A possible approach to the identification of inertial parameters of large-sized space debris using a specialized nanosatellite

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Abstract. The paper substantiates the possibility of space debris parameters estimation using a specialized nanosatellite. It is proposed that the nanosatellite is deployed from the main spacecraft and then attached to the space debris object (the attachment method is not considered in the work) and, using on-board measuring instruments, determines dynamic and inertial characteristics, thereby fulfilling the role of a remote measuring instrument. This approach was called the contact method. Such approach has an advantage over non-contact ones, as it allows to get rid of the problems associated with the use of optical or infrared cameras, planning photographs. In addition, with the help of a nanosatellite, the problem of establishing a physical connection between a towing vehicle and space debris can also be solved. To show the solution of this problem, the second stage of the Cosmos 3M launch vehicle was used as an example.

Introduction
Currently, the problem of space debris is becoming increasingly relevant, as the number of spacecraft launches into high orbits is growing. Particular danger for space missions implementation is represented by large objects, for example, the rocket orbital stages, which after use were not de-orbited [1]. The problem of de-orbiting space debris objects (SDO) is aggravated by unknown inertial characteristics of SDO and unknown rotation in advance, which complicates their capture and transportation.

The uncertainty of the inertial characteristics is caused by unspent fuel components. For example, the amount of unspent fuel for the Cosmos 3M orbital stages can be up to 4% of the mass of whole fuel [2], which corresponds to the mass up to 680 kg. The lack of reliable information about the angular velocities of the SDO and its inertial characteristics requires the development of a special technique for their determination, which is the goal of this work. To solve this problem, it is proposed to use a nanosatellite as an auxiliary means of the space complex for capturing and towing space debris.

Today, there are many works on the estimation of the inertial characteristics of space debris. So, in [3], the inertia tensor and other parameters of the object are estimated using the extended Kalman filter based on the results of processing stereo photographs. In [4], cameras are also used to estimate moments of inertia, however, the authors propose their own algorithm, which allows determining the moments of inertia of space debris with an error of ± 8%. Modification of this algorithm as shown in [5] allows to obtain an error of identification of moments of inertia of the order of 0.001 kg m².
This article shows the possibility of identifying the parameters of space debris using nanosatellites (NS). It is proposed that the spacecraft is separated from the main spacecraft and then attached to the space debris object (the attachment method is not considered in the work) and determines the dynamic and inertial characteristics using on-board measuring instruments, thereby fulfilling the role of a remote measuring instrument. This approach was called the contact method.

1. Problem formulation

Using the set of measurements from sensors installed on the nanosatellite (tri-axial magnetometer and angular rate sensors (ARS)), estimate the moments of inertia of the orbital stage of the Cosmos 3M rocket. To write the equations of motion of the center of mass (point O) (Fig. 1), as well as the equations used in data processing, three right-handed Cartesian coordinate systems are introduced.

The satellite coordinate system (SCS) associated with the NS is formed by the main central axes of inertia and has the designation OXcYZc. The Earth-centered inertial (ECI) is designated CXaYaZa with the origin at the center of mass of the Earth (point C). Xa axis is directed to the vernal equinox. Za axis is directed to the north pole of the world. Ya axis complements the system to the right. The local vertical local horizontal (LVLH) is designated OXνYαZα. The beginning of the system is in the center of mass of the spacecraft. Xν axis is directed along the radius vector of NS. Zα axis is perpendicular to the orbit plane. Ya axis complements the system to the right.

Transition between ECI to LVLH is set by three consecutive rotations by the angle of longitude of the ascending node Ω around Za axis, by the inclination angle i around the new axis X′za and by the argument of latitude υ the district of the new axis Z′za. The SCS position relative to the LVLH is defined by three successive rotations through the precession angle ψ around Ya axis, the angle of attack α around the new axis Z′α and the angle of proper rotation φ around the new axis Y′α.

According to [6], in the problems of reconstructing the angular motion of spacecraft at altitudes of more than 500 km, dynamic Euler equations are usually used in the form:

\[
\begin{align*}
\dot{\omega}_x &= \mu (\omega_y \omega_z - ν a_{z1} a_{31}) \\
\dot{\omega}_y &= \frac{1-\lambda}{1+\lambda} (\omega_x \omega_z - ν a_{z1} a_{11}) \\
\dot{\omega}_z &= -(1 - \lambda + \lambda \mu) (\omega_x \omega_y - ν a_{z1} a_{11}),
\end{align*}
\]

where \( \lambda = I_x/I_y \), \( \mu = (I_y - I_x)/I_x \) - dimensionless inertial coefficient, \( ν = 3 \cdot \mu_0/3^2 \) - gravitational moment coefficient, \( a_{ij} \) - elements of rotation matrix A between LVLH u SCS [10]. The kinematics of the orbital stage rotation is described by equations in quaternions [10].

