Open Joint-stock Company «Research-and-Production Corporation
«Precision Systems and Instruments»

THE CONCEPT AND PRELIMINARY RESULTS OF USE OF SATELLITE LASER RANGING FOR IMPROVEMENT OF GLONASS ACCURACY







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Agenda

1. **Current plan of using of laser measurement systems in GLONASS ground and space segments;**

2. **Structure and technical characteristics of GLONASS ground segment laser stations;**

3. **Structure and technical characteristics of GLONASS space segment laser measurement systems;**

4. **Goals and methods of use of laser systems for improvement of accuracy of ephemeris and time parameters of GLONASS and user navigation definitions;**

5. **Preliminary results of in-flight testing of on-board and ground laser systems.**

The concept of use of laser measurement systems in GLONASS ground and space segments

Goal:

Provide GLONASS with higher-accuracy geodetic and ephemeris-time data

GLONASS frequency-time support goals:

1. Measurement of difference between on-board and ground time scales, check and real-time corrections of time and frequency in customer's navigation message;

2. Calibration of radio navigation receivers to measure and take into account time-delay in on-board and ground navigation equipment.

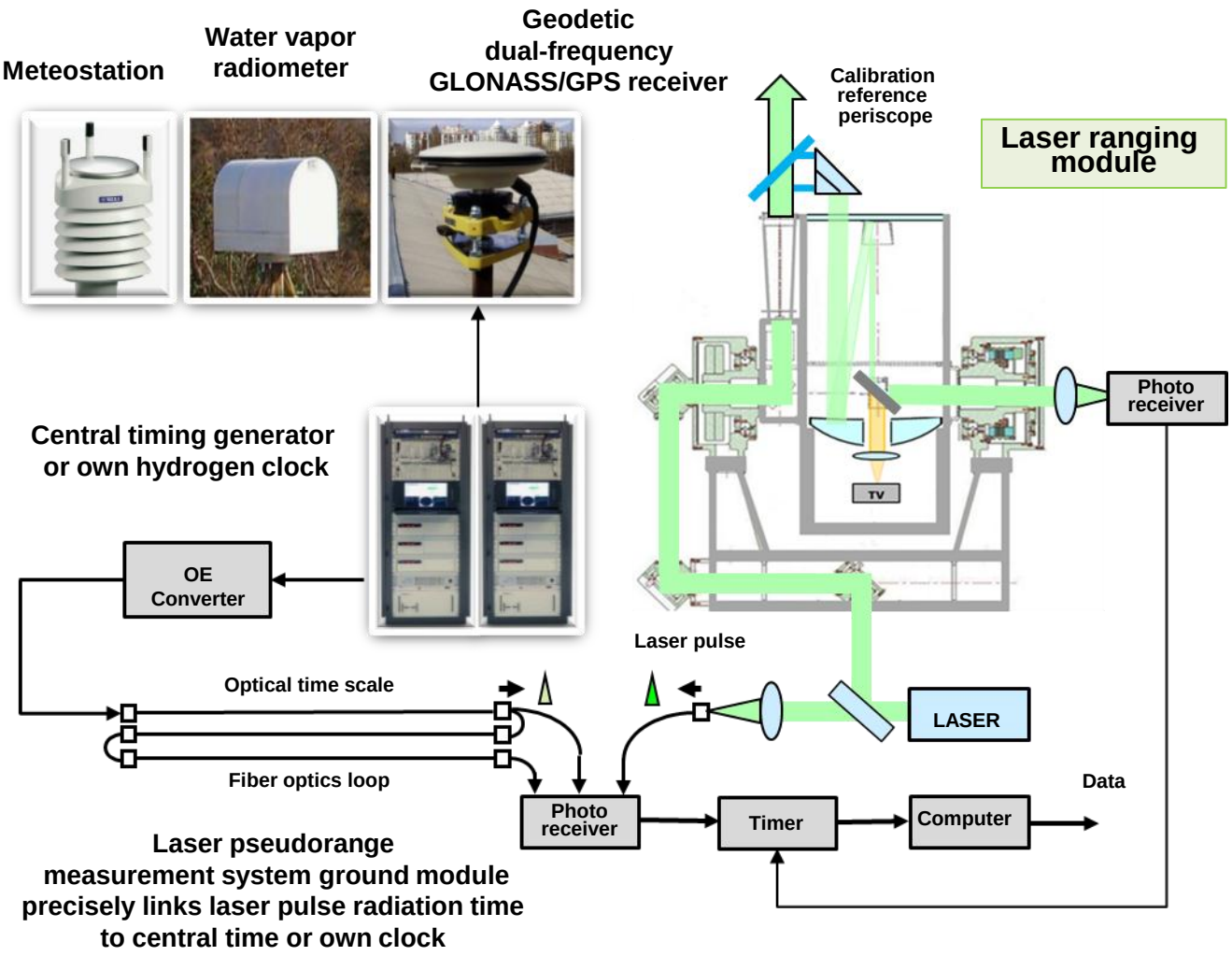
GLONASS geodetic and ephemeris data support goals:

