

Research and Production Corporation
“Precision Systems and Instruments” RPC PSI



*System for high-accuracy
determination of ephemeris and time
corrections (SVOEVP) GLONASS*

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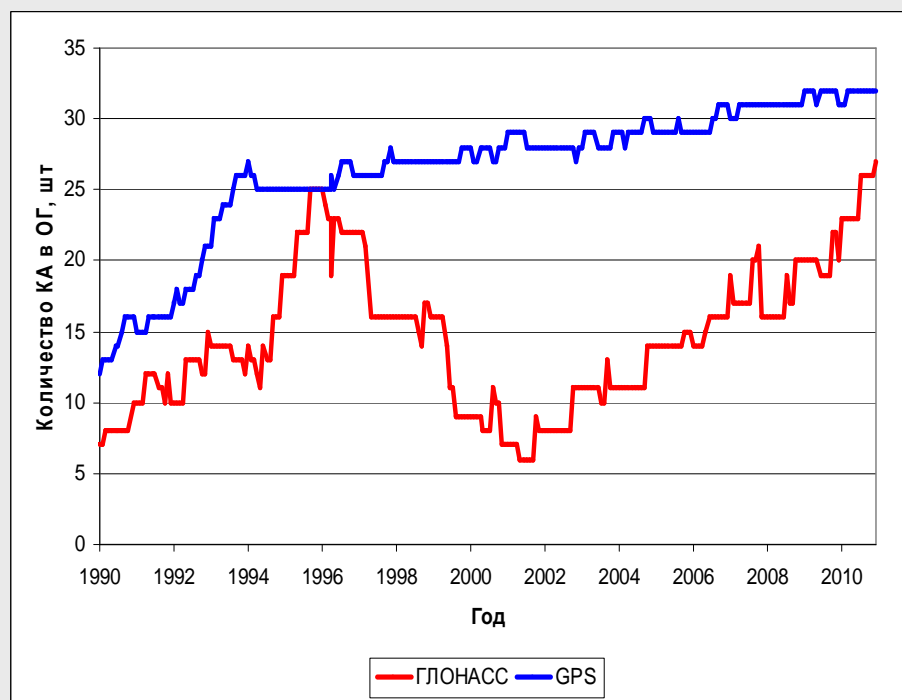
**International conference
«One- and two-way SLR in collocation with radio systems for GNSS»
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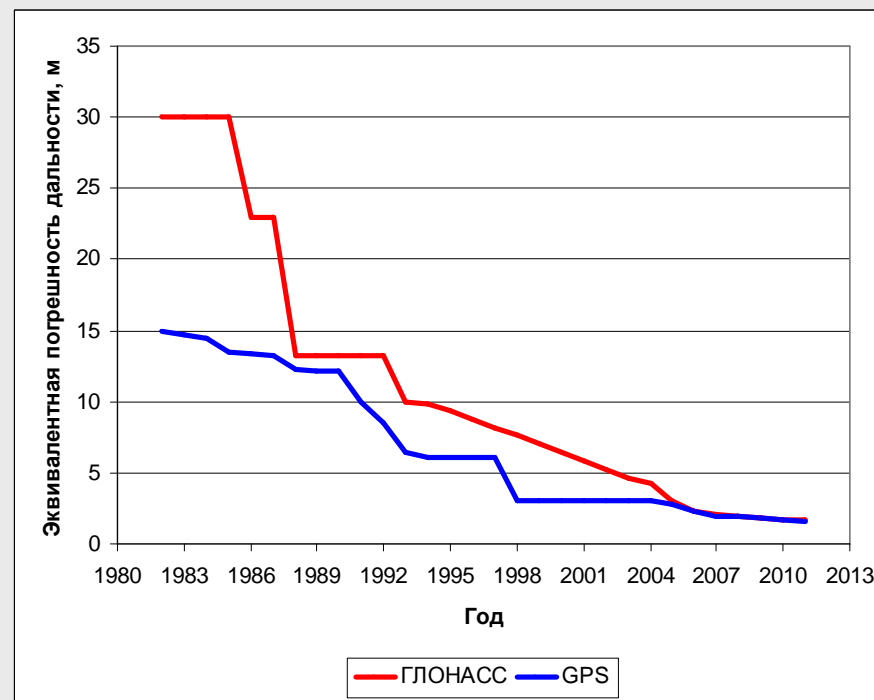
Global Navigation System GLONASS

Federal Target Program «Global Navigation System»

Orbital constellation



Navigation field accuracy





Ways to improve navigation services

1. Improvement of accuracy of S/C motion models and measurements interpretation used for calculation of ephemeris and time information (ETI).
2. Improvement of accuracy of geodetic support for the Ground Control System (GCS).
3. Formation and transmission of ETI accuracy factor within navigation message.
4. Implementation of assistive technologies for accredited users.
5. Correction of errors due to frequency division of GLONASS navigation signals by calibration of user navigation equipment.