It should be noted that the angular velocities of the orbital stages can be quite high, for example, the orbital stage of the Cosmos 3M has angular velocity \( |\dot{\omega}| = 10^6 \, s^{-1} \) [7]. In this regard, the first terms in the equations of system (1) will significantly prevail over the second, let

\[
\omega_x = 5 \, ^\circ/s, \, \omega_y = 5 \, ^\circ/s, \, r = 7071 \, km, \mu_0 = 398600 \, km^3/s^2, a_{z1} a_{11} \leq 1,
\]

then \( \omega_x \omega_y = 0.0076 \, 1/s^2, \, ν a_{z1} a_{11} = 3.4 \cdot 10^{-6} \, 1/s^2 \).

Therefore, it seems possible to use dynamic equations (1) without taking into account the gravitational moment:
Two measurement models are used in the work. Magnetometers measurement model, which is the Earth’s magnetic field vector \( \vec{B}_{IGRF} \), which was calculated using International Geomagnetic Reference Field data. This vector is measured in the SCS orbital stage, therefore the measured vector \( \vec{B}_{\text{meas}} = A \cdot (M \vec{B}_{IGRF}) \), where \( M(\phi_1, \phi_2, \phi_3) \) – rotation matrix from the main axes of inertia of the stage to the measuring axes of the sensors, \( \phi_1, \phi_2, \phi_3 \) – angles between the main axes of the stage and the axes of the NS’s measuring sensors. We also add to the measured vector the measurement noise \( \omega \), determined by normal distribution law with a given standard deviation \( \sigma_\omega \). Thus, the mathematical model of the magnetometer measurements is written in the form:

\[
\vec{B}_{\text{meas}} = A \cdot (M \vec{B}_{IGRF}) + \omega \sigma_\omega
\]

ARS measurement model is a solution to system (1) \( \vec{\omega} \) with measurements noise \( \omega \), determined by normal distribution law with a given standard deviation \( \sigma_\omega \). Thus, the mathematical model of the ARS measurements is written in the form:

\[
\vec{\omega}_{\text{meas}} = M \vec{\omega} + \omega \sigma_\omega
\]

The problem is solved under the following assumptions: The orbital stage (OS) is adopted by a dynamically symmetric absolutely rigid body i.e. \( \lambda = 1 \); The influence of the aerodynamic moment is not taken into account, since at altitudes of more than 700 km (on which the largest number of worked out orbital steps is concentrated [8]) its value is much less than the gravitational moment; During the rotation of the orbital stage, the remains of unprocessed fuel are evenly distributed along the inner walls of the tank, which is confirmed by [9]; The center of mass of the orbital stage lies on the longitudinal axis; Due to the lack of information about the geometry of the oxidizer and fuel tanks, they are combined into one tank, and the fuel density is considered as average. The axes of the measuring instruments are aligned with each other and SCS.

Thus, the problem can be formulated as follows: determine orbital stage’s vector of estimated parameters \( \vec{b} = [\omega_x(t_0), \omega_y(t_0), \omega_z(t_0), \psi(t_0), \alpha(t_0), \varphi_1(t_0), \varphi_2(t_0), \varphi_3(t_0), \mu] \), using measurements \( \vec{B}_{\text{meas}} \) and \( \vec{\omega}_{\text{meas}} \) on the period T. Measurements are processed by least squares method, minimising the following objective functions is determined:

- for magnetometers measurements:

\[
J(b) = \sum_{a=x,y,z} \sum_{k=1}^{N} \left( B_{\text{meas} \ ak} - \vec{B}_{\text{meas} \ ak} (b) \right)^2
\]

- for ARS measurements:

\[
J(b) = \sum_{a=x,y,z} \sum_{k=1}^{M} \left( \omega_{\text{meas} \ ak} - \vec{\omega}_{\text{meas} \ ak} (b) \right)^2
\]

Thus, the identification problem is reduced to the problem of multi-parameter optimization. A two-step approach to solving the problem is considered.