1. Refinement of reference of the State Geocentric Coordinate System (SGCS) to the center of mass of the Earth, calculation SGCS transfer to the International Terrestrial Reference Frame (ITRF);

2. Refinement of geocentric coordinates of GLONASS ground segment measurement systems;

3. Check of GLONASS ephemeris accuracy, check accuracy of transfer of SGCS parameters by GLONASS ephemeris.

Structure and technical parameters of ground segment laser stations modified for joint range and pseudorange measurements



Laser pseudorange measurement system ground module precisely links laser pulse radiation time to central time or own clock

Technical parameters and measurement errors:

(σ NP at 30 s interval)

Range
(using laser measurements)
……..…….... <3 mm (1 mm);

Pseudorange
(using laser measurements)
…….…….....<50 ps (20 ps);

Time scales difference
(using laser measurements)
……..…….. < 50 ps (20 ps);

Pseudorange
(using navigation signals)
using ranging code …….< 0.1 m;
using carrier phase ……..... < 2 mm;

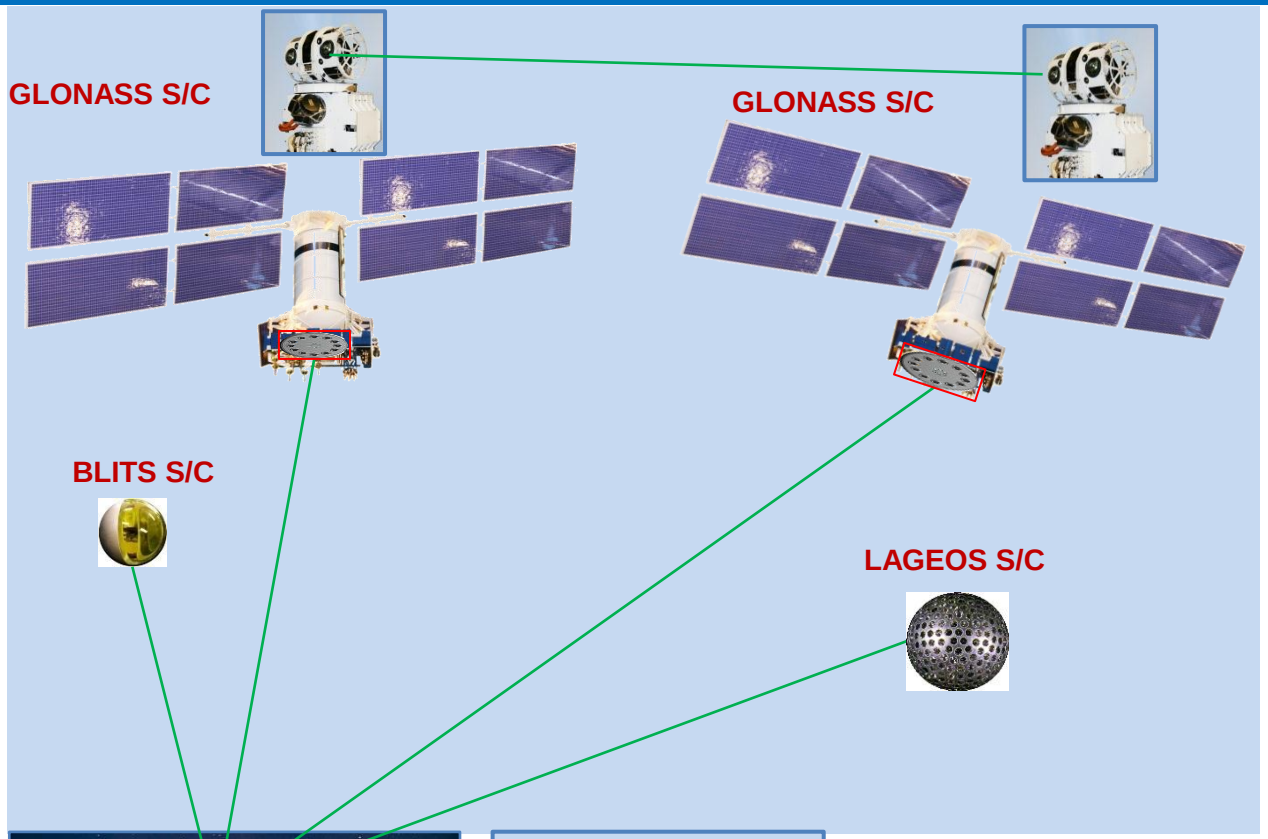
Tropospheric delay
(in the direction of zenith) .... < 0.01 m;

