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# **Application of Fractal Analysis While Designing of Family of Spacecraft for Needs of Space Industry**

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Additional information is available at the end of the chapter

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## **Abstract**

This paper deals with methods of fractal analysis, which allow creation of a line of spacecraft from different classes as addition to classical methods for needs of space industry. It is shown that the fractal analysis that widens opportunities of classical methods can become a base for solution of the modern problems of space technologies. Besides, the results of fractal analysis in this chapter are practically valued recommendations for designing of the line, algorithms of control over equipment to measure microaccelerations and of majority control over measuring data. It clearly demonstrates potential and applicability of methods of fractal analysis in practice.

**Keywords:** fractal analysis, fractal property, spacecraft, microaccelerations, majority control

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## **1. Introduction**

Space technologies have given a lot of new materials and medicines with unique features. For instance, semiconducting germanium for purposes of radio industry was firstly gotten under space conditions. Its purity achieved 99.9999%. Ultrastrong and thermostable monocrystals for development of blades of a turbine for aviation and rocket engines were also firstly grown in space laboratories. The metal foam is of great interest for engineering industry. It has a weak structure and combines high durability with lightness.

Such unique features can be achieved for materials, which are developed out of the field of terrestrial gravity. The absence of the field allows thorough mixing of melted metal with air for creation of foam metal with weak structure or exclusion of admixtures from the melt to significant reduction of crystallization centers to get large monocrystals, etc. Such technological processes, which require almost absolute absence of force action for their successful realization, are called as gravity-sensitive processes.

The best resources and significant funds were wasted for realization of ambitious space projects. For instance, in USA, it was developed and realized grand project of space laboratory "Skylab." The laboratory was placed into near-earth orbit by legendary carrier rocket "Saturn-5" on 14 May 1973 for realization of more than 300 series of different experiments connected with cross-cutting technologies [1]. There were realized growth of monocrystals, experiments on directed crystallization and others among gravity-sensitive processes. The project "Skylab" was unprecedented in the scales of funds—its budget is considered to be 2.5 bn of dollars.

The large numbers of gravity-sensitive processes in Russia were conducted during realization of large-scale project of orbital complex "MIR." This platform was prepared better for technological and biomedicine experiments than space laboratory "Skylab." "Skylab" was the one big laboratory but "MIR" represented the complex of separated orbital modules with detail specialization of experiments conducted in each module. During realization of the project "MIR," the experience of "Skylab" was taken into account as well as finished by that moment Russian projects of manned orbital stations of the "Salut" series. For providing the research part of the project, the unique equipment was created such as the ovens "Krater-VM" and "Gallar," the complex to control conducting of experiments "Onyx," glass oven "Optyzon" experimental devices "Katalyzator" and "Titus," gauges "Alice" and others.

Evidently that high pace of development of scientific-technical progress today and also significant changing of earth technologies are the results of large-scale space projects. It seemed like space technologies would make a real revolution, but revolution was postponed due to small knowledge of the new conditions which determined realization of technological processes.

Investigations showed that it is wrong to believe that there is absolute weightless into inner environment of space laboratory. An influence of outer (gravitational field, aerodynamic drag, light pressure, etc.) and inner (running of operating elements, proper oscillations of big elastic elements, running of system of orientation, and control of spacecraft's movement) disturbing factors causes a microacceleration field in inner environment.

It influences the results of gravity-sensitive processes negatively. Today, the row of such processes, which demand microacceleration level no higher than 10.7 g for their successful realization, has been already developed. However, modern developmental stage of space technic has not yet allowed realization of the processes on a board of space laboratory. It is necessary to investigate the structure and nature of microaccelerations, to find out their new features to provide the necessary level for successful realization of gravity-sensitive processes. It is necessary to understand that requirements for microacceleration level will become tougher to the extent of development of space technologies.

Investigations show that microacceleration field as the test subject has several features, which significantly complicate its investigation. One of the features consists in overloads of micro-accelerometers during launching of spacecraft/these overloads can achieve 10 g. It is approximately in 7–8 orders bigger than microacceleration values [2]. Such situation significantly complicates getting the reliable experimental data using onboard gauges. The following situation [3] was registered when testing of Canadian vibration isolator MGIM (microgravity

isolation mount) during 2 years in orbital complex "MIR" and also during the flight of space shuttle STS-85 by gauges. In one series of experiments which were considered to be successfully realized, the oscillation amplitude inside was protected by the MGIM area that was significantly lower than the outside area. However, in another series of experiments which were marked as unsuccessful, the oscillation amplitude inside the protected area was higher than the outside area. The values of amplitudes (in successful and unsuccessful series) differed more than in 20 times. Later, during measurements of microaccelerations on the board of specialized technological spacecraft "FOTON-11" by French equipment BETA, the situation was similar [4]. Microaccelerometers, installed at different axes of bound coordinate system, showed data that differed more than 20 times. Nevertheless, there were not any obvious causes for it. Sazonov et al. [4] suppose that the software of BETA equipment was applied incorrectly. However, failure of some microaccelerometers is quite possible too. It is also remarkable that the equipment was not applied more on the spacecraft from "FOTON" series. Thus, the reliable way to control adequacy of microaccelerometers on the operational stage of spacecraft, after launching overloads, is required.