Purpose of SVOEVP

The system for high-accuracy determination of GLONASS ephemeris and time corrections (SVOEVP) is intended for provision of high-accuracy solutions of user navigation and time determination problems:

❑ **in real time**

- ❑ by refining SVOEVP adaptive parameters of S/C GLONASS motion model and measurements model,
- ❑ by calculating SVOEVP calibration corrections for user navigation equipment to compensate for errors errors due to frequency division of GLONASS navigation signals.

❑ **not in real time**

- ❑ by calculating high-accuracy ephemeris and time information, parameters of Earth rotation, ionosphere model parameters, wet component of troposphere, assisting data, etc.



SVOEVP composition

**GLONASS
navigation
equipment
calibration facility**

**Information
collection,
processing, and
control center**

**Metrological check
station**

**Station for
calculation of
assisting
information and
provision of
assisting
technologies for
GLONASS
accredited users**



**Own measurement
stations (GMS and
SLR)**

**Station for collection,
analysis and preliminary
processing of information
from domestic civilian and
foreign information sources
and presentation of results
to civilian organizations
and individual users.**



SVOEVP measurement information composition

SVOEVP is a multifunctional system for processing and analysis of diverse measurement information.

2011

1. Global network of GMS stations – up to 250 stations
2. Network of international (30) and domestic (10) SLR stations
3. Very Long Baseline Interferometry (VLBI) “Quasar-KVO” – 3 stations

By 2020 SVOEVP is planned to include

1. DORIS network stations – up to 50 stations.
2. Water vapor radiometers (WVR) network in Russian territory – up to 15-18 stations.
3. Expansion of networks: GMS – up to 400 stations, SLR – up to 50-60 stations (including more than 30 from ILRS network), VLBI – up to 4-5 stations.



SVOEVP tasks

SVOEVP is a part of GLONASS, an unique system having no world analogs because it implements most part of abilities of various international services such as IGS, ILRS, IERS, etc.

Quality improvement of navigation services

- calculation of initial data for navigation frame accuracy factor,
- refinement of adaptive parameters of motion and measurements model,
- refinement of initial geodetic data of measurement stations

Solution of fundamental problems

- support of Federal Geocentric Coordinate System,
- calculation of geodynamic data

Provision of navigation in posterior mode

- Posterior ETI GLONASS/GPS,
- parameters of local models of ionosphere, troposphere, etc.,
- positioning in relative mode;
- navigation of orbital users in absolute mode



Real-time navigation

- assisting technology,
- user navigation equipment calibration

Information support
(computer bulletin, general evaluations of GLONASS and GPS navigation field characteristics, information decision-making bulletins, etc.)



Состав выходной информации СВОЭВП

For GNSS users (SVOEVP web site <http://www.glonass-svoevp.ru>):

1. High-accuracy ETI GLONASS/GPS (Galileo, Compass – as soon as they are in operation) – SP3, RINEX, RINEX_CLOCK, SINEX, IONEX, ANTEX, ERP, TRO, etc.
2. Official information from the System Control Center (SCC)
3. Distribution of GGSK PZ-90.02 (stations catalogue)
4. Calibration delays for GLONASS navigation equipment
5. For accredited users - SBAS, RTCM SC-104, PMD, etc.

Legal aspect:

SVOEVP is the **only legitimate source** of distribution of bulletins about past and planned events with GLONASS S/C (“computer bulletin”), information bulletins about state of orbital constellation

In addition: accuracy characteristics of navigation fields of GLONASS and GPS (Galileo, Compass – as soon as they are in operation), their comparison results, recommendations.



Accuracy of solutions with use of SVOEVP data

Parameter name	Value
Equivalent error of pseudo range at the probability level $P=0.95$ due to errors of the space segment at any daily interval using posterior ETI	0.33 m
Error, at the probability level $P=0.95$, of calculation of translation parameters between Federal Geocentric Coordinate System and coordinate systems of other navigation systems: <ul style="list-style-type: none"> - parameters of relative reference to the Earth center of gravity - parameters of mutual orientation 	0.05 m 0.001 arc s
Error (RMS) of determination of Earth rotation parameters: <ul style="list-style-type: none"> - pole coordinates - duration of day 	0,0004 arc s 0,07 ms
Error, at the probability level $P=0.95$, of determination of GMS coordinates	0.02 m
Error, at the probability level $P=0.95$, of calculation of calibration corrections for GLONASS navigation equipment	0.2 m
Delay in determination of worsening of GPS navigation field characteristics	< 10 min