Meteoparameters
air temperature ……..….< 0.25 °C;
atmospheric pressure.. < 0.1 mbar;
air humidity ……..……..< 2 %;

Frequency instability
(daily) ……..……...……..…< $2 \cdot 10^{-15}$.

Location of modernized laser stations of GLONASS ground segment

Structure and technical parameters of GLONASS space segment onboard laser measurement systems



Technical parameters and measurement errors:

(σ NP at 30 s interval)

Range
(using inter-satellite measurements)
…….…… < 0.03 m (0.01 m);

On-board time scales difference
(using inter-satellite measurements)
…….…. < 0.3 ns (0.1 ns);

Pseudorange
(Using LPMS measurements)
……...< 0.05 ns (0.02 ns);

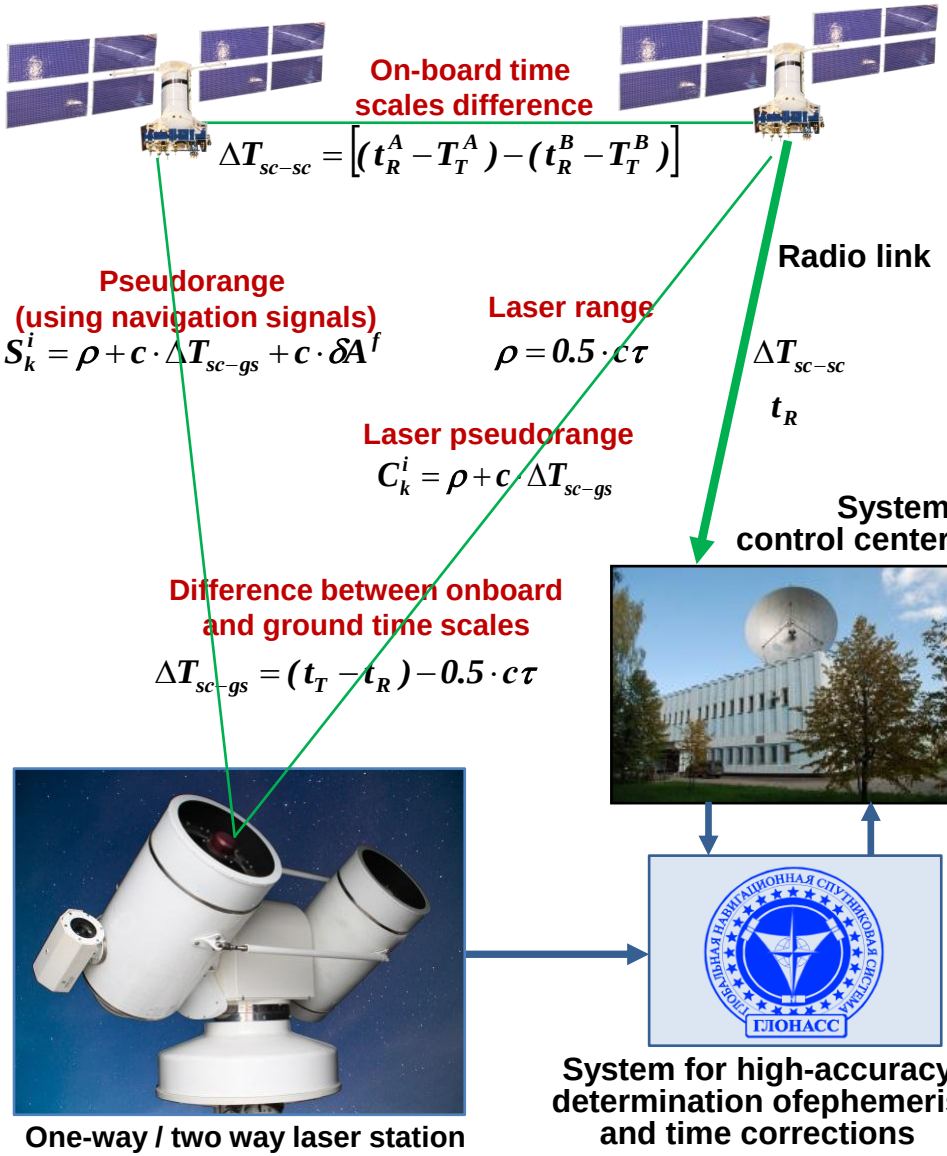
CRS effective area
…….…….…….100 (160)·10^6 m^2.