The second important feature of microacceleration field is impossibility to measure microaccelerations directly like temperature or angular velocity. That is why the measuring results are indirect estimations based on different methods. The gauges created according to the methods give only qualitative-similar data. It significantly complicates the investigation of microacceleration field too. For instance, tested on orbital complex "MIR," complex of gauges which included "Alice-2" (MEMS-technologies) and "DACON" (convection sensor) showed that "DACON" is insensitive to high-frequency microaccelerations. Although, "Alice-2" managed to register it [5]. The changing of working body of modification of convection sensor "DACON-M" allowed changing of characteristics of the device [6]. The equipment "GRAVITON" based on measurement of magnetic field of the Earth and also row of other gauges were developed [7]. All mentioned facts show that experimental data are the results of mathematical modeling but not of the pure experiment. Thus, the role of mathematical modeling for investigation of microaccelerations is very important and stimulates application of new mathematical methods, particularly, of fractal analysis for investigation of microacceleration field.

## 2. Main part

There are a lot of different classifications of microaccelerations. For instance, microaccelerations are divided into quasi-static (low-frequency) and vibrational (high-frequency) according to its frequency. According to the nature of the source, they are divided into inner and outer. There is offered the classification according to the method of their control [8] because it is important to provide and control designed microacceleration level while creating new space technic.

Microaccelerations can be divided into three groups in accordance with the classification feature:

- Metastable component of microacceleration is caused by the influence of permanent factors of cosmic space such as gravitational and electromagnetic fields, aerodynamic forces and momentums, light pressure, etc.

- Random component of microaccelerations is caused by multifocal uptake and oscillations of gravitational and electromagnetic fields, changes in solar activity and also by influence of random factors of space such as micrometeorites, multifocal uptake of the atmosphere, etc. Extraordinary situations, connected with failure of equipment, are also in the list.
- Constructive component of microaccelerations is caused by inner disturbances such as orbit correction of spacecraft, running of orientation engines, different operational elements, equipment for passive and active orientation, vital activity of crew, etc.

The constructive component is of the greatest interest among the three components because it is connected with construction of the spacecraft and the way of orbital control from the early stages of designing and development.

In a way, the constructive component of microacceleration field of the inner environment of spacecraft is formed while creating the constructional layout of space laboratory and developing the system of its orbital orientation in the early stages of designing.

Constructive component, which often mainly contribute to microacceleration field of inner environment, should be controlled for achieving of favorable microacceleration level.

Investigations of constructive component of microacceleration field show [9] that it has the feature which can be compared with fractal quality of scaling. For instance, the scaling of cosine part of Weierstrass-Mandelbrot function (WMF):

$$ReW(t) = C(t) = \sum_{n=-\infty}^{\infty} \frac{1 - \cos b^n t}{b^{(2-D)n}} \quad (1)$$

where  $D$  is fractal dimension and  $b$  is scaling parameter of WMF by the replacement of  $t$  to  $b^4 t$ , and  $C(t)$  to  $b^{4(2-D)} C(t)$  does not change the form of function (**Figure 1**).

