TEAM GERMANY SUPPORTS

IAC 69TH INTERNATIONAL ASTRONAUTICAL CONGRESS

BREMEN | 1-5 OCTOBER 2018

#INVOLVING EVERYONE

Flight Results of the Mission of TNS-0 #2 Nanosatellite Connected via Global Communication System

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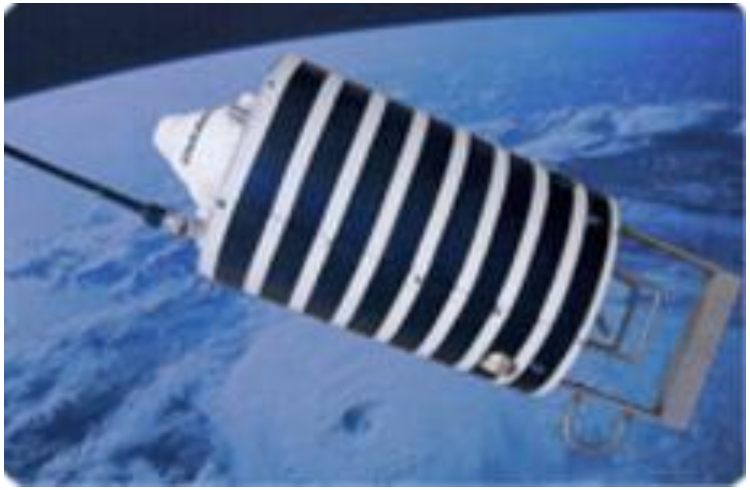
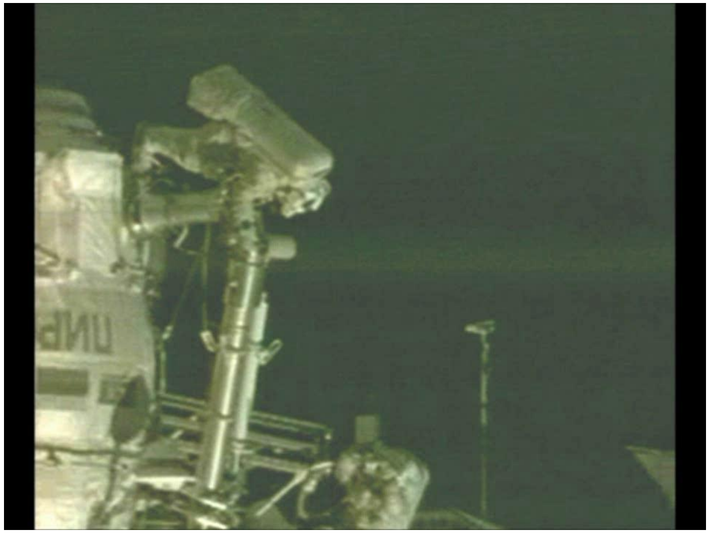
RSS RUSSIAN SPACE SYSTEMS

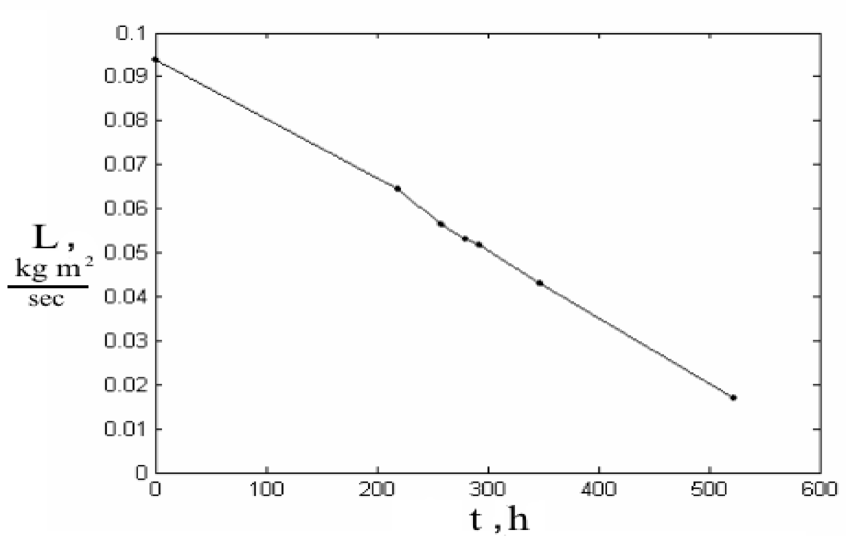
Prehistory: TNS-0 №1



Launch of TNS-0 №1 from ISS



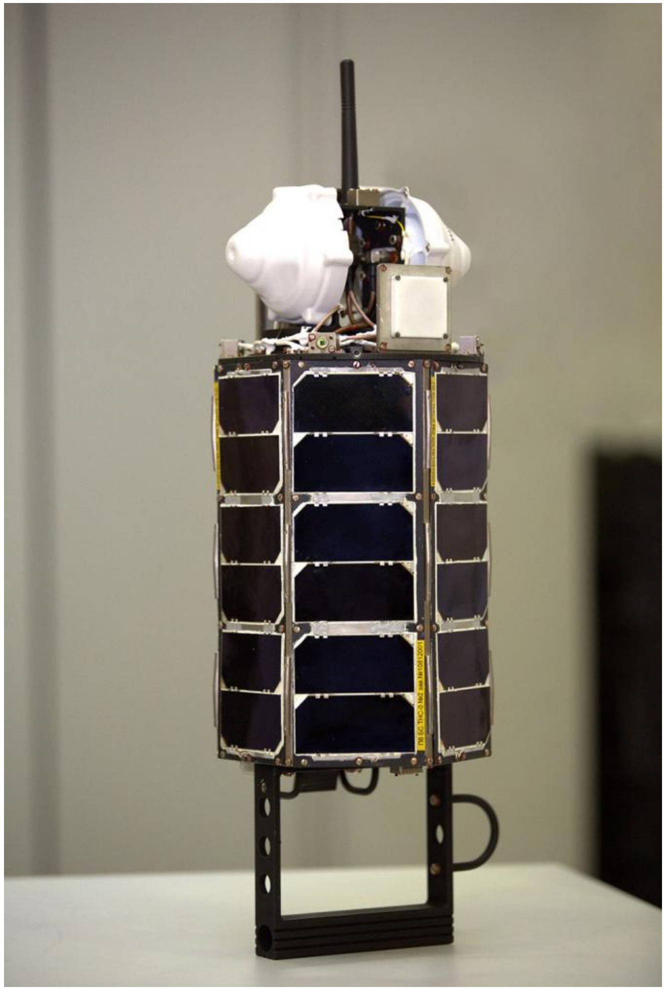
Decrease in the angular momentum



Mission goal	Experiment with Communication via Globalstar
Inclination	51.6 deg
Orbit altitude	360 km
Power supply	Two batteries
Mass	4.5 kg
Attitude control system	Passive magnetic

