GLONASS

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GLONASS (Russian: ГЛОНАСС - ГЛОбальная НАвигационная Спутниковая Система; tr.: Global'naya Navigatsionnaya Sputnikovaya Sistema; English: ***GLO****bal* ***NA****vigation* ***S****atellite* ***S****ystem*) is a radio-based satellite navigation system, developed by the former Soviet Union and now operated for the Russian government by the Russian Space Forces. Its United States' counterpart is the Global Positioning System (GPS).

GLONASS logo

GLONASS

Development on the GLONASS began in 1976, with a goal of global coverage by 1991. Beginning in 1982, numerous satellite launches progressed the system forward until the constellation was completed 1995. Following completion, the system rapidly fell into disrepair with the collapse of the Russian economy. Beginning in 2001, Russia committed to restoring the system by 2011, and in recent years has diversified, introducing the Indian government as a partner, and accelerated the program with a goal of global coverage by 2009.[1]

Contents

System description

Purpose

GLONASS was developed to provide real-time position and velocity determination, initially for use by the Soviet military in navigating and ballistic missile targeting. It was the Soviet's second generation satellite navigation system, improving on their Tsikada system which required one to two hours of signal processing to calculate a location with high accuracy. In contrast, once a GLONASS receiver is tracking the satellite signals a position fix is available instantly. It's stated that at peak efficiency system's standard positioning and timing service provide horizontal positioning accuracy within 57-70 meters, vertical positioning within 70 meters, velocity vector measuring within 15 cm/s, and time transfer within 1 µs (all within 99.7% probability).[2]

Orbital characteristics

A fully functional GLONASS constellation consists of 24 satellites, with 21 operating and three on-orbit spares, deployed in three orbital planes. The three orbital planes' ascending nodes are separated by 120° with each plane containing eight equally spaced satellites. The orbits are roughly circular, with an inclination of about 64.8°, and orbit the Earth at an altitude of 19,100 km, which yields an orbital period of approximately 11 hours, 15 minutes. The planes themselves have a latitude displacement of 15°, which results in the satellites crossing the equator one at a time, instead of three at once. The overall arrangement is such that, if the constellation is fully populated, a minimum of five satellites are in view from any given point at any given time.

Each satellite is identified by a "slot" number, which defines the corresponding orbital plane and the location within the plane; numbers 1-8 are in plane one, 9-16 are in plane two, and 17-24 are in plane three.

A characteristic of the GLONASS constellation is that any given satellite only passes over the exact same spot on the Earth every eighth sidereal day. However, as each orbit plane contains eight satellites, a satellite will pass the same place every sidereal day. For comparison, each GPS satellite passes over the same spot once every sidereal day.

Signals

GLONASS satellites transmit two types of signal: a standard precision (SP) signal and an obfuscated high precision (HP) signal.

All satellites transmit the same SP signal, however each transmits on a different frequency using a 25-channel frequency division multiple access (FDMA) technique spanning from 1602.5625 MHz to 1615.5 MHz. The equation to calculate the exact center frequency on L1 is 1602 MHz + $n \times 0.5625$ MHz, where n is a satellite's frequency channel number (n=0,1,2,...24). Signals are transmitted in a 38° cone, using right-hand circularly polarized, at an EIRP between 25 to 27 dBW (316 to 500 watts).

The HP signals use the same FDMA technique, but transmit in the L2 band between 1240 MHz and 1260 MHz, with the center frequency determined by the equation 1246 MHz + $n \times 0.4375$ MHz.[3] Other details of the HP signal have not been disclosed.

At peak efficiency, the SP signal offers horizontal positioning accuracy within 57-70 meters, vertical positioning within 70 meters, velocity vector measuring within 15 cm/s, and timing within 1 µs, all based on measurements from four satellite signals simultaneously.[2] The more accurate HP signal is available for authorized users, such as the Russian Military. And in November 2006, Defense Minister Sergei Ivanov announced that the HP signal will become available for civilian use in early 2007.

An additional civil reference signal on L2 frequency is to be added with the next generation of satellites to substantially increase the accuracy of navigation relaying on civil signals.

GLONASS uses a coordinate system named "PZ-90", in which the precise location of the North Pole is given as an average of its position from 1900 to 1905. This is in contrast to the GPS's coordinate system, named "WGS-84," which uses the location of the North Pole at its location in 1984.

Satellites

As with GLONASS's predecessor program, Tsikada, GLONASS satellites were developed under the leadership of the *Applied Mechanics NPO*, with the assistance of the *Institute for Space Device Engineering* and *the Russian Institute of Radio navigation and Time*. Also following the Tsikada precedent, serial production for GLONASS satellites was accomplished primarily by the *Polet PO*.

