Space Navigation in Russia: History of Development

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Krasnoyarsk, 18 – 22 may, 2015
Development of space activity in Siberia started on June 4, 1959 with the affiliated company of Design Bureau No.1 established in the city of Krasnoyarsk–26 (today, city of Zheleznogorsk).

The first practical implementation of the company was the 11K65 launch vehicle ("Cosmos") and three small satellites of the "Cosmos" series (No. 38,39,40) launched on 18 August, 1964 which successfully continues today.

1 August 1977 - NPO PM was established.

1997 - NPO PM was renamed as "Academician M.F. Reshetnev NPO PM".

3 March 2008 - rearranged as JSC «Academician M.F. Reshetnev “Information Satellite Systems”».
SATELLITE PRODUCTION CYCLE

- Development
- Manufacture
- Testing
- Maintenance

of satellites and systems designed for communication, TV-broadcasting, data relay, navigation, and geodesy for the benefit of national security, social and economic development, and cultural evolution of the country and international links.
SATELLITES FOR ALL ORBIT TYPES

- Raduga: Communication satellite
- Sesat: Communication satellite
- ГЕО-ИК: Geodesy satellite
- Луч: Communication satellite
- Ekran-M: Direct broadcasting satellite
- Molniya: Communication satellite
- Express-AM: Communication satellite
- Gonets-D1: Communication satellite
- Express-A4: Communication satellite
- Gorizont: Communication satellite
- Glonass-M: Navigation satellite
- СЕСАТ Спутник связи
- РАДУГА Спутник связи
- ГОРЕЗОНТ Спутник связи
- ЭКСПРЕСС-А4 Спутник связи
- ГЛОНАСС-М Навигационный спутник
- ГОНЕЦ-Д1 Спутник связи

Satellite Fleet of Russian Federation in total: 134 satellites

- 94 satellites were developed and manufactured by JSC ISS
- 40 satellites were developed and manufactured by other enterprises

JSC ISS 70%

Other 30%
JSC «ACADEMICIAN M.F. RESHETNEV « INFORMATION SATELLITE SYSTEMS» (ZHELEZNOGORSK) IS THE PIONEER OF SATELLITE NAVIGATION IN RUSSIA

SPACE NAVIGATION
NAVIGATION SATELLITE EVOLUTION

1967 1st Generation of SNS

1982 2nd Generation of SNS

2011 3rd Generation of SNS

Directive No. 823-247 of the CPSU Central Committee and the Council of Ministers of the USSR Dated of August 29, 1979


GLONASS Sustainment, Development and Use for 2012 – 2020 Federal Program.
Satellite navigation started with creation of space navigation systems based on Doppler navigation approach. With a Doppler frequency increment for one fast-moving satellite, an user defines his own position on the ground surface (which is especially for benefit of maritime users) with intervals of ~ 1.5 hours and accuracy of 100 meters.

These parameters determined the orbit type selected (circular subpolar orbit with altitude of ~ 1000 km) and number of satellites (~ 6).

**SNS based Tsiklon S/C**
- The first launch of Tsiklon No. 11F (Cosmos-192) – November 23, 1967
- Total 25 Tsiklons

**SNS based Tsiklon-B S/C (the Parus (Sail) System)**
- The first launch of Tsiklon-B No.11F (Cosmos -700) – December 26, 1974
- Total 93 Tsiklons-B

**SNS based Tsikada S/C (the Tsikada (Cicada) System)**
- The first launch of Tsikada No. 11F (Cosmos -883) – December 15, 1976
- Total 21 Tsikadas

**SNS based Nadezhda S/C (COSPAS-SARSAT):**
- The first launch of Nadezhda No.11F (Cosmos-1383) – June 30, 1982
- Total 10 Nadezhdas
GLONASS SYSTEM SPACE COMPLEX

GLONASS SPACE COMPLEX ARCHITECTURE

Generation and transmission of navigation signals
Orbit: circular, H=19140 km, I=64.8 degrees
Constellation: 24 operational satellites in 3 planes (8 satellites per plane)

LAUNCH VEHICLES
S/C launches, development and replenishment of the nominal orbital constellation

Plesetsk
Soyuz-2 LV
Fregat Booster
Glonass S/C

Baikonur
Proton-M LV
Breeze-M Booster
3 Glonass S/C

MODERNIZED GROUND CONTROL SEGMENT WITH SYNCHRONIZATION FACILITIES
Satellite monitoring and control, satellite maintenance;
GLONASS Time Scale generation and keeping, SIS phases synchronization for all S/Cs