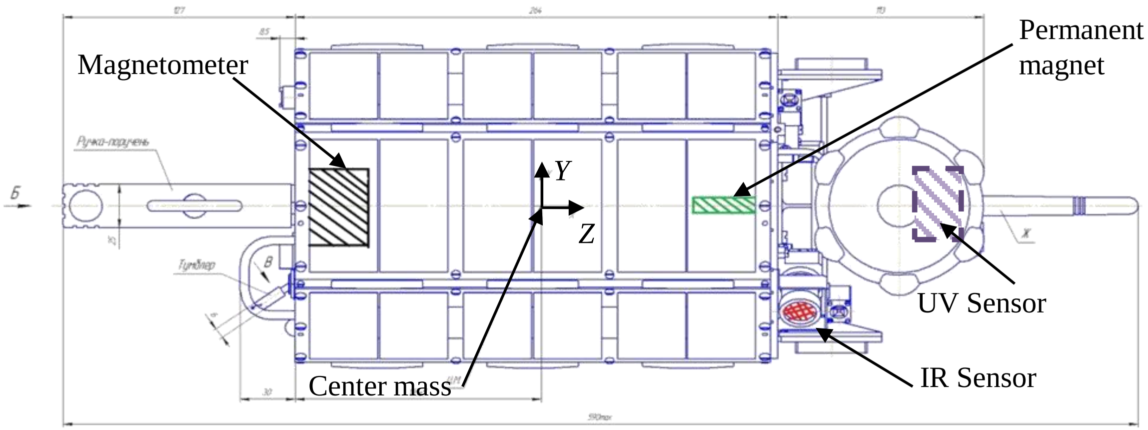
Nanosatellite TNS-0 №2

- **Mission goal:**
  flight tests of sensors and elements of satellite systems
- **Attitude control system:**
  - passive magnetic:
    permanent magnet, hysteresis rods
- **Attitude sensors:**
  - magnetometer
  - 6 photodiode sensors,
    1 IR sensor, 1 UV sensor
- **Communication via:**
  - Globalstar antennas
  - VHF

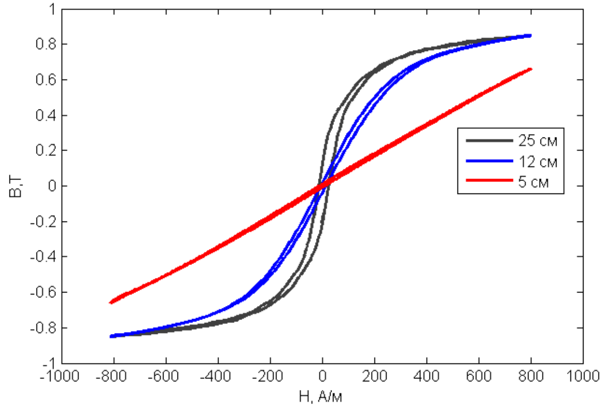


$$J = \begin{bmatrix} 0.06153 & -0.00013 & -0.00033 \\ -0.00013 & 0.06669 & -0.00012 \\ -0.00033 & -0.00012 & 0.01287 \end{bmatrix} \text{kg} \cdot \text{m}^2;\ m = 4.8\ \text{kg}$$