The two-stage approach uses model (2) and involves the decomposition of the optimization problem into two parts (division of vector \( \vec{b} \) into two vectors \( \vec{b}_1 \) and \( \vec{b}_2 \)): the first part is to minimize functional (4) and to determine the vector of estimated parameters of the form \( \vec{b}_1 = [\omega_x(t_0), \omega_y(t_0), \omega_z(t_0), \psi_1, \varphi_2, \varphi_3, \mu] \), the second part is to minimize functional (3) by estimating a vector \( \vec{b}_2 = [\psi(t_0), \alpha(t_0), \varphi(t_0)] \). Thus, at the first step, the initial angular velocities, the orientation of the NS relative to OS and the inertia coefficient of the OS are determined. Then, using estimations of \( \psi_1, \varphi_2, \varphi_3 \) matrix \( M \) is determined, which allow us to “combine” sensor axis and the main central axes of OS. The second step obtains estimates of the orientation of the OS in the LVLH.
2. Numerical method selection

There are papers, for example, [10] in which a problem with a similar formulation was solved using the Gauss–Newton method. Thus, the authors of [10] note that the application of the Gauss–Newton method in a similar problem is associated with problems: firstly, the choice of the initial approximation for the vector of estimated parameters, and secondly, the lack of global convergence. Therefore, in contrast to [11], the search for the minimum of objective functions (4), (5) is carried out using the differential evolution algorithm [12] (DE).

There are known works in which the DE solved problems in the space industry, for example, in [13] it was used to search for the optimal flight trajectory of the spacecraft, and in [14] the DE was used to search for the optimal motion trajectory of the robotic manipulator to capture space debris. In [15], the DE was used to determine the moments of inertia of the spacecraft in flight when control actions are applied to the spacecraft using flywheels and orientation engines. Solving a problem using DE is less dependent on the initial conditions than similar algorithms. Moreover, according to the [16], a more accurate result can be achieved with a wide range of possible values of the initial state vector.

The advantages of using DE compared to the other algorithms are, firstly, the absence of the need to search for an initial approximation for the estimated parameters. Secondly, there is no need to calculate the partial derivatives of the minimized function, which allows us to get rid of laborious mathematical transformations and makes it possible to use more complex mathematical models of angular motion and measurement models. Thirdly, an increase in the accuracy of the solution is achieved due to the absence of the need for the numerical determination of partial derivatives and the search for a global extremum is provided, in contrast to the first and second order methods, which often look for local extrema.

3. Analytical model of fuel distribution

To take into account the unused fuel according to [9], we assume that the fuel is evenly distributed over the wall of the cylindrical tank and is a thin-walled cylinder with a length \( L \), which is equal to tank length, outer radius \( R \) and wall thickness \( \delta \). Let’s determine \( \delta \) and inertia moments of fuel cylinder \( (I_{x_f}, I_{y_f}, I_{z_f}) \) taking into account the mass of unused fuel residues \( m_f \). Cylinder volume is defined as

\[
V_f = \pi L \left( R^2 - (R - \delta)^2 \right) \tag{5}
\]

or

\[
V_f = \frac{m_f}{\rho_f} \tag{6}
\]

where \( \rho_f \) fuel density. Substituting (6) into (5) and solving the quadratic equation, we obtain

\[
\delta = -\frac{2 R + \sqrt{D}}{2} \tag{7}
\]

where \( D = 4R^2 + 4m_f/\left( \rho_f \pi L \right) \).

The moments of inertia of the fuel are determined by the following formulas

\[
I_{x_f} = I_{z_f} = \frac{1}{12} m_f \left( 3R^2 + (R - \delta)^2 + L^2 \right) \tag{8}
\]

\[
I_{y_f} = \frac{1}{2} m_f (R^2 + (R - \delta)^2) \tag{9}
\]

Let the center of mass of the dry orbital stage \( C_c \) and center of mass of fuel \( C_f \) (fig.2.) lie on the longitudinal axis, then the center of mass of the orbital stage with fuel \( C_{os} \) определяется как:

\[
C_{os} = \frac{C_c m_c + C_f m_f}{m_c + m_f} \tag{10}
\]

where \( m_c \) – dry orbital stage mass. It should be noted that the center of mass of the fuel, by virtue of symmetry, always lies in the middle of the length of the fuel tank, i.e. \( C_f = 0.5L \).
The moments of inertia of the orbital stage with fuel are determined as

\[ I_{xos} = I_{xs} + m_s d_s^2 + I_{ef} + m_f d_f^2 \]  
\[ I_{yos} = I_{ys} + I_{ef} \]  
\[ I_{zos} = I_{zs} + m_s d_s^2 + I_{ef} + m_f d_f^2 \]

where \( d_s = C_{os} - C_s \) and \( d_f = C_{os} - C_t \) center of mass displacements.

