All the Birds in the Sky

A review of the evolution of the Russian GLONASS system.

by James P. Reilly, PhD

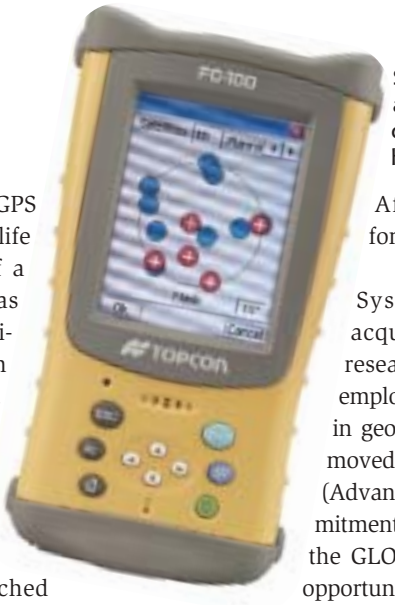
For a few years, the United States cornered the market on global navigation satellite systems with its Global Positioning System. However, Russia quickly caught up with its own constellation. The system is known as GLONASS (GLObal Navigation Satellite System), "a satellite-based radionavigation system, which enables [an] unlimited number of users to make all-weather 3D positioning, velocity measuring and timing anywhere in the world or near-Earth space."* Not too long after Russia's entrance into the satellite navigation arena came options for receiving signals from both GPS and GLONASS.

In the mid 1990s, the first dual constellation receiver boards appeared on the market that integrated single-frequency GPS plus GLONASS signals. A lot has happened since then. Let's take a concentrated look at the current and future GLONASS system, the status of receivers of signals from the NAVSTAR GPS constellation as well as the GLONASS constellation, and understand the benefits of both systems.

GLONASS History and Comparables

GLONASS was developed by the former Soviet Union (USSR) and is quite similar to GPS; in fact, there are more similarities than differences. Consider this brief comparison:

	GLONASS	GPS
Number of satellites	24 (planned)	30 (as of 07/09/04)
Number of orbital planes	3	6
Orbital Inclination	64.8°	55°
Orbital altitude	19,130 km	20,180 km
Period of revolution	$11^h\ 15^m$	$11^h\ 58^m$
Launch site	Baikonur Cosmodrome, Kazakhstan	Cape Canaveral, Fla.
Launch vehicle	Proton K/Dm-2	Delta II
Date of first launch	10/2/1982	2/22/1978
Number of spacecraft/launch	3	1
Carrier frequency		
L1	1602.0 – 1614.94 MHz	1575.42MHz
L2	7/9 of L1	60/77 of L1
Datum	PZ-90	WGS 84
Time reference	UTC (Russia) UTC Russia = UTC + 3^h	UTC (US Naval Observatory)



Surveyors can receive signals from both GPS and GLONASS satellites with the receivers developed by Topcon, making it possible to have 13 or more satellites visible at one time.

One of the major differences between the GPS and GLONASS systems was the initial design life of their satellites. The original design life of a GLONASS satellite from the early 1980s was one to two years. In contrast, the early experimental Block I GPS satellites, launched from 1978 to 1985, had a design life of seven to 7½ years; some of the current, encrypted Block II GPS satellites, launched from 1989 until 1997, have been on orbit for more than 10 years. The latest GLONASS satellites have a design life of three years, but the new GLONASS-M satellites currently being launched incorporate advanced engineering and have a design life of seven years. The new GLONASS-K satellites will have a design life of 10 to 12 years (see details on these new satellites below). Because of the short design life of the early satellites (those launched from 1982 to 1995), there were 64 GLONASS satellites launched and there were six launch failures.

GLONASS Modernization

Much has happened with GLONASS since the fall of the Soviet Union. The emerging Russian Federation government had some financial obstacles to overcome, but can now fully support the program with the help of other nations like China. GLONASS has been approved and funded through 2011, and, in addition to two newly designed satellites (GLONASS-M and GLONASS-K), will feature a new launch vehicle, the Soyuz-2 rocket, beginning in 2006. Soyuz-2 will carry up to nine satellites; the current vehicle carries only three satellites.

The new GLONASS-M satellites have a second civil code. The new GLONASS-K satellites will add a third civil frequency. Figure 1 shows the GLONASS system status as of July 2004. All the current 11 available satellites are operational, and the two listed in red are the newer M-type, already in orbit and transmitting. Surprising to many, the GLONASS addition of a second civil code is ahead of the planned L2C civilian code on the GPS satellites. The GLONASS-K satellites will be introduced this year; plans are to launch six satellites at one time. Looking forward, Figure 2 shows the program of orbital constellation deployment through 2012.

