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ScienceDirect
Procedia Engineering 185 (2017) 380 – 387
Procedia Engineering
www.elsevier.com/locate/procedia

The 6th Russian-German Conference on Electric Propulsion and Their Application

Traffic control systems of nanosatellites in the zone of the international space station

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Abstract

Ways and the automated devices for precision traffic control of nanosatellites (NS) in a zone of the Russian ISS segment are described. The complexity of management of these systems concerns the magnetic-induction system of separation of NS in the set directions specialized by NS supplied with ionic micromotors. The magnetic-induction system of separation contains a microprocessor system of management which allows high-precision start of the nanosatellite in the set azimuthal and zenith directions concerning the coordinate system connected with the ISS. The thrust vector of the ionic micromotors set on NS is regulated by means of a management system executed on microcontrollers. This combination of devices allows practically any trajectory to be set for NS concerned with the ISS.

Peer-review under responsibility of the scientific committee of the 6th Russian-German Conference on Electric Propulsion and Their Application
Keywords: *small spacecraft, nanosatellite, space station, magnetic-induction system of department, traffic control of SSC*

Nomenclature

SA	space aircraft
IE	ionic engine
APP	application program package
PCS	polar coordinate system

Peer-review under responsibility of organizing committee of the RGCEP – 2016.

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Peer-review under responsibility of the scientific committee of the 6th Russian-German Conference on Electric Propulsion and Their Application
doi:10.1016/j.proeng.2017.03.319

CCS	Cartesian coordinate system
NS	nanosatellites
LRE	liquid reactive engine
WC	working chamber
P	draft of IPE
I_{sp}	specific impulse of draft
η	efficiency
N	power of the IPE power source
U^+	acceleration voltage
I_{eff}	current of an ionic bunch
η_d	efficiency taking into account divergence of an ionic bunch from a nozzle
m*	full expense of a working body
j_i	density of an ionic bunch
e	elementary charge
α	half of a corner of divergence of an ionic bunch
T_i	temperature ionic components
U_p	plasma potential in WC of rather this electrode
η_m	coefficient of ionization of a working body

1. Introduction

With development of a configuration of space stations there are a set of tasks for small spacecraft's including nanosatellites to service the needs of the station including towage of rescue ropes, tools for astronauts, removal of space debris from the zone of the ISS, etc. In other words, today a problem existed in the organization of technological activity in an area of the ISS using automatic robotic systems which carry out tasks either completely independently or with the assistance of the operator. For solution of a number of tasks, such as towing of constructional elements in the set space points, rendering of a rescue rope to the astronaut, correction of disclosure is more than dimensional antennas and so forth SSC including NS equipped with ionic or plasma engines of a small draft, several tens watts can be used. Traffic control of such devices is exercised by means of the onboard microprocessor systems giving the chance change in direction of the movement and speed of SSC.

Electro reactive engines (ERE) opened a new direction in space engine construction. ERE differ from the existing space engines working with chemical fuels, as to higher profitability, but at the same time considerably smaller thrust-weight ratio, the possibility to receive small unit impulses, a large number of inclusions. At the same time, division of power sources and working substance in ERE and the use of an electromagnetic field for acceleration of working substance allows a specific impulse to be increased considerably (by one-two orders), and respectively the profitability of ERE in comparison with chemical reactive engines. This predetermines areas of applicability of EREI for space aircraft with long times of active functioning (5 - 10) years.

On the other hand, considering NS sizes like Cube Sat, it is possible to install only miniature IPE on such devices, developing draft of several watt. Today spacecraft's in the form of a cube with an edge of ten centimeters already receive their own ionic engines for correction of an orbit. It should be noted that the micro motor has the size, as a rule, of about a human nail and does not occupy more than a third of the internal volume of the satellite. It is clear, that this circumstance complicates management processes of NS and considerably increases time of its movement along the set trajectory. For solution of such tasks, it is reasonable to report an initial impulse in the set direction with an initial speed (0.5-2) m/s to the nanosatellite by means of magnetic-induction system of start (department) [2].