4. The solution to the problem on the example of the orbital stage Cosmos 3M

Until 2012, more than 400 launches of Cosmos 3M into high-circular orbits were completed. About 248 spent stages, which make up 6% of the total space debris, make uncontrolled flight in orbits at altitudes of 750 - 950 km, which raises the risk of their mutual collision and avalanche-like increase in the number of fragments [1]. The fuel components for the orbital stage of the Cosmos 3M launch vehicle are: oxidizing agent AK-27I (\( \rho_o = 1600 \text{ kg/m}^3 \)) and unsymmetrical dimethylhydrazine (UDMH) (\( \rho_u = 960 \text{ kg/m}^3 \)), therefore the average fuel density is \( \rho_f = 1280 \text{ kg/m}^3 \). Draw up a design scheme of the orbital stage (fig.2.) And determine the moments of inertia and all the necessary characteristics of the “dry” stage (table 1).

**Table 1**

| Parameter | Value |
|-----------|-------|
| \( m_c \text{, kg} \) | 1485 |
| \( m_s \text{, kg} \) | 0...680 |
| \( R \text{, kg} \) | 1,2 |
| \( L \text{, kg} \) | 3,02 |
| \( I_{xs} \text{, kg m}^2 \) | 6400 |
| \( I_{ys} \text{, kg m}^2 \) | 1374 |
| \( I_{zs} \text{, kg m}^2 \) | 6400 |
| \( C_c \text{, kg m}^2 \) | 2,2 |

The obtained parameters of the computational model are consistent with the work [18], and in this work the model is more detailed. In contrast to [18], the model takes into account the geometry of the propulsion system, the lower technological compartment and the upper compartment of the on-board equipment.

To assess the effectiveness of the approaches, we will carry out statistical simulation of the problem solution, as a result of which the errors in determining the vector \( b \) will be estimated. Simulation occurs under the following conditions:

- the module of the angular velocity of the orbital step does not exceed 10 deg/s according to [7];
- the mass of fuel residues is selected on the basis of an equally probable law in the range from 0 to 680 kg;
- for each numerical experiment \( D_1.1 - D_3.6 \) (see table 4), 400 simulations are carried out, which makes it possible to obtain an error estimation accuracy of 5% with a guarantee probability 0.9;
- Orbit altitude 900 km.

The following measuring tools were used in the work: NSS Magnetometer [19] (M1), HMC5883L magnetometer [20] (M2), MPU 9250 (M3), ARS CR S03 – 01 [21] (A1), MPU 9250 [22] (A2), ADXRS645 [23] (A3). The paper considers six cases for each approach, a list of cases with a description is given in table 2. For each case, the problem is solved at different time intervals according to table 3.
**List of cases**

| Case number | Sensor index | Description |
|-------------|--------------|-------------|
| 1           | M1-A1        | Most accurate measurements |
| 2           | M2-A2        | Medium Accuracy Measurements |
| 3           | M3-A3        | Least accurate measurements |
| 4           | M3-A2        | SamSat platform measuring instruments |
| 5           | M1-A3        | The most accurate magnetometers and least accurate ARS |
| 6           | M3-A3        | Least accurate magnetometers and most accurate ARS |

**Simulation conditions**

| Number of experiment | Time period \(T\), sec | Case |
|----------------------|--------------------------|------|
| D1.1                 | 200                      | 1    |
| D2.1                 | 500                      | 2    |
| D3.1                 | 1000                     |      |
| D1.2                 | 200                      |      |
| D2.2                 | 500                      |      |
| D3.2                 | 1000                     |      |
| D1.3                 | 200                      | 3    |
| D2.3                 | 500                      |      |
| D3.3                 | 1000                     |      |
| D1.4                 | 200                      |      |
| D2.4                 | 500                      |      |
| D3.4                 | 1000                     |      |
| D1.5                 | 200                      | 4    |
| D2.5                 | 500                      |      |
| D3.5                 | 1000                     |      |
| D1.6                 | 200                      |      |
| D2.6                 | 500                      |      |
| D3.6                 | 1000                     | 5    |

5. **Results discussion**

Consider the results of the first step of solving the problem using ARS. The task was solved for each sensor at different time intervals (table 3). The error distribution functions for angular velocity and inertia coefficient \(\mu\) errors were obtained (Figs. 3 and 4).