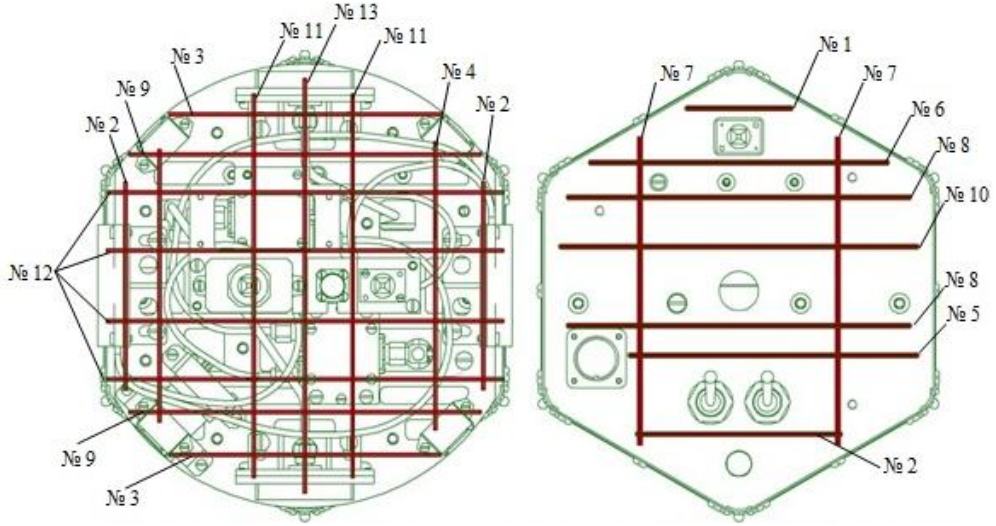
ACS parameters



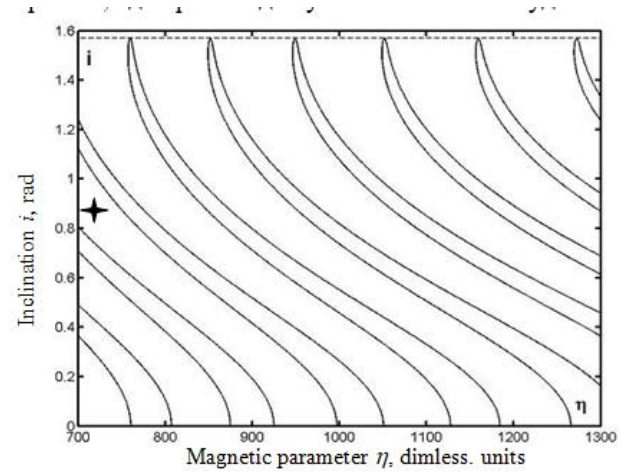
Hysteresis rods curves



. Location of hysteresis rods on the bases of the THS-0 №#2

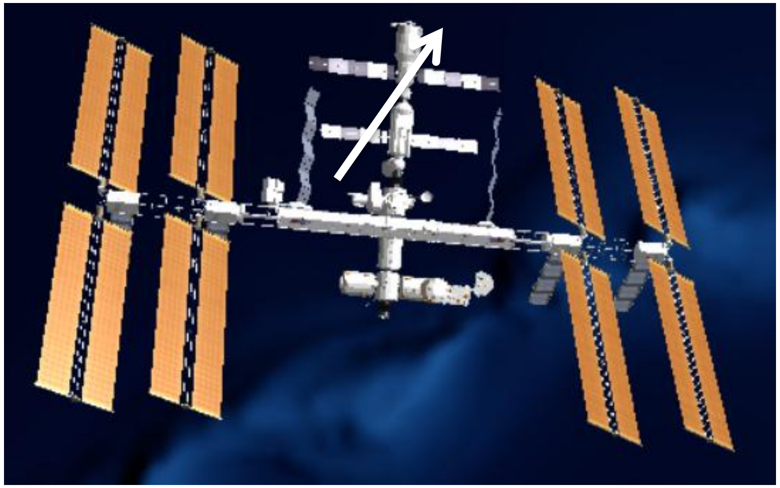


Ramification curves in the vicinity of η=1000 and the value for the TNS-0 #2



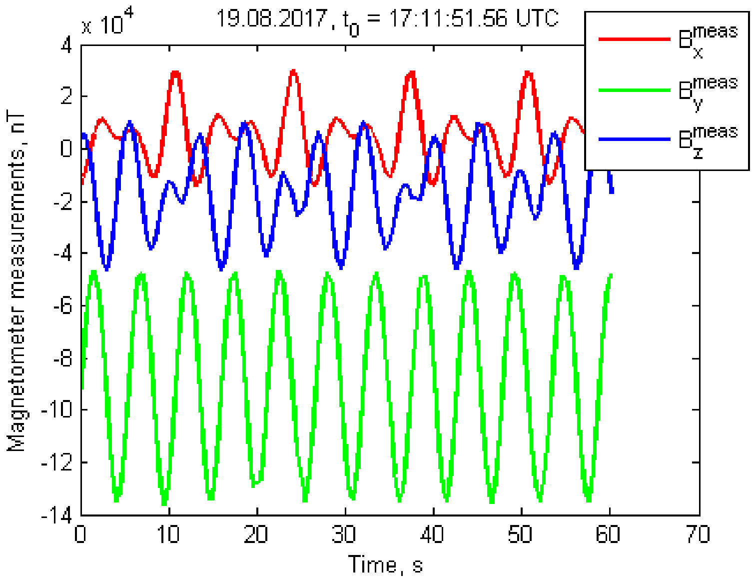
The launch 17.08.2017

The direction of the TNS-0 #2 launch from ISS

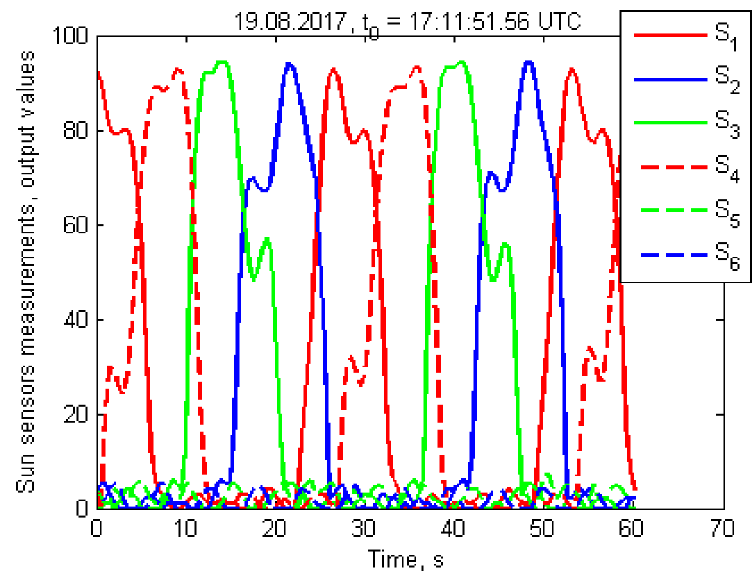


Hand launch testing

First telemetry data from sensors

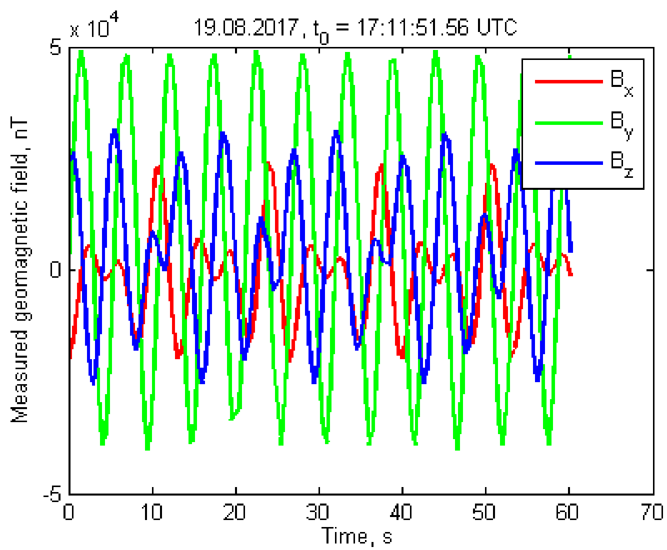


Magnetometer measurements



Photodiode sensors measurements

Measured geomagnetic field after processing



Magnetometer bias obtained

$$\mathbf{B}_{bias} = \begin{bmatrix} 5.8 & -90.8 & -20.9 \end{bmatrix} \cdot 10^3 \ \text{nT}$$