With such organization of the movement NS in a zone, for example, the ISS of IE set onboard the satellite will carry out a role of engines of orientation - to adjust a trajectory. For effective work of such MISO + NS complexes, the magnetic-induction system of a department should have an opportunity to orient the main axis of NS in the set zenith and azimuthal directions concerned with the coordinate system connected with space station. MISO of this kind contain microprocessor management systems [3] connected with the ISS onboard computer modules.

Automated control systems for the movement of NS in an ISS zone can be very effective for execution of rescue operations safety rope of an astronaut working in outer space. For solution of tasks of this kind, it is reasonable to set several MISO on the surface of ISS, each of which has an opportunity not only to carry out the start of the NS with a micro rope in the direction of the object, but also to carry out scanning of the space around the station, to calculate the location of the astronaut. The procedure of scanning of a half-space in this point of the MISO installation on the ISS is carried out by mechanisms of the drive of the system of the department in the zenith and azimuthal direction, and range sensing to object is made uing laser interferometers or lidar range finders. That is, the system of abnormal rescue constructed on the basis of MISO + by NS itself in the automatic mode defines location of object and directs to it the micro rope delivered to NS. Ideally, the NS can fix a rope on object, and the system of the drive installed in MISO will tighten the object to an ISS board.

For removal (change of a trajectory) of space debris from an ISS zone, the NS sensors should find such objects some time beforehand; calculate their speed and the direction of the movement. The trajectory of the movement is influenced by non sphericity of an orbit of Earth and irregularity of distribution of masses to its surfaces and in subsoil. Perturbations of a trajectory also arise because of resistance of a terrestrial atmosphere, an attraction of other celestial bodies, sunlight pressure. The main perturbations of satellite trajectories are caused by non sphericity of Earth and resistance of the atmosphere. The computer system onboard the ISS can consider the influence of these parameters and then orient one of the MISO + NS systems installed onboard station in the set direction and start the NS with a set impulse. Then the NS ionic engines which adjust the trajectory of the movement on the direction and motion speed turn on. Upon meeting with an object, it is either destroyed together with NS, or changes trajectory and then in a "safe area of space" the NS or try to destroy it.

Thus, development of automated control systems for the movement of SSC in space station zones is the actual task promoting an increase in the efficiency of functioning of the station, considerably raising the security level of the personnel working in outer space and facilitating execution of a number of technological jobs.

2. Magnetic-induction system of department of NS and automatic tracking objects in a zone of a space station

For scanning the space around a space station, the authors developed a microprocessor system of magnetic-induction type (see fig. 2a). This device allows the review of space, in relation to an installation site on an external surface of the station, in a spatial angle almost equal to value to be carried out. On the surface of the station it is reasonable to place several such systems working independently to have an opportunity, in the automatic mode, to trace objects in the space around, for example, the ISS.

This system contains a plate - the basis - 1 on which are set: an accumulator (heat-insulated) compartment - 2, an instrument compartment - 3 and mechanisms of turn in the azimuthal direction - 4, and in zenith the directions - 5. These mechanisms contain the drives of a gear type set in motion by small-size stepping electric motors. On an azimuth the turning angle makes 360 °, in the zenith direction 165 °. For turn in the zenith direction the semi-gear wheel is used, in combination with roller guides - limiters (fig. 2 and)). In this slave semi-gear wheel, the hollow vacuumed container in which the electrolytic condenser with a capacity of 0,01 F and an operating voltage of 100 V, and electronic components - the 6th module of management of the processes of a charge and the capacitor discharge on the high-current solenoid are fixed. In the upper part of this container the case of the magnetic-induction drive - the ejector, made of magneto soft material for shielding of the electromagnetic field momentums created by the high-current solenoid at discharge of the storage capacitor is installed. In this case the following elements are also placed: system of permanent ring neodymium magnets - 14, directing for the solenoid - 16 and a damping spring - 15. Outside of the case, are set a laser ranging sensor of pulse type - 7, a laser lidar - 13 and the coil with an abnormal rope - 8. The solenoid through a guide is rigidly connected with a platform of start of NS - 12 on which the nanosatellite - 10 is installed the miniature IPE fixed on it - 9 and (if necessary) uniaxial gyroscopes - 11.