One-way / two way laser station

Circular retroreflector system (CRS) with LPMS module lenses

Terminals of the Inter-satellite laser navigation and communication system (ISLNCS)

Goals and methods of use of laser systems for improvement of GLONASS accuracy and time-frequency parameters



Inter-satellite laser navigation and communication system

Goal: real-time refinment of navigation message time-frequency corrections for improvement of user navigation accuracy.

Method: direct laser measurement of onboard time scales difference and range between S/C, mutual laser data exchange.

System for laser measurements of range and pseudorange between ground station network and S/C

Goal: shorten time-frequency information refresh time, implement GLONASS distributed group time scale;

Method: measurement of time scale differences at remote stations using differences of their divergence from the onboard time scale of the same navigation S/C;

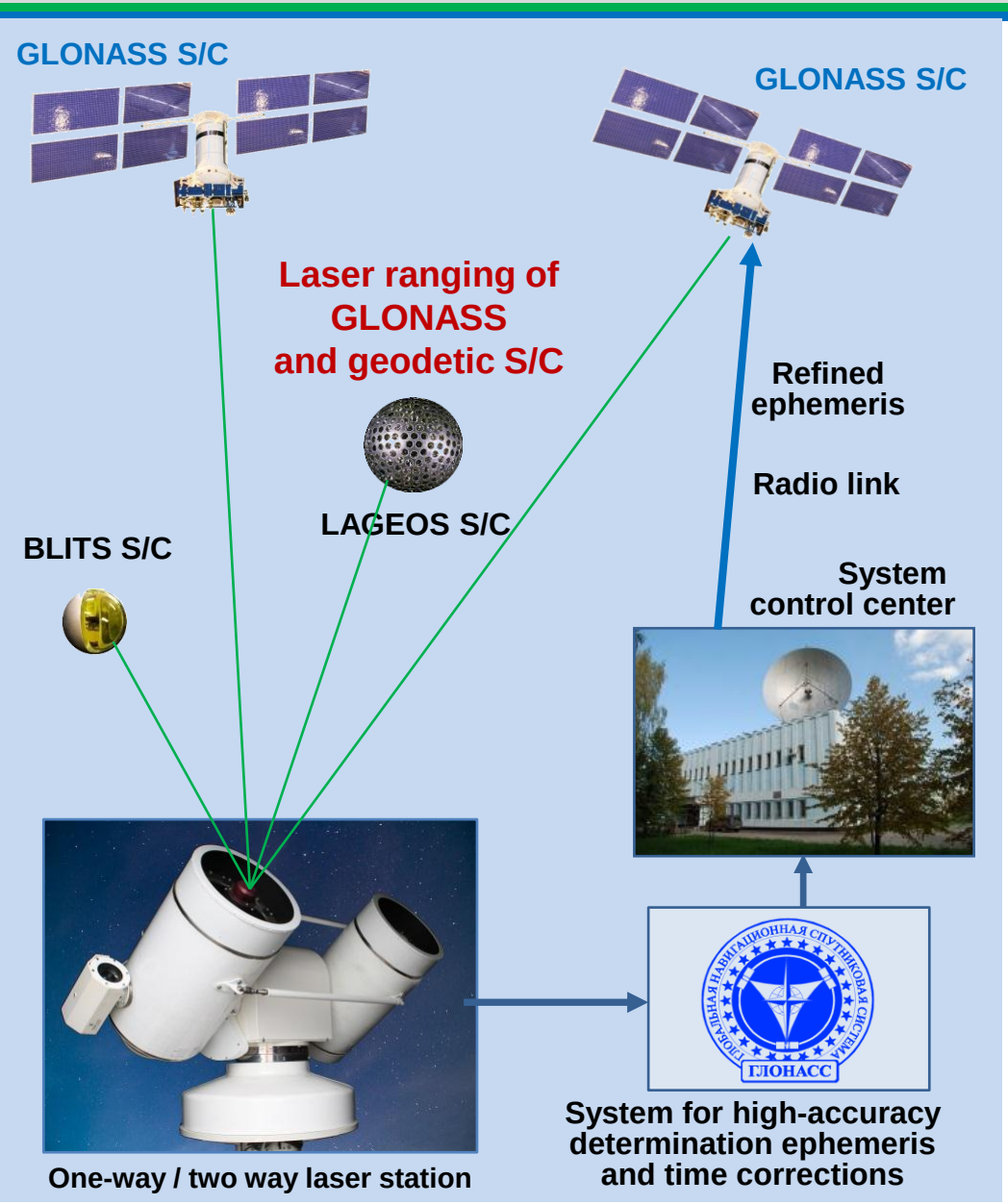