Attitude motion reconstruction technique

Motion equations

$$\mathbf{J}\dot{\mathbf{\Omega}} + \mathbf{\Omega} \times \mathbf{J}\mathbf{\Omega} = \mathbf{M}_{mag} + \mathbf{M}_{grav} + \mathbf{M}_{gist}$$

$$\dot{\Lambda} = \frac{1}{2}\mathbf{C}\Lambda \qquad \Lambda = \left(\mathbf{q}, q_0\right)$$

Measurements model

$$\mathbf{B}_{meas} = \mathbf{A}\mathbf{B}_o + \mathbf{B}_{bias}$$

Initial conditions vector

$$\xi = \left[q_1(t=0), q_2(t=0), q_{3,}(t=0), \omega_1(t=0), \omega_2(t=0), \omega_3(t=0) \right]^T$$

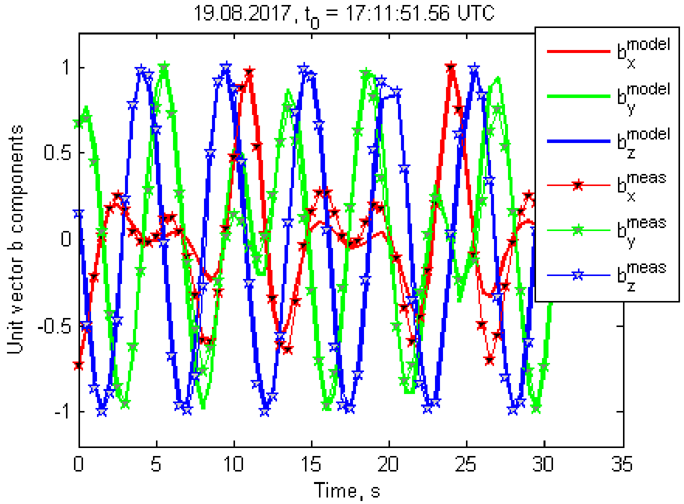
The problem of the vector of initial conditions determination reduces to the problem of the following function minimization

$$\Phi(\xi) = \sum_{k=1}^{N} \left(\left| \tilde{\mathbf{b}}^k_{\text{model}} - \mathbf{b}^k_{meas} \right| \right)^2$$

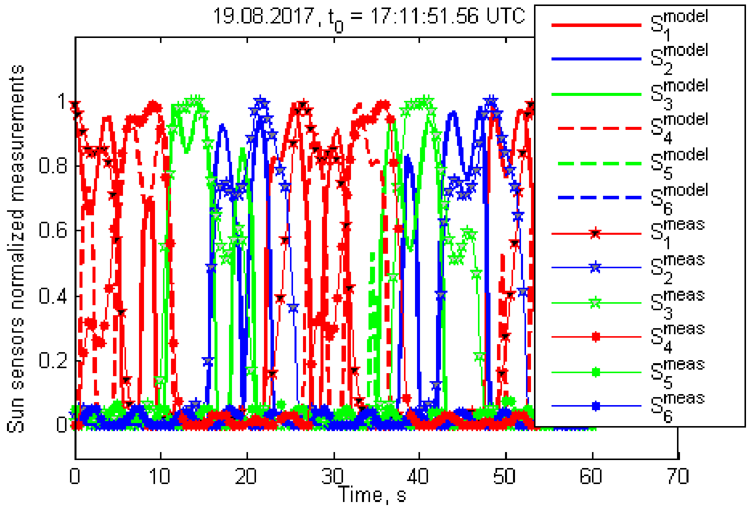
$\mathbf{b}^i_{meas}$ is the unit vector along the geomagnetic field calculated using measurements after excluding the constant bias

$\tilde{\mathbf{b}}^i_{\text{mod}\,el}$ is the unit vector along the geomagnetic field calculated IGRF model

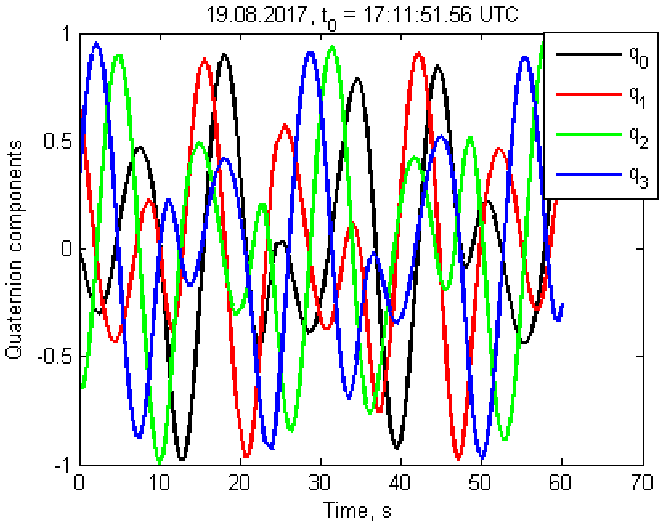
Measurements processing results



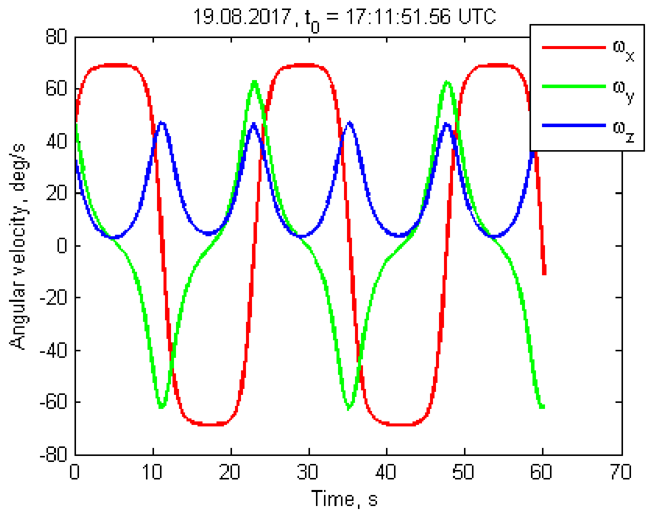
Measured and predicted unit vector along the geomagnetic field