3. Ways of the review of space in ISS zone, methods of detection, tracking objects

The principle of work of the considered system of the review of space in a zone of a space station is as follows. In a space scan mode, under control of the microprocessor, mechanisms of drives in the zenith and azimuthal directions turn on. Thus, the consecutive review on the spiral (extending) conic area is carried out. Therefore, the zone of scanning represents spatial angle. Scanning speed and a step of a spiral can be changed on commands of the microprocessor module of management.

Optical circuits of a laser ranging sensor and lidar are executed on the identical optical circuit that allows a range finder to work at the review of space in the lidar mode [10]. Space change of optical parameters on the route of sounding is connected with the value of back scattering (reflected signal) the equation:

$$P(\nu,r) = \chi\eta P_0(\nu)\frac{c\tau}{2}Ar^{-2}[\beta_m(\nu,r)+\beta_a(\nu,r)]\exp\{-2\int_0^r \alpha(\nu,r)dr\} \quad (1)$$

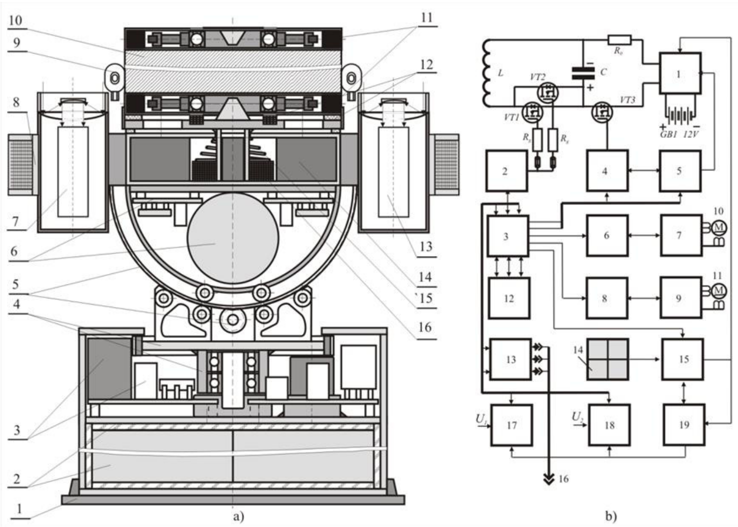

Fig. 1 Sketch of an automatic microprocessor system of scanning of space in zone ISS and start of NS - and), the skeleton diagram of system management of scanning and start of NS - b)

here where χ - a transmission of receiving optics of a lidar; η - efficiency of a photo detector; P_0 - the power of laser radiation sent from the lidar location; c - light speed; τ - pulse duration of laser radiation; A - effective area of receiving optical system; β_m and β_a - volume coefficients of molecular and aerosol dispersion of laser radiation in the direction back; $\alpha(\nu,r)$ - profile of coefficient of weakening of laser radiation. Comparing amplitude of an initial laser impulse and the signal reflected from object, the microprocessor of the module of management fixes the existence of the object in a scanning zone. At the same time its location concerning SK connected with station is defined, for CS of the system of the review it is azimuthal and zenith corners. Laser radiators, for this system, are developed on the basis of small-sized pulsing lasers TECH-527, the wavelength of 527 nanometers, pulse duration (50 - 100) by nanosecond, the frequency of following of impulses of 1 kHz. Mean energy of laser radiation in an impulse of 250×10^{-6} J. The receiving part of the lidar device (fig. 1 and), poses. 7, 13) contains large and small mirrors on which outer side laser radiators, the small-size PM (PM-68) installed in the screen are placed. Supply voltage of PM of 2000 V.