Over the three decades of development, the satellites themselves have gone through numerous revisions, separated here as generations. The name of each satellite was **Uragan** (English: *hurricane*), followed either by a number for operational satellites or by an acronym GVM (Russian: габаритно-весовой макет; English: *size weight dummy*) for test satellites. All Uragan satellites had a GRAU designation 11F654, and each of them also had the usual ordinal "Cosmos-NNNN" designation.[4]

Prototypes (Generation zero)

The first GLONASS vehicles to be launched, referred to as Block I vehicles, were prototypes and GVM dummy vehicles. Three dummies and 18 prototypes were launched between 1982 and 1985. Designed to last only one year, many averaged an actual lifetime of 14 months.

First generation

The true first generation of **Uragan** satellites were all 3-axis stabilized vehicles, generally weighing 1,250 kg and were equipped with a modest propulsion system to permit relocation within the constellation. Over time they were divided into Block IIa, IIb, and IIv vehicles, with each block containing evolutionary improvements

Six Block IIa satellites were launched in 1985-1986 with improved time and frequency standards over the prototypes, and increased frequency stability. These spacecraft also demonstrated a 16-month average operational lifetime. Block IIb spacecraft, with a 2-year design lifetimes, appeared in 1987, of which a total of 12 were launched, but half were lost in launch vehicle accidents. The six vehicles which made it to orbit worked well, each operating for an average of nearly 22 months.

Block IIv was the most prolific of the second generation. Used exclusively from 1988 to 2000, and continued to be included in launches through 2005, a total of 25 satellites were launched. The design life was three years, however numerous spacecraft exceeded this, with one late model lasting 68 months.[5]

Block II satellites were typically launched three at a time from the Baikonur Cosmodrome using Proton-K Blok-DM-2 or Proton-K Briz-M boosters. The only exception was when, on two launches, an Etalon geodetic reflector satellite was substituted for a GLONASS satellite.

Second generation

The second, and current, generation of satellites, known as **Uragan-M** (also called GLONASS-M), were developed beginning in 1990 and first launched in 2001.

These satellites possess a substantially increased lifetime of seven years and weigh slightly more at 1,480 kg. They are approximately 2.4 m in diameter and 3.7 m high, with a solar array span of 7.2 m for an electrical power generation capability of 1600 Watts at launch. The aft payload structure houses 12 primary antennas for L-band transmissions. Laser corner-cube reflectors are also carried to aid in precise orbit determination and geodetic research. The on-board cesium clocks provide absolute time accuracy of 1000 nanoseconds.

Eight satellites had been launched as of April 2007, with 14 planned in total. As with the previous generation, the second generation spacecraft can be launched in triplets using Proton-K Blok-DM-2 or Proton-K Briz-M boosters. At least one single launch using an Indian GSLV is also planned.

Third generation

The latest designed generation of **Uragan-K** (GLONASS-K) spacecraft are the third generation of satellites. These satellites are designed with a lifetime of 10 to 12 years, a reduced weight of only 750 kg, and offer an additional L-Band navigational signal. As with the previous satellites, these are 3-axis stabilized, nadir pointing with dual solar arrays. They will enter service following the Uragan-M inventory depletion, expected in 2008.

Due to their weight reduction, Uragan-K spacecraft can be launched in pairs from the Plesetsk Cosmodrome launch site using the substantially lower cost Soyuz-2 1a boosters or in six-at-once from the Baikonur Cosmodrome using Proton-K Briz-M launch vehicles.

Ground control

The ground control segment of GLONASS is entirely located within former Soviet Union territory. The Ground Control Center and Time Standards is located in Moscow and the telemetry and tracking stations are in Saint Petersburg, Ternopol, Eniseisk, Komsomolsk-na-Amure.[6]

Current status

As of May 2007, the system is not fully available, however it is maintained and remains partially operational. There were 11 operational satellites in the GLONASS system and one new satellite in its commissioning phase[7]

In recent years, Russia has kept the satellite orbits optimized for navigating in Chechnya, increasing signal coverage there at the cost of degrading coverage in the rest of the world. As of May 2007, GLONASS availability in Russia was 45.3% and average availability for the whole Earth was down to 30.5%, with significant areas of less than 25% availability.[8] Meaning that, at any given time of the day in Russia, there is a 45.3% likelihood that a position fix can be calculated.

History

Development by the Soviet Union

In the late 1960s and early 1970s, the Soviet Union identified the need and benefits of developing a new satellite-based radio navigation system. Their existing Tsikada satellite navigation system, while highly accurate for stationary or slow-moving ships, required several hours of observation by the receiving station to fix a position, making it unusable for many navigation purposes and for the guidance of the new generation of ballistic missiles.