Goal: metrological control of accuracy of navigation message time-frequency corrections;

Method: determine difference of onboard time scales of a navigation S/C from GLONASS onground time scale using range and pseudorange measurements;

Goal: calibration of one-way and two-way radio measurement systems in the operation process;

Method: comparison of laser pseudorange and range measurements with radio pseudorange and range.

Goals and methods of use of laser systems for improvement of GLONASS ephemeris and geodetic support



Laser Ranging System

Goal: accuracy control of GLONASS ephemeris

Method: comparison of laser range measurements with projection of navigation S/C ephemeris onto slant range from SLR.

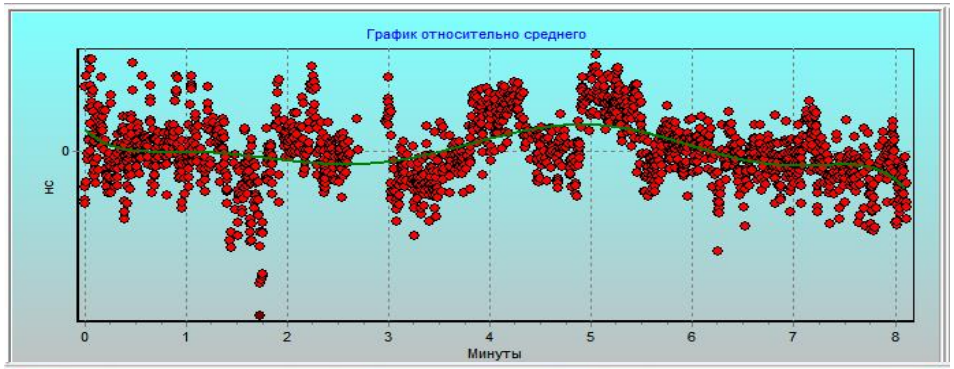
Goal: refinement of measurement stations geocentric coordinates, linking of State Geocentric Coordinate System (FGCS) to the center mass of Earth, as well as correspondence of parameters of SGCS to ITRF.