GLONASS plus GPS

In the mid-1990s, Ashtech founder Dr. Javad Ashjaee took on the task of forming a research group of Russian scientists in Moscow to build a satellite receiver with the capabilities of receiving signals from both GPS and GLONASS satellites. He was successful, and Ashtech introduced a single frequency receiver in the late 1990s. After that, Dr. Ashjaee left Ashtech and formed Javad Positioning Systems.

In 2000, Topcon bought Javad Positioning Systems. Through the purchase, Topcon acquired the entire Moscow engineering and research facility, complete with more than 150 employees, many with multiple advanced degrees in geodesy and related fields. Topcon has recently moved into a new facility they call the Topcon ATC (Advanced Technology Center). With the new commitment of the Russian government to fully deploy the GLONASS constellation, and with the potential opportunities through Europe's upcoming Galileo system, this group continues to focus on the future of positioning technology.

With the contribution of its research and engineering resource, Topcon, like several other manufacturers, plans to include all satellite signals into its next generation of

Current GLONASS System Status

GLONASS Constellation Status (July 20, 2004)

GLONASS number	Cosmos number	Plane/ slot	Frequency channel	Launch date	Intro date	Status
794	2402	1/02	04	10-12-2003	02-02-2004	operating
789	2381	1/03	12	01-12-2001	04-01-2002	operating
795	2403	1/04	06	10-12-2003	30-01-2004	operating
711	2382	1/05	02	01-12-2001	15-04-2003	operating
701	2404	1/06		10-12-2003		
787	2375	3/17	05	13-10-2000	04-11-2000	operating
783	2374	3/18	10	13-10-2000	05-01-2001	operating
792	2395	3/21	05	25-12-2002	31-01-2003	operating
791	2394	3/22	10	25-12-2002	10-02-2003	operating
793	2396	3/23	11	25-12-2002	31-01-2003	operating
788	2376	3/24	03	13-10-2000	21-11-2000	operating

Note: All the dates (DD.MM.YY) are given at Moscow Time (UTC+0300).

Figure 1. The current GLONASS system status shows that the newer M-type satellites (shown in red) are already in orbit and transmitting.

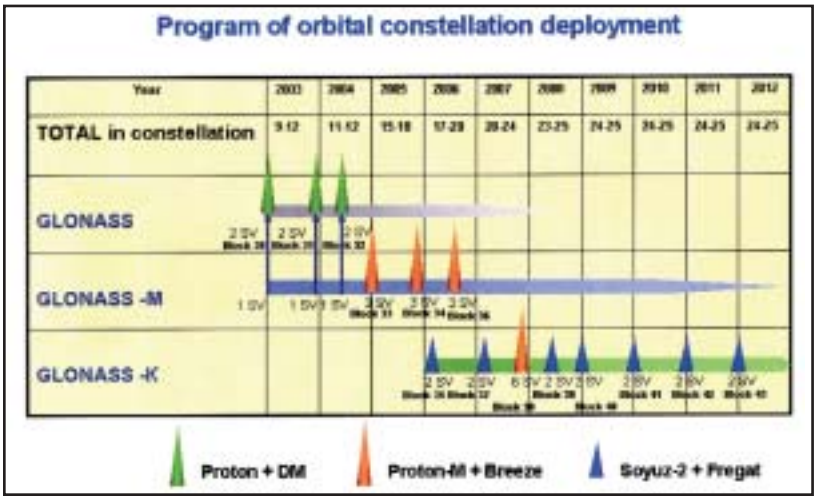


Figure 2. Program of orbital constellation deployment through 2012.

