracking two or more GLONASS satellites when there are less than four GPS satellites available. For there to be less than four GPS satellites, the conditions must be very difficult, such as in areas of urban canyon or canopy. As with any DOP improvement, you must have access to a reference station that is also tracking the same two GLONASS satellites. In addition, when you have a restricted view of the sky the DOP of the augmented position is often outside acceptable levels. For improved signal acquisition, you can use high-sensitivity tracking of the GPS constellation to provide higher productivity in harsh environments.

How are system differences reconciled to provide GLONASS augmentation to GPS?

Because of the different system architectures of GPS and GLONASS, you must have at least two GLONASS satellites and three GPS satellites to calculate a position. The second GLONASS satellite is required to determine the offset in time between the two systems, which can otherwise translate into ten meters of error.

Do I still need to differentially correct my data if I have dual-constellation tracking?

Yes, if you want to achieve the manufacturer's specifications for accuracy you need to observe all correction and GNSS constellation requirements, such as maximum DOP values, minimum SNR values, and minimum elevation values, as well as the requirement for differential correction, which may require using carrier processing techniques.

What differential correction (DGPS or DGLONASS) services are available for GPS and GLONASS?

Differential correction is required to eliminate errors from GNSS position measurements before the specified accuracy is obtained. Thus, a submeter receiver is only submeter after the data has been differentially corrected. Some correction services are broadcast in real time and some consist of data files that can be used to differentially correct GNSS data during postprocessing.

The following DGNSS services are available for GPS and GLONASS:

Correction service	GPS	GLONASS
Publicly available GPS reference station data for postprocessing[a]	>2500 reference stations worldwide	Some
Satellite-Based Augmentation Systems (SBAS) WAAS EGNOS MSAS	Yes, United States, Europe and Japan	None
DGPS beacon[b]	>320 reference stations worldwide	None
OmniSTAR L-Band satellite broadcasts[c]	Yes, World wide	No
VRS™ network[d]	Yes	Some
Personal reference stations[e]	Yes	Yes

a. Trimble maintains a list of over 2500 reference stations that provide data via the Internet, and most of the data is freely available. The data comes from GPS companies, government agencies, education providers, or private users, and includes data from Continually Operating Reference Stations (CORS) (http://www.ngs.noaa.gov/CORS/cors-data.html) and Scripps Orbit and Permanent Array Center (SOPAC) (http://sopac.ucsd.edu). For a full list of reference stations, go to www.trimble.com/findtrs.asp.

b. DGPS beacon conforming to the International Association of Lighthouse Authorities (IALA) (www.iala-aism.org) broadcast corrections free to air. Availability varies from country to country. For a full list of beacon stations, go to www.trimble.com/findbeacon.asp.

c. OmniSTAR L-Band satellite differential-based differential correction service is a subscription-based service that provides DGPS corrections globally. For more information, go to www.omnistar.com.

d. VRS networks are becoming more widespread. Consisting of dense networks of GPS receivers, they deliver corrections by means of cellular communications. Some VRS networks are private, but many are publicly available through subscription services or cooperative agreement. For a list of available VRS networks, go to www.trimble.com/vrsinstallations.shtml. While all VRS systems support GPS, not all support L1 code corrections used by mapping receivers. Check availability of L1 code corrections (DGPS) with your virtual reference station provider.

e. Users can set up their own reference station where other services are not available. This requires surveying techniques to establish known coordinates for the reference station, a secure location with a clear view of the sky, and infrastructure to install and run the reference station.

What new developments are planned for GPS?

Development of the GPS system has been ongoing since the first Block I concept validation satellite was launched in 1978. GPS Block II satellites were first launched in 1989, and launches continue today, with the most recent launch in October 2007. Block II satellites have seen many iterative improvements, which are designated II/IIA/IIR/IIR-M/IIF.

GPS Block IIR-M satellite improvements include a new military signal on both the L1 and L2 channels, and a more robust civilian signal (L2C) on the L2 channel. Presently the GPS constellation includes four GPS Block IIR-M satellites. A further four Block IIR-M satellites remain to be launched.

GPS Block IIF satellites are the next generation of GPS satellites. The GPS Block IIF satellites will provide all the capabilities of the previous blocks, with additional benefits to include an extended design life of 12 years, faster processors with more memory, and a new civilian signal on a third frequency (L5). GPS Block III will be the next block of GPS satellites. In addition to the other signals, GPS III will transmit a new civilian signal (L1C), which is designed to be highly interoperable with Galileo[4]. The GPS III satellites will not support Selective Availability (SA). (SA introduces random clock errors into GPS, thereby degrading autonomous accuracy, but has been disabled since May 2000)[5].