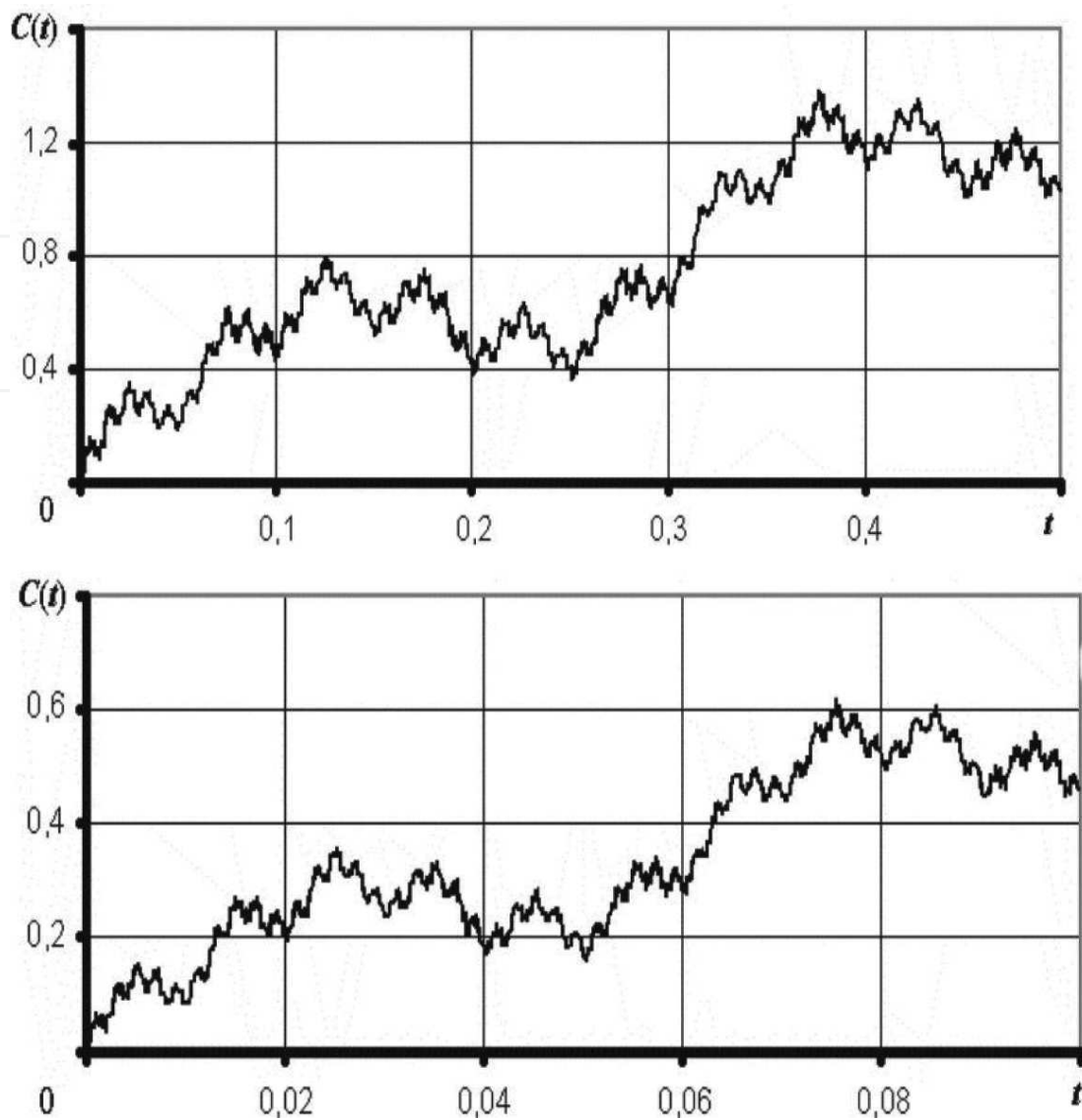
According to the scale invariance of differential equations which describe oscillations of big elastic elements of spacecraft time-dependence of microaccelerations has the similar feature. However, not graph of function but the spacecraft itself is scaled: its sizes and inertia-mass parameters (**Figure 2**).

The results are described in detail below. For investigation of the fractal quality of constructive component, the simple scheme of spacecraft was chosen with the purpose of qualitative demonstration of the quality. The spacecraft represents the central absolutely rigid body that is rigidly attached to its elastic elements (**Figure 3**).

The elastic elements are considered to be the Euler-Bernoulli beams to simplify the investigation process. The estimation of microaccelerations using such models gives a bit overevaluated results [10].

The vibrations of elastic element are caused by inner and outer disturbing factors on spacecraft (**Figure 3**). Just the vibrations make the most important contribution to constructive component of microacceleration field. The impulse firing of engines of orientation and control of orbital motion of spacecraft [11], permanent running of operational equipment [2, 12] or the other factors, including the outer, can be considered to be the sources of vibrations.