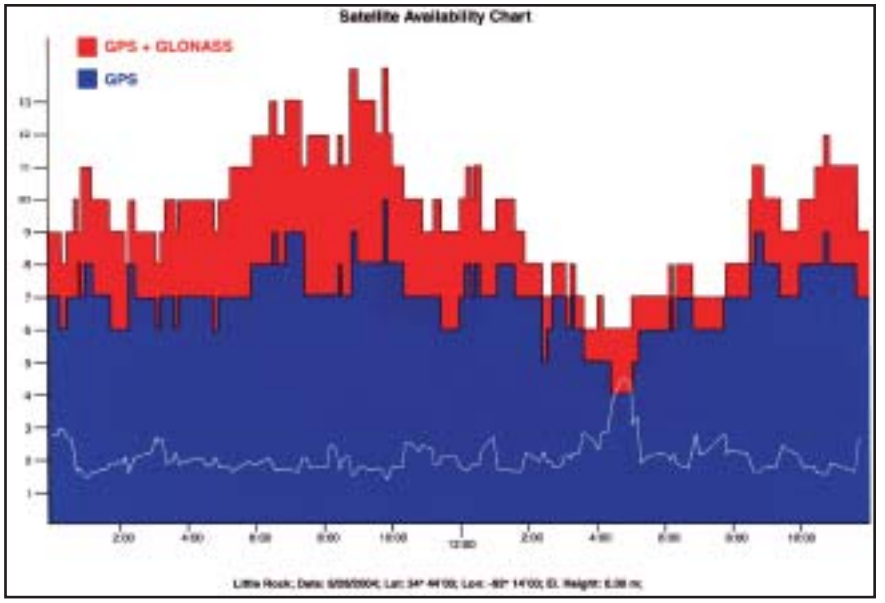


Figure 3. At times, five GLONASS satellites are visible along with the average seven GPS satellites, adding strength to positioning.

receivers. This includes the planned new GPS L5 frequency, L2C code message, third GLONASS frequency and the future Galileo satellite signals.

GLONASS Signals

Are there instruments that receive only GLONASS signals? Yes, but at this time the number of satellites in the GLONASS constellation is not enough to make GLONASS-only receivers compete with GPS-only receivers. The advantage to users is the combination of technologies to provide additional satellite signals and performance over GPS alone. Today, surveyors can receive signals from both GPS and GLONASS with the receivers developed by Topcon, making it possible to have 13 or more satellites visible at one time.

To make a comparison of GPS only, and dual GPS and GLONASS constellations, I contacted Mark Contino, marketing manager of Topcon Positioning Systems. Contino generated the Satellite Availability Chart shown in Figure 3. As the figure shows, at times five GLONASS satellites are visible along with the average seven GPS satellites. Does this add strength to positioning? Yes. Figure 4, a satellite availability comparison, shows that at all times the Dilution of Precisions (GDOP, PDOP, TDOP, HDOP and VDOP) are lower numbers when GLONASS satellites are included—another plus for surveyors.

For surveyors working in high latitudes, adding GLONASS to GPS can add strength to positioning. With the inclination of GPS orbits being 55˚, all satellites are south of the observer's zenith in the second and third quadrants. In Fairbanks, Alaska, for example, the only satellites to the north are on the other side of the North Pole and just barely above the horizon. With the inclination of GLONASS orbits almost

SATELLITE AVAILABILITY COMPARISON

SITE: Little Rock, AR

Latitude: N34°44'00" Longitude: W92°14'00" Altitude: 100.00 m

GPS satellites: 28 GLONASS satellites: 10

Almanac Date: 6/28/2004 UTC Offset: -7:00 Time: Local (CDT)

SATELLITE AVAILABILITY WITH GLONASS

Local Time	Number SVs	GDOP	PDOP	TDOP	HDOP	VDOP
0:00	9	3.31	2.81	1.75	1.2	2.54
0:15	9	3.19	2.72	1.65	1.23	2.43
0:30	9	3.16	2.69	1.66	1.25	2.39
0:45	10	1.9	1.66	0.923	0.872	1.41
1:00	11	1.67	1.49	0.755	0.766	1.28
1:15	10	1.84	1.62	0.864	0.872	1.37
1:30	10	1.94	1.7	0.936	0.916	1.44
1:45	9	2.2	1.9	1.11	0.991	1.62
2:00	9	2.2	1.9	1.11	1.01	1.6
2:15	8	2.46	2.1	1.3	1.06	1.81
2:30	9	2.46	2.1	1.27	1	1.85
2:45	9	2.51	2.16	1.29	0.992	1.93
3:00	9	2.62	2.27	1.31	1.07	2
3:15	9	2.92	2.51	1.48	1.15	2.23
3:30	10	2.23	1.93	1.1	0.933	1.69
3:45	10	2.11	1.82	1.06	0.924	1.67
4:00	10	2.29	1.97	1.18	0.965	1.71
4:15	10	2.37	2.03	1.22	1	1.76
4:30	10	2.36	2.02	1.22	1.05	1.73
4:45	10	2.15	1.85	1.1	0.952	1.58
5:00	10	2.09	1.78	1.1	0.96	1.5
5:15	10	2.12	1.8	1.13	0.967	1.52
9:00	13	1.94	1.7	0.925	0.753	1.53
9:15	13	2	1.76	0.941	0.746	1.59
9:30	13	1.92	1.71	0.882	0.748	1.54