At detection of the "stranger" lost of required object the lidar - 7 switches the mode of a pulse range finder and defines, more precisely, than in the lidar mode, distance to the object in compliance with expression:

$$L = \frac{c\Delta t}{2n} \quad (2)$$

Where L - distance to object, Δt - time of passing of a laser impulse to object and back, n - index of refraction of the environment. It is clear, potential measurement accuracy of range is defined by the measurement accuracy of time of passing of a laser impulse to the object and back (the pulse edge is shorter; the distance to object is defined more precisely, for model option of duration of front and back fronts made $\Delta\tau \approx 2$ *нс*). Let's notice that discovered system objects can be based concerning station, or move with some speed on a certain trajectory. The system of scanning can automatically trace these statuses and determine coordinates of bodies in relation to CS connected with station.

In fig. 1 b) the skeleton diagram of the electronic management system by the device for the review of space is provided in a zone of station and department of nanosatellites with the set parameters from ISS. Central node is the microprocessor module here - 3 which is controlled software packages, sewn up in an external ROM - 12. The microprocessor is connected to the shaper of a bit impulse - 2, the module of management of a capacitor charge - 4, tension transformer control box - 5, to shapers of control signals of the stepping motors (SM) - 6, - 8, to the controller of 15 solar panels 14, and to the communication module 13 with one of on-board computers of station. The communication module 13 is connected to a vehicle network of a delivery system via the connector 16. The electronic management system contains an autonomous system of a power supply which consists of the rechargeable batteries charged by means of tension transformer - 1 which is connected to the controller of solar panels - 15 and to control box of the transformer of tension 5. Drivers of electric motors - 7, 9 mechanisms of drives in the zenith and azimuthal directions are connected to stepping motors - 10, 11. The solenoid is connected to the condenser via the key device executed from several field transistors connected in parallel. Tension transformer - 1 is connected to the condenser through a key. The autonomous system of the power supply also contains solar panels - 14 which via the controller - 15 are connected to a tension transformer - 1.

The device for department of nanosatellites from the Russian ISS segment works with the set parameters as follows. The robot the manipulator installs the nanosatellite - 10 with the uniaxial gyroscopes fixed on it - 11 on a platform of start of MISO. The microprocessor - 3 includes a winding of the solenoid of the start set on a platform which plays an electromagnet role, thus, the nanosatellite is rigidly connected with a platform. The microprocessor - 3 obtains data on orientation of means of station concerning the coordinate system connected with Earth from the ISS on-board computer via the communication module 13. After that promotion of uniaxial gyroscopes - 11 on commands of the microprocessor - 3 to required value of the moment of an impulse is made. Further the microprocessor turns on the shaper of a bit impulse - 2 which opens the key device therefore the capacitor discharge, via the solenoid is made. As a result of interaction of the pulse magnetic field excited by the solenoid with a field of permanent magnets - 14 (fig. 2 and)) the solenoid - 16 gets a mechanical impulse which is transferred to a start platform as it is rigidly connected with the solenoid. In a time point the defined pulse leading edge created by the shaper of a bit impulse - 2, the microprocessor switches-off the solenoid installed on a platform, as a result the platform of start transfers a mechanical impulse to the separated device. Speed of start is regulated by the pulse duration, the created shaper of a bit impulse - 2 on commands of the microprocessor - 3. Force operating on the solenoid from an external magnetic field can be evaluated by means of the known formula of Ampere which can be presented in the form:

$$F(t)\Big|_0^{t_1} = [\int_0^{t_1} i(t)dt]B_0 l \tag{3}$$

here $i(t)$ - we will remind the resulting current via the solenoid,: $i(t) = i_C(t) - i_i(t)$ where $i_i(t)$ - induction in a circuit arising at the movement of the solenoid, B_0 - total induction of the magnetic field created by permanent neodymium magnets l - length of a wire of the solenoid which is in a gap $l = n\pi D_2$, n - number of the rounds which are in a gap D_2 - the outer diameter of the coil. In the developed MISO model 4 ring (Nd-Fe-B) magnets collected in a packet, $(D = 95,\ d = 40,\ h = 10)$ $мм^3$ in size and characterized by induction of a magnetic field $B = 1.5$ $Тл$ and a cylindrical magnet were applied $(d = 10,\ h = 20)$ $мм^3$. This magnet plays a guide role for the coil of the solenoid and aligns a field in a gap.