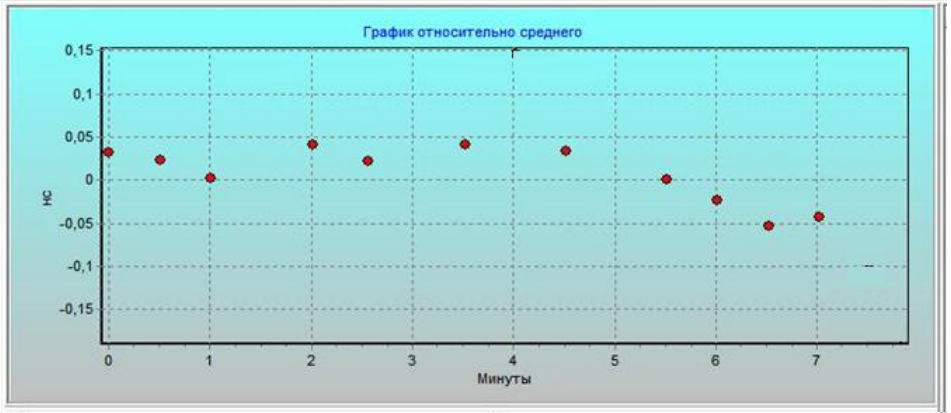
Method: determination of stations geocentric coordinates using laser ranging data of LAGEOS and BLITS S/C.

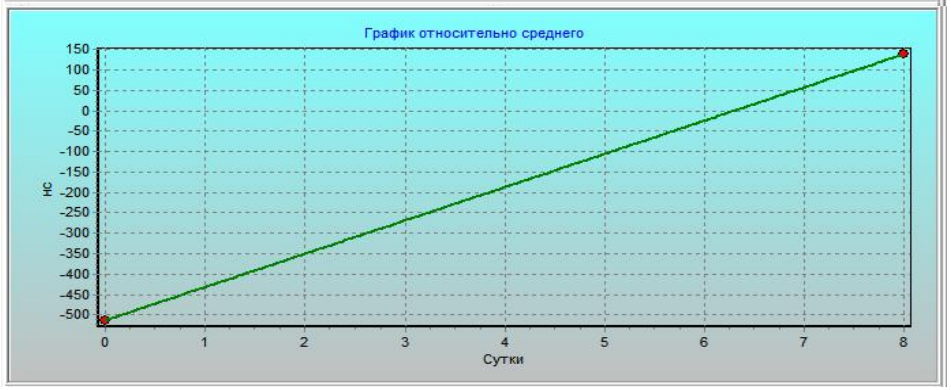
Goal: accuracy control of SGCS parameter transmission by GLONASS ephemeris.

Method: determination of stations coordinates using laser ranging of LAGEOS and BLITS S/C and their comparison with coordinates of the same stations obtained using GLONASS S/C laser ranging and ephemeris data of its navigation message.

Preliminary space flight testing results of laser systems for measurement of ranges, pseudoranges, and time scales differences







Measurements of Altay optical-laser center (12.07–20.07. 2013)

Accuracy estimation of "raw" measurements of difference between onboard time scale of GLONASS № 747 and time scale of AOLC hydrogen frequency standard

Standard deviation = 144 ps.

The same measurements (normal point) at averaging intervals of 30 s.

Standard deviation < 50 ps.

Estimation of GLONASS №747 onboard time scale change of rate relative to time scale of AOLC hydrogen frequency standard at 8-day interval taking into account relativistic corrections:

Measured change rate = 81.55 ns/day.

Measured shift of scales = 20488.09 ns

Preliminary space flight testings results of inter-satellite laser navigation and communication system using «board-ground» link

GLONASS №728

inter-satellite laser navigation and communication system terminal

Space experiment contents:

1. Refinement of standard algorithms for search and tracking of onboard terminal;
2. Measurement of mutual pseudoranges;
3. Processing of measurements results for estimation of accuracy of measurements of relative difference between onboard and ground time scales.

Results of processed measurement sessions

Standard deviation of time scales difference measurement error at one-second averaging interval is 0.19…0.23 ns with normal point of at least 17 pulses;

When number pulses was increased to 60, standard deviation of time scales difference decreased to 0.1 ns.

Inter-satellite laser navigation and communication system ground module

Laser station of Altai optical laser center

ГЛОНАСС

System for high-accuracy determination of ephemeris and time corrections

Thank you

for your attention ☺