Sun sensors normalized measurements and its predicted values



Attitude quaternion

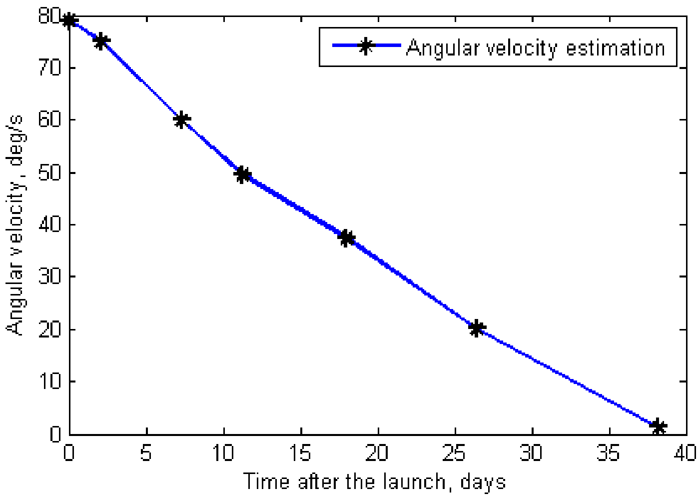


Angular velocity vector

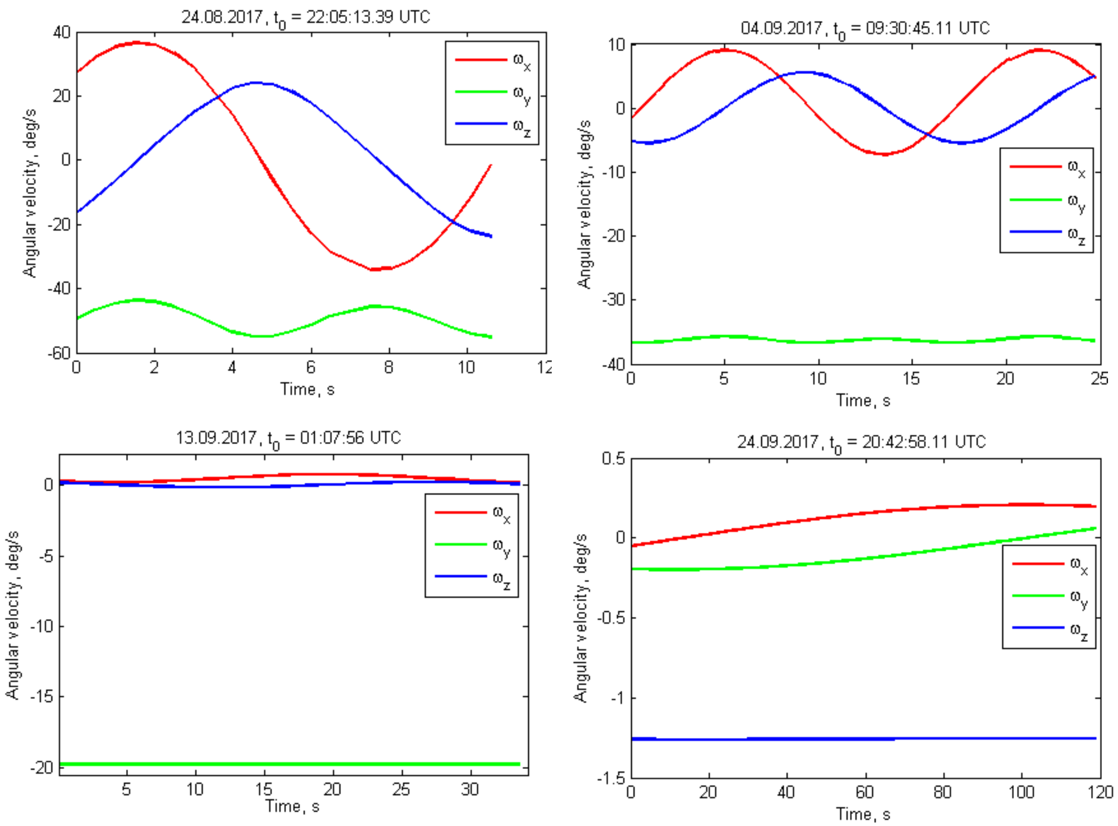
Angular velocity damping

- For the telemetry data available the angular velocity was estimated
- For a period of about 17 days the satellite changed its attitude motion from a rotation about all three axes to rotation predominantly around the Y axis
- Time of damping is about 36 days