It is obvious that maximum efficiency of conversion of magnetic field energy in the coil in mechanical energy, under all other equal conditions, is defined by an inequality: $n \le H / d$, H - thickness of the magnetic conductors forming a gap d - diameter of a wire of the solenoid. Let's notice that the formula (9) has an evaluation character, for more exact calculation of Ampere force it is necessary to break the outside margin formed of a neodymium ring and cylindrical magnets into ring zones, suitably to each layer of a winding of the solenoid. In each such ring zone to calculate the mean value of a magnetic field and to consider it invariable on zone width, for each layer of a winding to calculate Ampere force and to sum up results of all layers of a winding. Besides it is necessary to consider the fact that the changing current in time in each round excites induction currents in the next rounds. With accuracy, sufficient for practice, it is reasonable to consider only 2 next rounds in each direction (i.e. only 8 rounds of neighbours). At such approach, the received dependence of kinetic energy of the separated device from (9), and integral value of the corresponding force for the considered case is equal: It $\int_0^{0.005} F(t)\,dt = 5.365\ J$ is quite enough to start nanosatellites masses from 1 kg to 3 kg with speeds of 1 m/s,…, 3 m/s.

After separation of NS from a platform, through the set period the microprocessor installed on NS turns on ionic engines. It gives the chance to adjust a movement NS trajectory, its speed. When carrying out rescue operations, on system of scanning of space and department of NS the coil with a rope - 8 as it is shown on the sketch should be installed (fig. 2 and)). The rope is also connected to NS, thus, after calculation of location of the astronaut who lost a safety fall for some reason, the nanosatellite delivers an abnormal rope. In principle, the abnormal rope on the astronaut's space suit is capable to fix NS in the automatic mode, and the system of the department can tow it off to a board of station. For this purpose it is enough to supply the coil - the 8th mechanism of winding of a rope. For signal processing from a range finder and lidar modules - 17, 18 which are connected with the microprocessor - 3 serve.

We will provide the MISO some parameters in the conclusion. It is simple to show that its efficiency defined as the relation of the mechanical energy necessary for start of the device with set speed, to the energy reserved in the condenser is about (6 ÷ 9) %. Thus, proceeding from the specified start conditions, in the condenser it is necessary to reserve not less than 50 J of energy that can be provided by means of the electrolytic condenser 0.01 F ×100 V. Solenoid parameters - number of rounds, diameter of a wire are, etc. are selected also proceeding from energy relations and breakdown strength of system. Proceeding from these reasons, the multilayer solenoid with the following characteristics was calculated: number of rounds (in two wires), number of layers = 6, inductance of L = 251×10-6 Gn, outer diameter of R2 = 40 mm, inside diameter of R1 = 11 mm, h height = 16 mm, pure resistance of R = 0.2 Ohms, natural frequency ω0 = 631 Hz, frequency ω= 490 Hz, attenuation coefficient β = 398, critical resistance is 0.32 Ohms, diameter of wire = 1 mm.

4. Influence of potential of a gravitational field in zone ISS on parameters of start of NS

For exact removal of NS on the found object, in a viewing field, it is necessary to select exact values of corners in the zenith and azimuthal directions it is relative CS the station and to report to the satellite the corresponding initial impulse. Parameters of an impulse of department of NS depend on the nature of the movement of the station [11], in particular its speed $\vec{V} = \vec{V}_n + \vec{V}_n$, value of gravitational potential in a point of its finding of time which is defined by total value of a geopotential at present - φ_G, influence of the Sun $\varphi_{\odot}$ and Jupiter φ_U, the Moon φ_M i.e.: $\varphi = \varphi_G + \varphi_{\odot} + \varphi_U + \varphi_M$. Besides determination of the exact parameters of start of NS in the direction of the found object, at the time of department it is necessary to know its speed and parameters of a trajectory concerning the station. Such parameters as potentials of fields of Earth, the Sun, and Jupiter can be set with help of table, according to calculations of the ISS on-board computers, and characteristics of the movement of the found object need to be determined by data of system of tracking.