GLONASS CONSTELLATION

Glonass 1982
Glonass-M 2003
Glonass-K 2011
Glonass-K2 2018

GLONASS SYSTEM SPACE COMPLEX

ARCHITECTURE

GLONASS SPACE COMPLEX

GLONASS TIME SCALE GENERATION AND KEEPING, SIS PHASES SYNCHRONIZATION FOR ALL S/Cs

LAUNCH VEHICLES
S/C LAUNCHES, DEVELOPMENT AND REPLENISHMENT OF THE NOMINAL ORBITAL CONSTELLATION

PLESETSK
Soyuz-2 LV
Fregat Booster
Glonass S/C

BAIKONUR
Proton-M LV
Breeze-M Booster
3 Glonass S/C

MODERNIZED GROUND CONTROL SEGMENT WITH SYNCHRONIZATION FACILITIES
SATELLITE MONITORING AND CONTROL, SATELLITE MAINTENANCE;
GLONASS TIME SCALE GENERATION AND KEEPING, SIS PHASES SYNCHRONIZATION FOR ALL S/Cs

GLONASS SYSTEM SPACE COMPLEX

ARCHITECTURE

GLONASS SPACE COMPLEX

GLONASS TIME SCALE GENERATION AND KEEPING, SIS PHASES SYNCHRONIZATION FOR ALL S/Cs

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MODERNIZED GROUND CONTROL SEGMENT WITH SYNCHRONIZATION FACILITIES
SATELLITE MONITORING AND CONTROL, SATELLITE MAINTENANCE;
GLONASS TIME SCALE GENERATION AND KEEPING, SIS PHASES SYNCHRONIZATION FOR ALL S/Cs
SECOND GENERATION OF THE SPACE NAVIGATION SYSTEM

Glonass

Design life - 3 years;
Mass - 1413 kg;
Power consumption - 1000 W;
Accuracy of S/C Earth orientation - ± 0.5 deg.;
Accuracy of S/C Sun orientation - ± 2 deg.;
Stability of onboard frequency generator - 1×10⁻¹³;
Navigation signals: Frequency Division Multiple Access - L1OF; L1SF; L2OF; L2SF;
Launched - 88 S/Cs

Glonass-M

Design life - 7 years;
Mass - 1415 kg;
Power consumption - 1250 W;
Accuracy of S/C Earth orientation - ± 0.5 deg.;
Accuracy of S/C Sun orientation - ± 2 deg.;
Stability of onboard frequency generator - 1×10⁻¹³;
Navigation signals: Frequency Division Multiple Access - L1OF; L1SF; L2OF; L2SF;
Launched - 42 S/Cs
THIRD GENERATION OF THE SPACE NAVIGATION SYSTEM

Glonass-K1

- Design life: 10 years;
- Mass: 962 kg;
- Power consumption: 1600 W;
- Accuracy of S/C attitude control: ± 0.5 deg;
- Stability of onboard frequency generator: $5 \times 10^{-14}$;
- Navigation signals:
  - FDMA
  - CDMA
- Launched since 2018

Glonass-K2

- Design life: 10 years;
- Mass: 1645 kg;
- Power consumption: 4370 W;
- Accuracy of S/C attitude control: ± 0.25 deg;
- Stability of onboard frequency generator: $5 \times 10^{-14} \div 5 \times 10^{-15}$;
- Additional PL equipment: 6
- Navigation signals:
  - FDMA
  - CDMA
  - L1OF; L1SF;
  - L2OF; L2SF;
  - L3OC;
  - 2 S/Ca
- Launched since 2018
GLONASS CONSTELLATION

Status as of May 18, 2015.

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<td>Under flight test</td>
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The Ground Control Segment (GCS) serves for automated control of GLONASS satellites.

Within the management process GCS resolves the following tasks:
- Planning of work with satellites for GCS means, control of satellite injected into orbit;
- Control and analysis of satellite operation and status;
- Determination and prediction of satellite orbit parameters and calculation of ephemeris, clock, and almanac data;
- Upload and control of mission data (ephemeris, clock data, etc.) with the purpose of navigation frame generation;
- Check, phasing, and correction of Onboard Time Scale;
- Control of navigation data downloaded;
- Control of SIS performances.
# PROGRAM OF THE GLONASS CONSTELLATION

## DEVELOPMENT AND SUSTAINMENT

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*Program of the Glonass Constellation Development and Sustainment*
HIGH PRECISION INFORMATION PROVISION

HIGH-PRECISION COORDINATE DETERMINATION
Constellation of GLONASS navigation satellites
Relay satellite
Navigation signal
Updating information
User coordinates
Differential station

MONITORING OF OBJECTS
Constellation of GLONASS navigation satellites
Relay satellite
Navigation signal
Object position data
Object coordinates
Monitoring centre

Cartography and Land Use
Constellation of GLONASS navigation satellites
Communication links (Internet etc.)
Navigation signal
Navigation data users
Electronic Data Bases for data gathering and processing received from navigation data users

Monitoring of Extended Objects Condition
The project of the motorway bridge structural monitoring for M-53 federal highway near Krasnoyarsk was designed and is in use currently. Technology of bridge member control using GLONASS technology was proven under real-time testing. Accuracy characteristics for relative motion of bridge reference points: 1-3 mm
SPACE SYSTEM FOR AUTOMATED OIL PIPELINE MONITORING USING GLONASS GNSS
(one of the prospective projects)
Thank You for Your Attention!

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