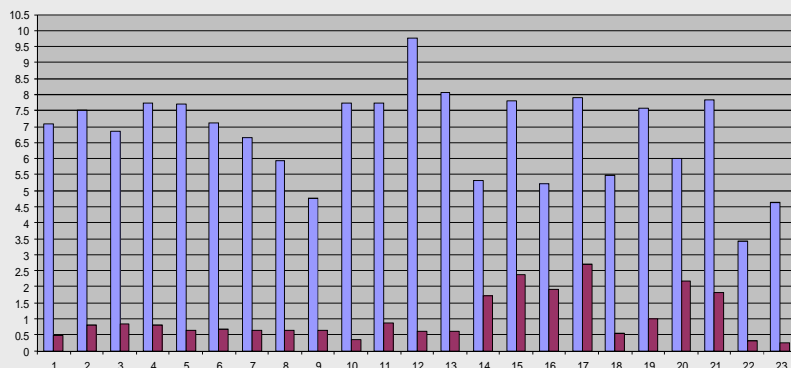
Use of collocation nodes measurements in SVOEVP



Calibration of user navigation equipment

Methods of calculation of relative inter-frequency delays in GMS were developed and implemented in SVOEVP. Relative inter-frequency delays for the global network of stations are available at the SVOEVP web site

<http://www.glonass-svoevp.ru>



World Time (UT1)

Mutual coordination of mathematical models of measurements has been performed in SVOEVP. As a result, mutual processing of GMS and VLBI measurements with obtaining closed-form series of Earth rotation parameters and GLONASS ephemeris was implemented at the competitive level.

$$\{\bar{q}_{KA}, K_1, K_2, K_3\},$$

$$\delta\Delta\psi, \delta\Delta\varepsilon, \Delta UT1, DD, x_p, y_p(TT)$$



SLR place in provision for current SVOEVP tasks

1. Check of distribution of the Federal Geocentric Coordinate System (FGCS) by GLONASS navigation signals.
2. Calculation and check of translation parameters FGCS - ITRF.
3. SVOEVP ephemeris verification using SLR measurements, verification of corrections of onboard time scale using combined one-way and two-way SLR and GMS range measurements.
4. Refinement of initial geodetic data of GLONASS GCS stations (calculation of ground stations velocities)
5. Refinement of location determination of phase centers of satellite antennae systems and analysis of spacecraft attitude system work quality.
6. Support of malfunctioning GLONASS satellites in the case of partial and complete failure of onboard radio systems.
7. Verification and refinement of models parameters used in SVOEVP (motion model, measurements model, geopotential model, etc.)



Perspective of development of laser ranging and SVOEVP

Near-term outlook – development and implementation of models, methods and technology for implementation of one-way SLR in SVOEVP

Accuracy of comparison of on-board and ground time scales ~ 0.1 ns (σ).

First time in GLONASS history!

One-way SLR creates prerequisites for building in SVOEVP a complete close-loop feedback system checking all components of navigation field errors due to space segment:

- ✓ errors of ephemeris and geodynamic parameters;
- ✓ errors of time and frequency information;
- ✓ errors of FGCS



Ways of refinement of SVOEVP characteristics

1. Creation of **sub-millimeter accuracy** one-way and two-way SLR and development of stations network.
2. Development of **S/C “BLITS”** with millimeter-level target error for refinement of the geocenter position determination and relative reference of measurement stations at the promising levels of accuracy
3. Commissioning of a **one-way SLR**, determination of S/C GLONASS time scale differences at picosecond level of accuracy.
4. Development of **inter-satellite SLR**.
5. Building of SVOEVP-based **system for check** of ephemeris and time and frequency corrections of GLONASS, geodynamic information, distribution and transfer of FGCS to end users.



Expected results of improvement of SVOEVP by year 2020

Parameter	Value
Positioning error in Federal Geocentric Coordinate System due to space segment: -in real time -in posterior mode	0.10 m 0.03 m
Errors of Federal Geocentric Coordinate System: -reference between FGCS and the center of gravity of the Earth and rotation angles -distribution and transmission of FGCS	0.01 m 0.02 m
Error in determination of Earth rotation parameters: - pole coordinates – duration of day	0.0001 arc s 0.01 ms
Error of time scales: – GLONASS system time scale and UTC(SU) – UTC(SU) and UTC	4 ns 3 ns
Error of determination of user time in GLONASS system time scale due to space segment errors	1 ns