Angular velocity damping

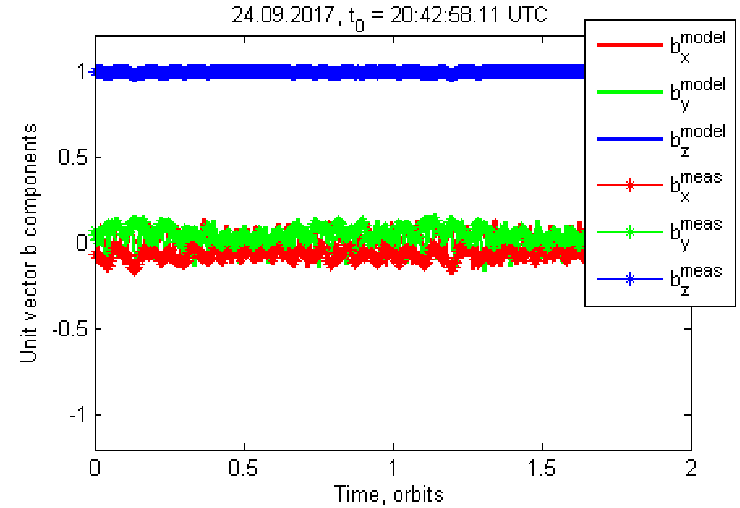


Obtained angular velocity

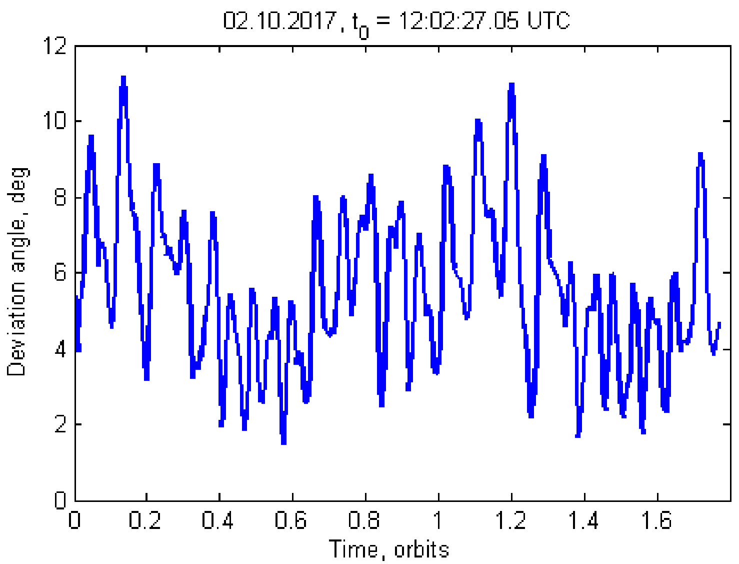


Steady-state motion

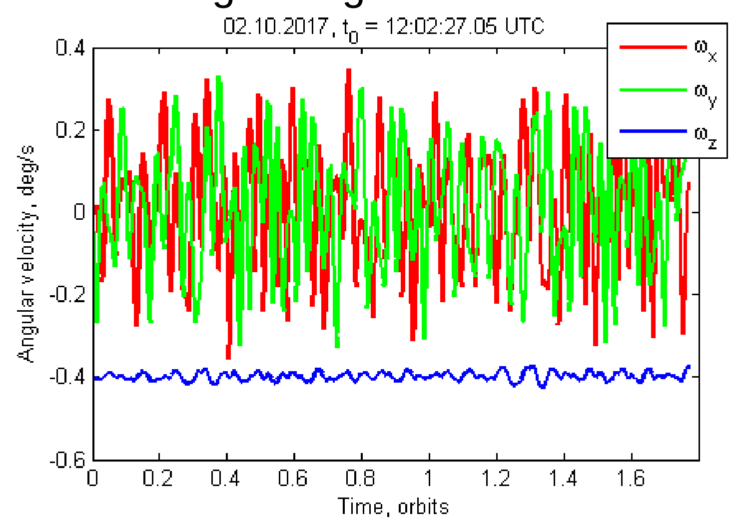
- In October 2 it was possible to obtain telemetry recorded on the onboard storage in a time approximately equal to 2 orbits
- The angle between the longitude axis and local geomagnetic field does not exceed 12 deg



Measured and predicted unit vector along the geomagnetic field



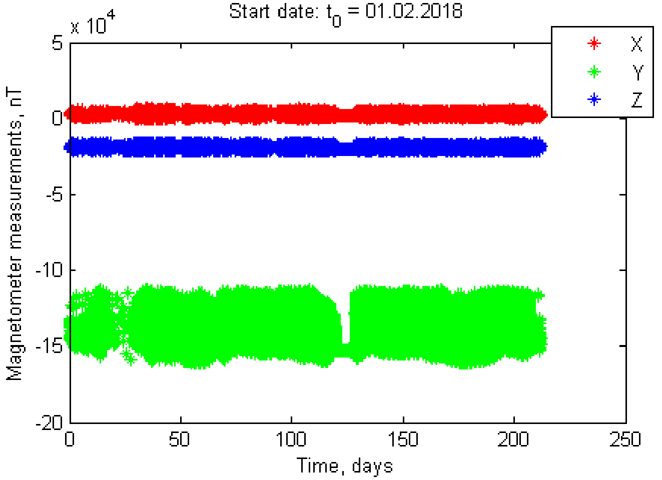
Angle of deviation of the OZ axis of the satellite from the direction of the local magnetic field



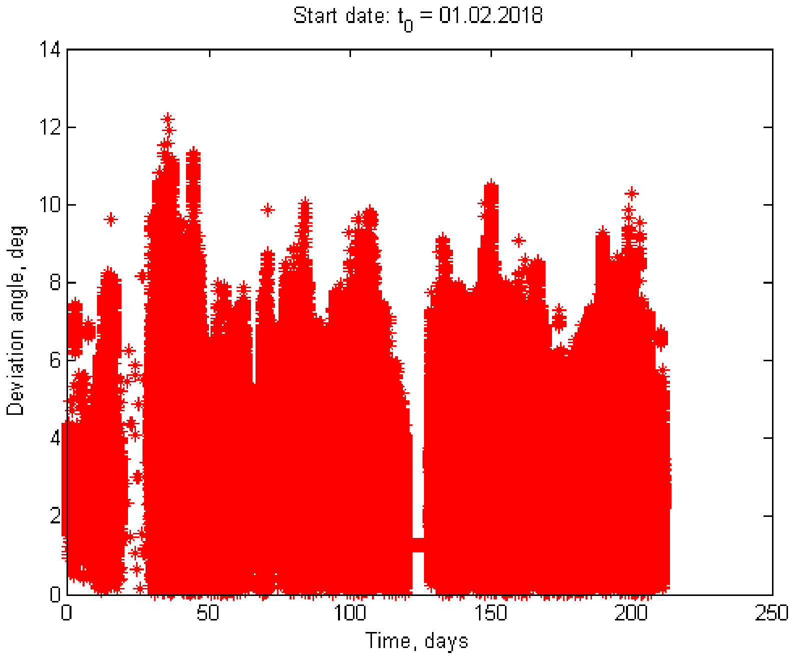
Angular velocity during steady-state motion

Attitude during the year of service

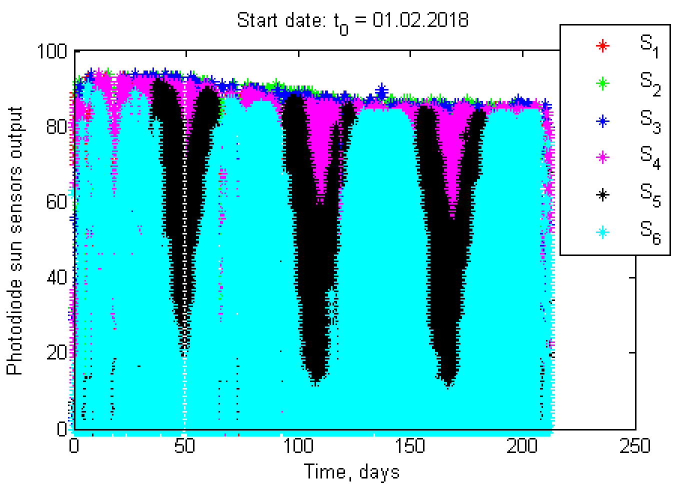
- Since stabilization the TNS-0 #2 is in the magnetic attitude mode during one year
- The photodiode sensors measurements maximum values are gradually decreasing