![Angular velocity error distribution](image1.png)

![Coefficient \(\mu\) error distribution](image2.png)

According to the results obtained, with an increase in the period for solving the problem, the errors in the determined parameters decrease. Thus, the best result is achieved using the most accurate ARS over the longest time interval. The numerical standard deviations (STD) values of the estimated parameters for each sensor and the measurement period are given in table 4. As can be seen from table 4, the STD of angular velocity is an order of magnitude smaller than the STD of the ARS noise, which
indicates the effective filtering of measurement noise, as well as the correct choice of the mathematical model of motion and the interval for solving the problem. At the second step of solving the problem, the following STD errors were obtained at the orientation angles of the orbital stage in the LVLH (table 5). The distribution function of the probability of error in the orientation angles for the calculated case is presented in Figure 5.

### Table 4

| Sensor | $\sigma_{\omega}$, º/c | Period, sec | $\sigma(\Delta\omega)$, º/c | $\sigma(\Delta\mu)$ |
|--------|------------------------|-------------|-----------------------------|------------------|
| A1     | 0.025                  | 200         | 0.006                       | 0.009            |
|        |                        | 500         | 0.005                       | 0.004            |
|        |                        | 1000        | 0.0044                      | 0.003            |
| A2     | 0.1                    | 200         | 0.022                       | 0.015            |
|        |                        | 500         | 0.014                       | 0.013            |
|        |                        | 1000        | 0.0097                      | 0.01             |
| A3     | 0.25                   | 200         | 0.053                       | 0.03             |
|        |                        | 500         | 0.033                       | 0.022            |
|        |                        | 1000        | 0.025                       | 0.016            |

### Table 5

| Sensor | $\sigma(\Delta\psi)$, º | $\sigma(\Delta\alpha)$, º | $\sigma(\Delta\phi)$, º |
|--------|--------------------------|-----------------------------|--------------------------|
| D 1.1  | 1.75                     | 0.5                         | 1.2                      |
| D 2.1  | 1.82                     | 0.9                         | 1.3                      |
| D 3.1  | 2.5                      | 1.6                         | 2                        |
| D 4.2  | 2.8                      | 1.4                         | 2.1                      |
| D 2.2  | 3.2                      | 1.9                         | 2.3                      |
| D 3.2  | 3.7                      | 3.1                         | 2.9                      |
| D 1.3  | 3.6                      | 2.7                         | 3                        |
| D 2.3  | 3.7                      | 3.1                         | 3.1                      |
| D 3.3  | 3.8                      | 4                           | 3.3                      |
| D 1.4  | 3                        | 1.5                         | 2.2                      |
| D 2.4  | 3.3                      | 2                           | 2.4                      |
| D 3.4  | 3.6                      | 3                           | 2.8                      |
| D 1.5  | 3.5                      | 2.6                         | 2.9                      |
| D 2.5  | 3.8                      | 3                           | 3                        |
| D 3.5  | 3.8                      | 4                           | 3.3                      |
| D 1.6  | 2                        | 0.7                         | 1.5                      |
| D 2.6  | 2.3                      | 0.9                         | 1.6                      |
| D 3.6  | 2.5                      | 1.6                         | 2                        |

**Fig. 5.** Distribution of attitude angle errors for simulation case No.1
According to the STD simulation results, orientation angle errors increase with increasing measurement period. It happens due to increase in the mismatch of the model and real motion, because the gravitational moment is not considered in the model.

Let us analyze the effect of the error in determining the dimensionless coefficient of inertia \( \Delta \mu \) on the error in determining the mass of unspent fuel \( \Delta m_f \). The relationship between these quantities is determined by the formula of the form:

\[
\Delta m_\tau = \left( \frac{\partial m_\tau}{\partial \mu} \right) \Delta \mu
\]

where \( m_f \) (\( \mu \)) - dependence of the mass of unspent fuel on the dimensionless inertia coefficient, \( \Delta \mu \) - absolute error of \( \mu \), \( \Delta m_f \) - absolute error of \( m_f \). Using relations (5) - (13), it is easy to obtain the dependence \( \mu(m_f) \), moreover, such a dependence is a sixth degree polynomial with respect to \( \mu \); therefore, it is impossible to find function \( m_\tau(\mu) \) analytically. In this connection, we construct numerically the dependence \( m_\tau(\mu) \) (Fig. 6).