As it was already noted, the movement of the satellite, ISS happens in a heterogeneous gravitational field. This heterogeneity is connected with uneven distribution of density in a geoid, influence of location of the Moon, planets of giants - their situation concerning Earth. Real orbits of satellites including ISS, are far from circular. This is explained by irregularity of distribution of mass of the planet concerning its geometrical center. Therefore in the theory of the movement of artificial satellites it is considered to be that the satellite - material particle moves in a potential field of the planet, function of potential - the potential of an attraction or force function of a body K in a point $P(\xi,\eta,\zeta)$ can be generally defined by the known expression:

$$U = f\iiint_T \frac{\tilde{\Theta} d\tau}{\Delta} \tag{4}$$

Where f - an inclination constant, $\Delta = \sqrt{(\xi-\xi')^2 + (\eta-\eta')^2 + (\zeta-\zeta')^2}$ - distance from the point $P(\xi,\eta,\zeta)$ defining location of this satellite to some current point $P'(\xi',\eta',\zeta')$ on a planet surface; T - the volume occupied with a planet body K. For Earth the different forms of record of potential of an attraction [12] are taken, for example, the standard form approved by the commission No. 7 MAC has an appearance:

$$U = \frac{fM}{r}\left\{1 - \sum_{n=2}^{\infty} J_n \left(\frac{r_0}{r}\right)^n P_n(\sin\varphi) + \sum_{n=2}^{\infty}\sum_{m=1}^{n} P_{n,m}(\sin\varphi)\left[C_{n,m}\cos m\lambda + S_{n,m}\sin m\lambda\right]\right\} \tag{5}$$

In computational modeling the most general form of record is used:

$$U=\frac{fM}{r}\left\{\sum_{n=0}^{\infty}\sum_{m=0}^{n}\left(\frac{r_0}{r}\right)^{n+1}P_{n,m}\left(\sin\varphi\right)\left[\bar{C}_{n,m}\cos m\lambda+\bar{S}_{n,m}\sin m\lambda\right]\right\} \quad (6)$$

Where:

$$P_{n,0}=P_n,\ \bar{C}_{n,0}=\sqrt{\frac{(n-m)!}{2(n-m)!}}\frac{J_n}{\sqrt{2n+1}},\ \bar{S}_{n,0}=0 \quad (7)$$

Let's notice that in modern standard representations of a geopotential coefficients J_n are not selected.

Differential equations of the movement of a particle in the inertial rectangular coordinate system connected with the central body (Earth) can be presented in the form:

$$\frac{d^2}{dt^2}\vec{x}(t)=-\frac{\partial}{\partial\vec{x}}+\vec{P} \quad (8)$$

Initial conditions have an appearance: $\vec{x}_0=\vec{x}(t),\ \dot{\vec{x}}=\dot{\vec{x}}(t_0)$ where $U(r)=-(\mu/r)-R$. Let's note that first composed in U - the potential caused by an attraction of the spherical planet considered as material particle, and second composed represents the potential of the perturbing forces; $\vec{x}=(x_1,x_2,x_3)^T$ - satellite position vector; t - physical time; r - position vector module; $\mu = k^2M$, k^2 - universal gravity constant; $U=U(t,\vec{x})$, $\partial/\partial\vec{x}$ - gradient.

As the perturbing force, for example for Earth having geopotential influence of an aspheric component of a gravitational field of Earth is considered, as a rule. Nevertheless other forces, including influence of the Moon and Sun which situation is set or from table, or in the form of the ranks received out of a task about the movement artificial satellite belong to forces which do not have potential.