Measurements of the magnetometer



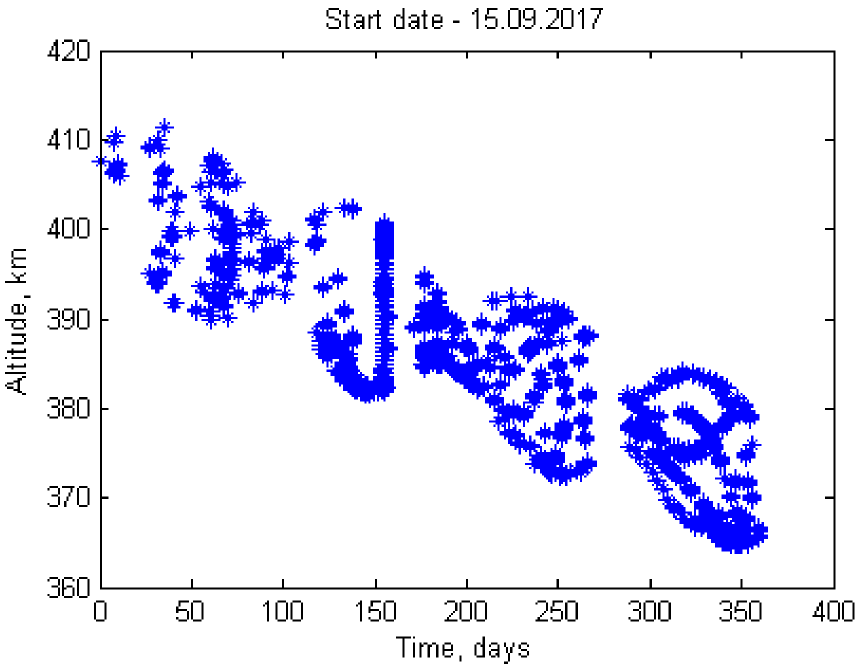
Angle of deviation of the OZ axis of the satellite from the direction of the local magnetic field



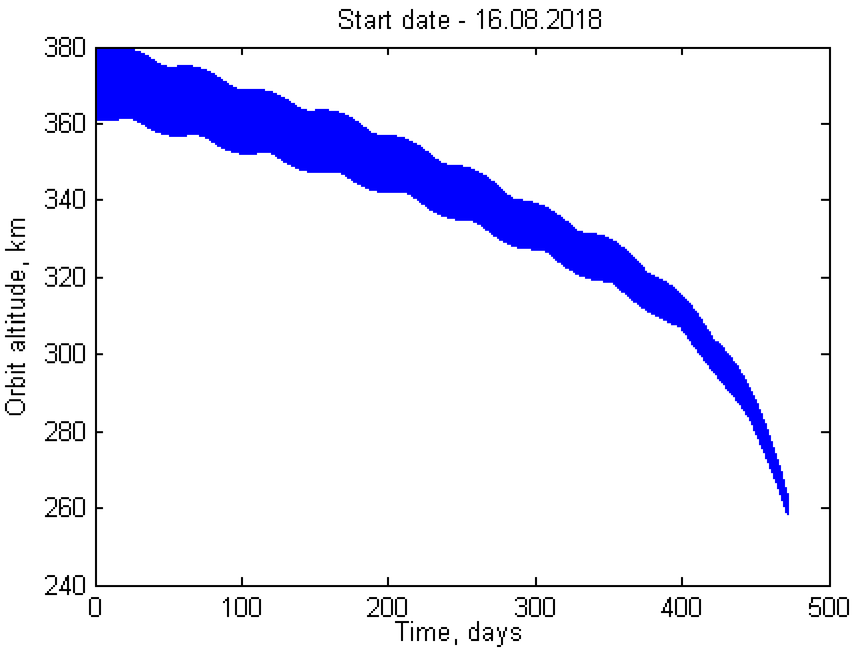
Photodiode sun sensors measurements

TNS-0 #2 orbit degradation

- For a year the altitude of the orbit decreased by only 30 km
- If the low solar activity continues the TNS-0#2 will be on the orbit at least one more year



Altitudes calculated using GPS/GLONASS receiver

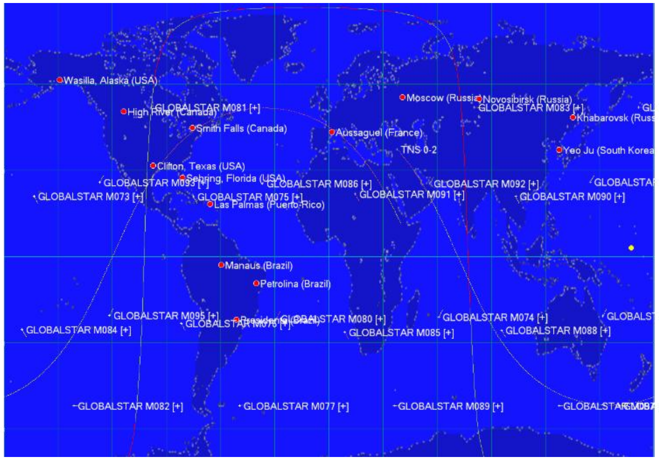


Predicted orbit altitude under low solar activity

RUSSIAN SPACE SYSTEMS

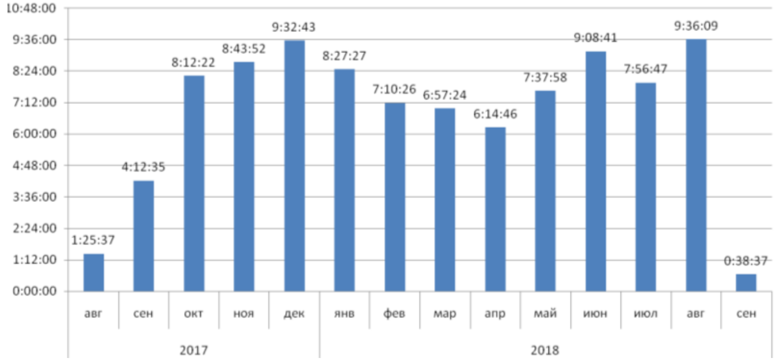
Communication Details

- The TNS-0 #2 satellites upload and download the telemetry and other information via Globalstar antennas installed onboard and via VHF channel
- For successful communication session via Globalstar it is necessary for the TNS-0 and Globalstar satellites to be in the line of sight, and at the same time the Globalstar satellite and the Globalstar gateway also to be in the line of sight