SATELLITE AVAILABILITY WITHOUT GLONASS

Local Time	Number SVs	GDOP	PDOP	TDOP	HDOP	VDOP
0:00	7	4.07	3.44	2.18	1.75	2.96
0:15	7	4.06	3.45	2.14	1.88	2.9
0:30	7	3.91	3.31	2.1	1.78	2.78
0:45	8	1.98	1.75	0.927	0.947	1.47
1:00	8	1.89	1.68	0.862	0.923	1.4
1:15	7	2.11	1.86	0.994	1.05	1.53
1:30	7	2.25	1.98	1.08	1.12	1.63
1:45	6	2.7	2.32	1.38	1.24	1.96
2:00	6	2.73	2.35	1.4	1.28	1.97
2:15	6	2.64	2.27	1.33	1.27	1.88
2:30	7	2.59	2.21	1.34	1.18	1.87
2:45	7	2.67	2.29	1.38	1.18	1.96
3:00	7	2.81	2.42	1.43	1.26	2.07
3:15	7	3.22	2.75	1.68	1.36	2.39
3:30	7	3.45	2.94	1.81	1.4	2.59
3:45	7	2.51	2.15	1.29	1.08	1.86
4:00	7	2.84	2.42	1.49	1.12	2.14
4:15	7	3.02	2.56	1.6	1.16	2.28
4:30	7	3.08	2.62	1.63	1.23	2.31
4:45	7	2.86	2.45	1.48	1.26	2.11
5:00	7	3.01	2.54	1.62	1.52	2.04
5:15	7	2.76	2.35	1.45	1.42	1.88
9:00	6	2.32	2.04	1.11	0.963	1.79
9:15	6	2.46	2.14	1.18	0.949	1.91
9:30	6	2.42	2.12	1.17	0.947	1.9

Figure 4. This satellite availability comparison shows that at all times the Dilution of Precisions are lower numbers when GLONASS satellites are included—a plus for surveyors.

10° higher, observers in Fairbanks will have observable GLONASS satellites in all four quadrants.

The addition of the second civil code to the GLONASS-M satellites is also a plus for the Russian system. A second civil code is planned for GPS Block IIR (replenishment) GPS satellites, which will be called Block IIR-M satellites. However, with recent delays in the launch schedule, that may not happen for some time. On June 22, 2004, a new GPS satellite was launched from Cape Canaveral, Fla. This satellite is GPS IIR-12 (SVN60, PRN 23), a satellite without the second civil code. Block IIR satellites are only launched as needed, and at this time the constellation is full. Now that Russia has three satellites with the second civil code, they may be able to build GLONASS-only receivers that receive these signals.

There is also a second civil code message planned for the next generation GPS satellites due to start launching as replacements next spring. The additional code messages have little impact on precision applications, but are important for GIS/mapping type receivers. The additional code message is thought to assist satellite tracking of low satellites on the horizon, which could benefit precision applications slightly in a few cases.

The Benefits of the Birds

Because of the support from the Russian federal government, GLONASS is alive and developing. The Russian Ministry of Defense is responsible for GLONASS operations. The modernization program's goal is to make the constellation compatible with GPS and the future Galileo system of Europe. The second civil code was added to GLONASS-M satellites, which are now on orbit, and a third carrier frequency will be included on the future GLONASS-K satellites. Being able to launch as many as six satellites in one launch will make the constellation fully operational in a short period of time.

Surveyors today have the option of accessing additional satellites due to GLONASS availability. This can increase performance in obstructed environments and improve precision with lower DOP values. The possibility of systems that utilize GPS plus GLONASS—and perhaps Galileo, too—can allow surveyors to utilize satellite-based positioning technology like never before. I can't wait to see what comes next!

Dr. James P. Reilly is a past president of ACSM and retired department head of the Department of Surveying Engineering at New Mexico State University. He is a regular contributor to POB *magazine and serves on its editorial advisory board.*

*Taken from the website of the German Federal Agency for Cartography and Geodesy's GPS Information and Observation System known as GIBS (found at http://gibs.leipzig.ifag.de/cgi-bin/Info_hom.cgi?en). The function of GIBS is "to satisfy the GPS information requirements of business, science and administrations in Germany."