Application of a method of a variation of arbitrary constants to the equations (8) allows writing artificial satellite motion equations in the touching elements. Such equations are used at creation of both numerical and analytical prediction algorithms of the movement. In numerical forecasting use of the equations in the touching elements has that advantage that the no perturbed part of these equations is integrated without methodical errors by any numerical method. The solution of the equations (8) in case of the no perturbed movement has an appearance:

$$\begin{aligned}
&x_1=r\alpha, && \dot{x}_1=\sqrt{f(m_0/p)}\left[\alpha e\sin v+(p\alpha'/r)\right],\\
&x_1=r\beta, && \dot{x}_1=\sqrt{f(m_0/p)}\left[\beta e\sin v+(p\beta'/r)\right],\\
&x_1=r\gamma, && \dot{x}_1=\sqrt{f(m_0/p)}\left[\gamma e\sin v+(p\gamma'/r)\right],\\
& && r=p/(1+e\cos v),
\end{aligned} \quad (9)$$

Here:

$$\alpha=\cos u\cos\Omega-\sin u\sin\Omega\cos i,\ \alpha'=\frac{d}{du}\alpha,\ \beta=\cos u\cos\Omega+\sin u\sin\Omega\cos i,\ \beta'=\frac{d}{du}\beta,$$

$$\gamma=\sin u\sin i,\qquad \gamma'=\frac{d}{du}\gamma$$

Values $\Omega, i, \omega, p, e, \tau$ are the traditionally used elements of the Kepler's orbit, i.e.: longitude of the ascending node, an orbit inclination to the main coordinate plane, pericenter longitude from a node, the focal parameter of an orbit, its eccentricity, the passing moment through a pericenter. Parameters α,β,γ represent direction cosines of orbital coordinate system of rather inertial system used in the equations (8). The argument of width of u is defined by a formula $u=\upsilon+\omega$; true anomaly is connected with independent variable a ratio:

$$t-\tau=(p^{3/2}/\sqrt{fm_0})\int_0^v\frac{d\varphi}{\left(1+e\cos\varphi\right)^2} \quad (10)$$

Elements of a Kepler's orbit are constants in two last formulas and are completely determined by initial conditions of system of equations (8). If to apply a method of a variation of arbitrary constants to the equations of the perturbed movement (8), in the assumption that the solution of the equations (8) saves a form (9), then it is possible to receive set of the equations of Newton-Euler. Existence of eccentricity in a denominator of a number of members in Newton-Euler's equations can lead to loss of accuracy in the analysis of circular satellite orbits.

For taking note on the value of gravitational potential in this point of a trajectory of ISS of the Sun, Moon, Jupiter, at NS launch in the direction of the found object, it is convenient to use the generalized equation of gravitational interaction, for example, in the form of [13]:

$$F_{12} = fm_1 r_{12} \sum_{i=2}^{n} \frac{m_i}{r_{1i}^3} \tag{11}$$

here $\sum_{i=2}^{n} \frac{m_i}{r_{1i}^3}$ is vector value.

The considered approach allows quite precise calculation of the parameters of separation of NS from system of tracking, namely: components of an initial impulse, zenith and azimuthal corners it is relative CS connected with ISS.

5. Conclusion:

1. The system of the automatic review of space in an ISS zone, capable to find "unknown" objects, to determine their coordinates and to analyze the nature of their movement in real time is offered.
2. This small-size MISO allows to display NS of the ISS with masses of (1 ÷ 5) kg from a board including via the sluice chamber into the set orbits with speeds (1 ÷ 3) m/s, in certain strict zenith and azimuthal directions. After the moment of separation, the NS movement is adjusted by miniature IPE in relation to SK connected with the spacecraft or with ISS.
3. The way of delivery of an abnormal rope to the astronaut who lost a safety fall by means of NS is offered.
4. Systems as such can be used for execution of different technological operations in an outer space in a zone of space crafts: towage of assembly elements for antenna mirrors and so forth.

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