Globalstar ground stations and Globalstar satellites traces

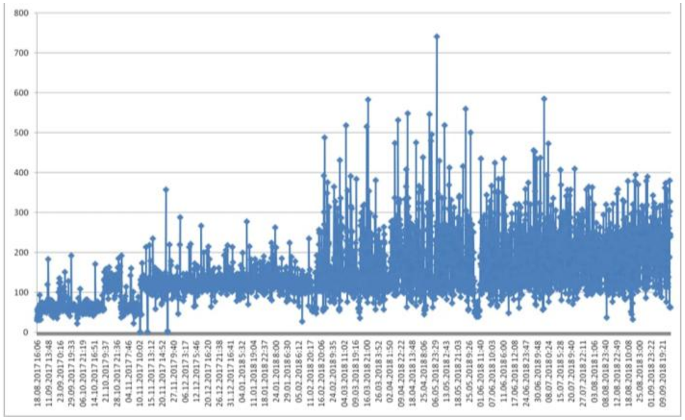
Type of session	Successful	Failed	Total	Total duration	Mean duration
Globalstar (internet)	4053	533	4586	95:29:49	0:01:25
Globalstar (modem)	9	34	43	0:25:35	0:02:51
VHF	848	132	982	84:04:04	0:05:57
Total	4910	699	5611	179:59:28	0:02:12



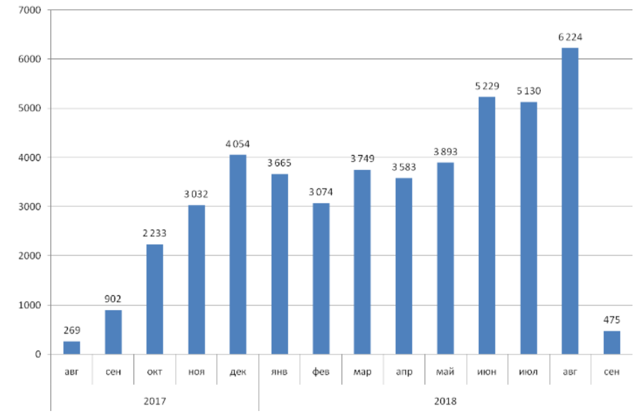
Total duration of sessions via Globalstar

Communication Channels Capacity

- In the Globalstar-internet mode the satellite transmits packets of 4 frames every 600 msec
- In practice, there are delays in the transmission of data over the Internet as the result of packet loss during transmission through the radio link between the TNS and the Globalstar satellites
- The elaboration of on-board algorithms for communication via Globalstar-internet allowed to obtain actual channel capacity up to 420-440 bytes/s



Mean channel capacity Globalstar-internet during the session (bytes/sec)



The total size of the telemetry obtained via Globalstar per month (kB)

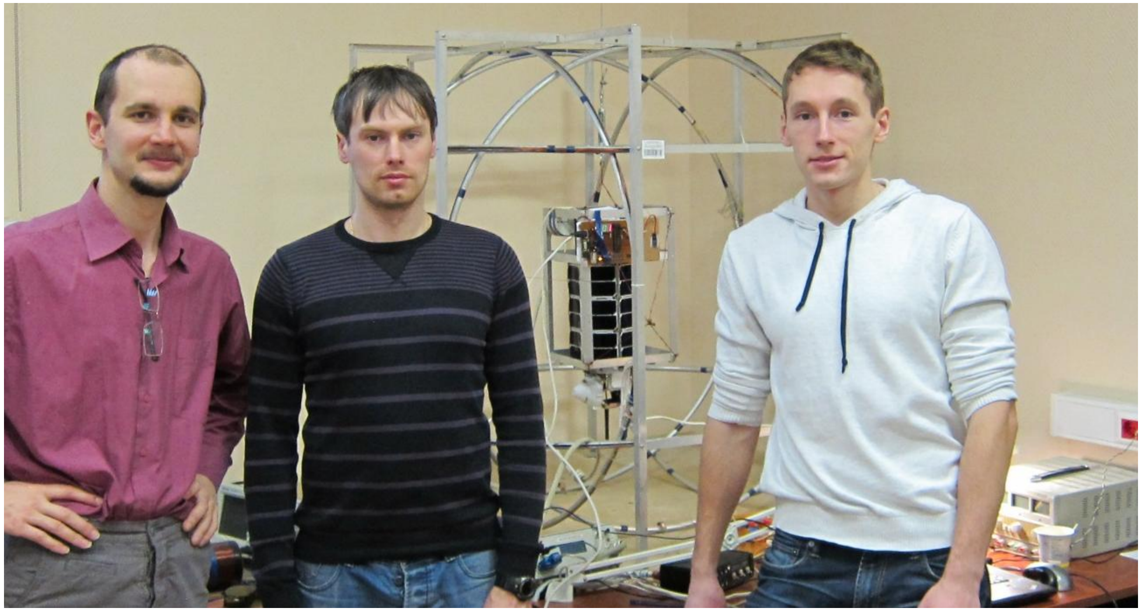
Mean channel capacity (byte/sec)	Globalstar-internet	Globalstar-modem	VHF
Actual	420-440	64	32
Theoretical	900	900	1200

Conclusions

- Using the telemetry data the angular motion is estimated, based on this data the damping time is 36 days
- In the steady-state motion the satellite rotates relative to the local geomagnetic filed direction with an angular velocity of 0.4 deg/s, and the amplitude of oscillations of the longitudinal axis with respect to the magnetic field vector reaches 11 degrees, the oscillation period is about 9 minutes
- After one year on orbit the perigee is reduced from 410 km to 380 km, the TNS-0#2 will be in orbit at least one more year
- The satellite is communicated via both the Globalstar system and VHF channel. The actual average Globalstar channel capacity of about 430 bytes/s was achieved

The work is supported by Russian Science Foundation, grant 17-71-20117

Thank you for attention!



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