We calculate the derivative \( \frac{\partial m_\tau}{\partial \mu} \), as the ratio of the increment of the function to the increment of the argument and get the following dependence (Fig. 7).

As can be seen from Figure 7, even small errors in the determination of \( \mu \) will give significant errors in determining the mass of fuel residues.

Consider the effect of errors in determining the mass of fuel residues \( \Delta m_\tau \), errors in determining moments of inertia \( \Delta I_xos \) и \( \Delta I_yos \) (Fig. 8), for this we use the following formulas:

\[
\Delta I_{xos} = \left| \frac{\partial I_{xos}(m_f)}{\partial m_\tau} \right| \Delta m_\tau
\]

\[
\Delta I_{yos} = \left| \frac{\partial I_{yos}(m_f)}{\partial m_\tau} \right| \Delta m_\tau
\]

Figure 8 shows that the calculated derivatives practically do not change, so we take them equal to their average values \( \frac{\partial I_{xos}(m_f)}{\partial m_\tau} = 15,05 \) и \( \frac{\partial I_{yos}(m_f)}{\partial m_\tau} = 1,37 \). Thus, using formulas (15) - (17), we calculate the errors \( \Delta m_\tau, \Delta I_{xos}, \Delta I_{yos} \) for all sensors A1-A2 (table 6). Higher derivative value \( \frac{\partial^2 I_{xos}(m_f)}{\partial m_\tau^2} \) it is explained by the fact that not only the moment of inertia of the fuel, but also the displacement of the center of mass, which is caused by the presence of fuel, affects the magnitude of the moment \( I_xos \).

According to table 6, the maximum error in determining the mass of fuel residues is 280 kg, which is about 13% of the mass of the orbital stage, and the minimum is 21 kg and 1%, respectively. The maximum estimation error of \( I_{xos} \) - 4200 kg m\(^2\) what is 54%, minimum
400 kg m² or 5%. The maximum error in determining the moment of inertia $I_{xos}$ – 380 kg m² which is 16%, the minimum is 37 kg m² or 1.6%. When using the SamSat nanosatellite platform, the maximum achievable accuracy in determining the moments of inertia of the orbital stage will be 18% for $I_{xos}$ and 5% for $I_{yos}$, the accuracy of determining the orientation of the orbital stage will be of the order of 3°. The errors obtained are consistent with paper [24], in which the spacecraft inertia tensor was determined by the results of telemetric information processing (errors were 5% -17%) and with [25], in which the ISS inertia tensor was determined with the errors being 10% -20%.

Table 6

| Sensor | $\sigma_\omega$, °/s | $T$, sec | $\Delta m_f$, kg | $\Delta I_{xos}$, kg m² | $\Delta I_{yos}$, kg m² |
|--------|-------------------|--------|----------------|------------------|------------------|
| A1     | 0,025             | 200    | 84             | 1260             | 115              |
|        |                   | 500    | 37             | 550              | 50               |
|        |                   | 1000   | 27             | 400              | 37               |
| A2     | 0,1               | 200    | 140            | 2100             | 190              |
|        |                   | 500    | 120            | 1800             | 164              |
|        |                   | 1000   | 93             | 1400             | 127              |
| A3     | 0,25              | 200    | 280            | 4200             | 380              |
|        |                   | 500    | 204            | 3000             | 280              |
|        |                   | 1000   | 150            | 2200             | 200              |

Conclusion
The method for identifying space debris parameters using on-board measuring means of a nanosatellite has been proposed and confirmed with simulation results. The possibility of using a simplified model of the orbital stage motion has been shown, which significantly reduces the computational complexity of the algorithm with a slight increase in errors.

The possibility of decomposition the problem of estimating the orbital stage inertia moments has been shown. The proposed two-step approach allows one to obtain estimates of the mass of the orbital step with a maximum accuracy of 1% and the moments of inertia with an accuracy of 5%, an orientation estimate can be obtained with an accuracy of the order of 1°. Obtained accuracy characteristics are consistent with the works [25, 26].

Thus, the possibility of using the SamSat nanosatellite platform to solve the identification problem of large-sized space debris characteristics has been shown.

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