What benefits will the L2C signal offer?

L2C is a code modulation on the L2 frequency. It offers improved signal strength and tracking of the L2 signal. This means simpler receiver techniques are required to track L2, and that it may be tracked in locations where today the L2 signal is not able to be tracked with a given receiver, such as around trees. The benefits of L2C will be incremental to users that currently use dual-frequency GPS.

What benefits will the L5 signal offer?

The addition of L5 allows better ambiguity resolution and ionosphere modeling. This will result in higher accuracies being achieved faster and maintained over longer distances (baselines) between the roving receiver and the reference station. Expected to be stronger than L1 or L2, the L5 signal should provide robust tracking in difficult environments.

What new developments are planned for GLONASS?

The first GLONASS satellites were launched in 1982 shortly after GPS, and launches have continued to the present day. However, a combination of short operational life of satellites, launch failures, and economic challenges have meant that GLONASS has lagged behind GPS in attaining global coverage.

The current generation of GLONASS satellites, GLONASS-M, comprises nine of the thirteen usable satellites, and benefits from a longer design life of seven years. At the time of writing, three satellites launched in December 2007 have yet to be declared operational. A further three GLONASS-M satellites are scheduled for launch in September 2008, and the first GLONASS-K launch of two satellites is scheduled for October 2008. This plan should see GLONASS reach the eighteen satellites required for minimal global coverage in 2008.

Political commitment to GLONASS from Russia has lead to the modernization of the constellation in a relatively short period of time. In addition, Russia and the US issued a joint statement in December 2006, announcing cooperation in joint development of GNSS and a plan to resolve some of the fundamental differences between the systems[6]. Plans include implementation of a new datum for GLONASS based on ITRF (completed in September 2007), and plans to introduce new L1 and L5 GLONASS signals using CDMA.

When will the new signals be usable?

The table below shows estimates of when the new signals can be used.

Signal	Augmentation only (6-12 satellites)	Usable (12 satellites)	Global 24/7 (18 satellites)	Full constellation with redundancy (24 satellites)
GPS L1, C/A code and L2	Today	Today	Today	Today
L2C[a]	2008	2010	2012	2014
L5[a]	2010	2012	2014	2016
GLONASS G1, G1 code and G2[b]	Today	Today	2008	2009
Galileo, All signals[c]	Full operational capability targeted for 2013			

a. Based on the 2008 scheduled launch rate for IIR-M satellites of three per year. These should be regarded as the earliest the signals may be deployed, as delays occur in launch schedules for many reasons.

b. Based on planned launches and the assumption that no further existing satellites will be decommissioned until subsequent launches. It should be remembered that not only does there need to be a reasonable level of satellite coverage, but readily available ground-based infrastructure for differential correction that supports the new signals. This infrastructure modernization would typically lag the GNSS signal modernization by a significant period, subject to user demand.

c. Currently in the development phase, as private partnership funding has failed to eventuate and is in the process of being replaced with a public funding strategy from the EU[7]. This has yet to be ratified. Any timeline is subject to securing adequate funding.

Which Trimble Mapping & GIS receivers support L2C or L5?

Trimble® receivers with R-Track technology support L2C and L5 signals, however at this time neither L2C nor L5 are supported in any Trimble Mapping & GIS receiver. GPS Pathfinder® ProXH™ receivers and GeoExplorer® series GeoXH™ handhelds are dual-frequency receivers, designed to track and use the L1 code and carrier and L2 carrier signals, but are not configured to track and use L2C.

Which Trimble Mapping & GIS receivers support GLONASS or Galileo?

At this time there are no Trimble Mapping & GIS receivers that support GLONASS or Galileo. Trimble receivers with R-Track technology do support GLONASS, however these are survey, infrastructure and construction-grade receivers that employ RTK solutions which benefit from faster initialization times when using dual-constellation tracking techniques.

Can I upgrade my Trimble receiver to support L2C or L5?

At the time of writing no such upgrades are available.

Can I upgrade my Trimble receiver to support GLONASS or Galileo?

At the time of writing no such upgrades are available.

Where can I get further information?

For further information, go to www.trimble.com or contact your local Trimble reseller.

References

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