From 1968 to 1969, the research institutes of the Ministry of Defence, Academy of Sciences, and Soviet Navy cooperated to develop a single system for navigation of their air, land, sea, and space forces. This collaboration resulted in a 1970 document that established the requirements for such a system. Six years later, in December, 1976, a plan for developing GLONASS was accepted in a *Decision of the Central Committee of the CPSU and of the Council of Ministers of the USSR* entitled "On Deployment of the Unified Space Navigation System GLONASS."

From 1982 through April 1991, the Soviet Union successfully launched a total of 43 GLONASS-related satellites plus five test satellites. In 1991, twelve functional GLONASS satellites in two planes were available; enough to allow limited usage of the system.

Completion, then decay, under Russia

Following the disintegration of the Soviet Union in 1991, continued development of GLONASS was undertaken by the Russian Federation. It was declared operational on September 24, 1993 by then-president Boris Yeltsin, however the constellation was not completed until December 1995.

In the six years following completion, Russia was unable to maintain the system. By April of 2002, this resulted in only eight satellites remaining in operation, which rendered the system almost useless as a global navigation aid.

Restoration and modernization

With GLONASS falling rapidly into disrepair, a special-purpose federal program named "Global Navigation System" was undertaken by the Russian government on August 20, 2001. According to it, the GLONASS system was to be restored to fully deployed status (i.e. with 24 satellites in orbit and the global continuous coverage) by 2011.[9]

The New York Times reported that Russia had committed to accelerated launches, with eight satellites scheduled to be orbited in 2007 and a goal of reaching global coverage in 2009.[1] As of April 2007, the number of operational satellite had increased to twelve, in addition to one new satellite in its commissioning phase.[7]

Cooperation with the Indian government

In January, 2004 the Russian Space Agency (RSA) announced a joint venture deal with India's space agency, the Indian Space Research Organization, where-in the two government agencies would collaborate to restore the system to constant coverage of Russian and Indian territory by 2008 with 18 satellites, and be fully operational with all 24 satellites by 2010.[10]

Details announced in mid-2005 reported that Russia would build the satellites and that between 2006 and 2008 two satellites would be launched from India’s Satish Dhawan Space Center in Andhra Pradesh state, using the Indian Geosynchronous Satellite Launch Vehicle (GSLV) rockets.[11] As of April, 2007, India has yet to launch any satellites as part of this project.

During a December 2005 summit between Indian Prime Minister Manmohan Singh and Russian President Vladimir Putin, it was agreed that India would share some of the development costs of the GLONASS-K series and launch two of them from India, in return for military-grade signal access.

Discussions with United States government

Following the December 2006 meeting in Moscow of the GPS-GLONASS Interoperability and Compatibility Working Group (WG-1), an announcement appeared on both US and Russian government websites stating both sides had made significant progress in understanding the benefit to the user community of changing GLONASS to a signal pattern that is in common with GPS and Galileo.[12] A change in the GLONASS system from its current FDMA technique to the GPS and Galileo's CDMA format would enable a simply-designed receiver to use both satellite systems simultaneously.

GPSWorld reported that the group had met twice prior to then and that the working group would likely make an announcement when they meet again in April 2007, during the International Satellite Forum 2007 in Moscow.[13] However, as of May 2007, no announcement has been made.

Civilian signals made officially available

On May 18th 2007, Russian president Vladimir Putin signed a decree officially providing open access to the civilian navigation signals of the GLONASS system, to Russian and foreign consumers, free of charge and without limitations. The Russian president also directed the Federal Space Agency to coordinating work to maintain, develop and enable the system for civilian and commercial needs.[14]

See also

- Global Navigation Satellite System - the generic term for a global satellite positioning system
- Multilateration - the mathematical technique used for positioning

Notes and references

1. ^ ***a b*** Kramer, 2007
2. ^ ***a b*** "A Review of GLONASS" Miller, 2000
3. **^** GLONASS transmitter specs

4. ^ *Uragan*, Russian Space Web
5. ^ GLONASS #787, 68.7 operational months; as reported by RSA "GLONASS constellation status" on 6 April 2007
6. ^ GLONASS Summary, Space and Tech
7. ^ [a] [b] "GLONASS constellation status..." RSA, 2007
8. ^ "Integral accessibility..." RSA, 2007
9. ^ Russian Government, 2001
10. ^ "Russian space agency plans..." MosNews, 2004
11. ^ "India to launch..." MosNews, 2005
12. ^ "Joint announcement..." GPS/GLONASS, 2006
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14. ^ "The services of system..." Ria Novosti, 2007

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External links

- Russian Spacy Agency's English language GLONASS site (http://www.glonass-ianc.rsa.ru/pls/htmldb/f?p=202:1:16827457493506720876)

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