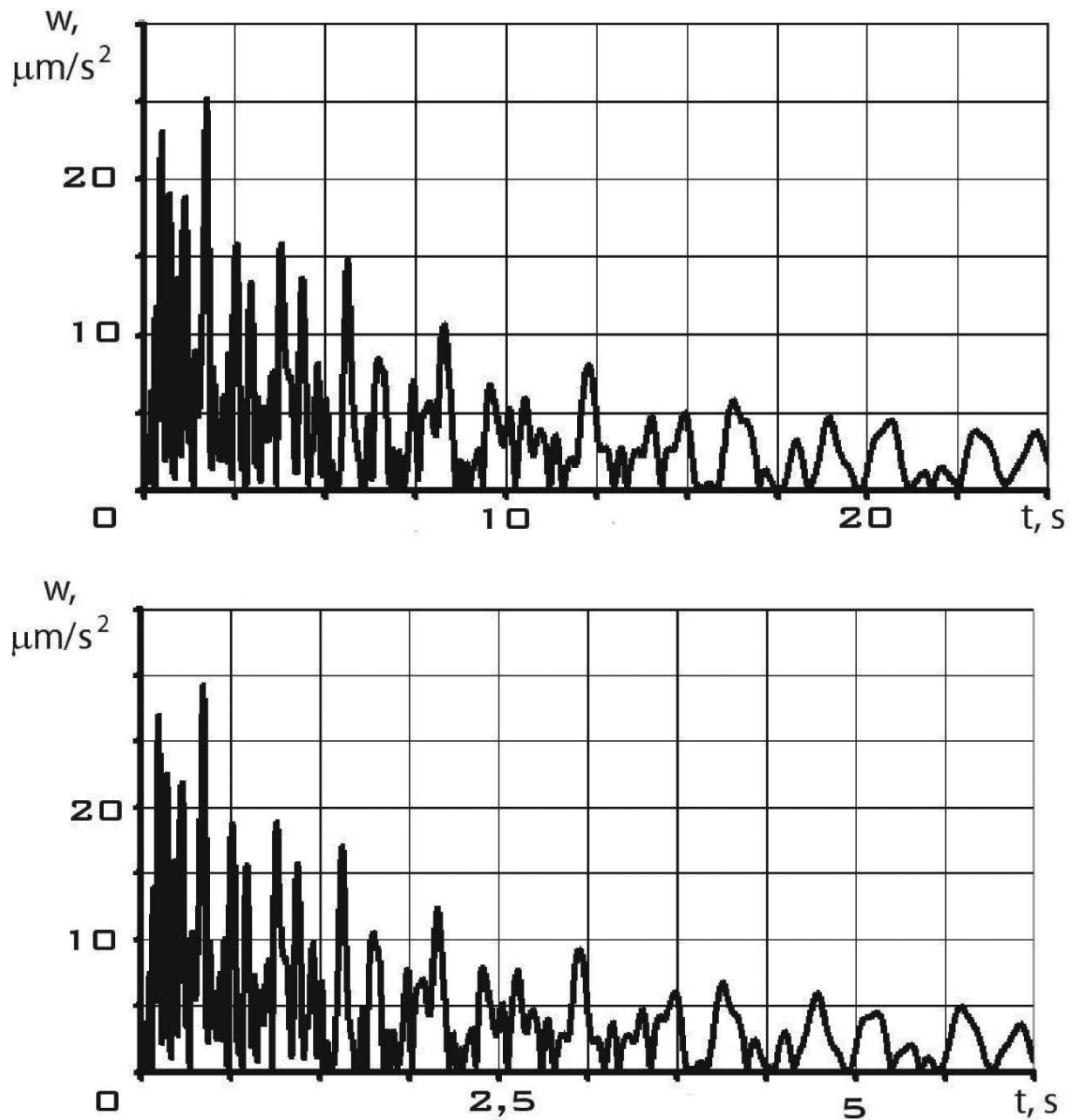
**Figure 1.** The self-affine property of the cosine part of Weierstrass-Mandelbrot function.

Proper frequency when cantilever attaching is performed by the following formula:

$$\omega_i = \frac{\eta_i^2}{l^2} \sqrt{\frac{EI}{\mu}}, \quad (2)$$

where  $\eta_i$  is  $i$ -equation root,  $\cos \eta_i \cosh \eta_i + 1 = 0$ ;  $i$  is number of oscillation mode;  $l$  is length;  $EI$  is flexural rigidity; and  $\mu$  is linear mass of elastic element.

Linear mass and rigidity are constant for the designed material. Roots  $\eta_i$  are also constant. Thus, frequency is the function of beam's length. So, double decrease of the length will lead to fourfold increase of frequency or fourfold decrease of period of vibrations. At that, microacceleration's amplitude will change. Beam with less length and mass will create less microaccelerations when central body of space laboratory will be permanent. Tangential inertia force influences each point of a beam:



**Figure 2.** The feature of constructive component of microacceleration field when scaling of inertia-mass parameters and sizes of spacecraft.

$$d\Phi_\tau = \mu \frac{M}{I} (x + s) dx, \quad (3)$$

where  $M$  is moment of orientation engine,  $s$  is projection of radius vector of fixing point of elastic element relatively to center of mass of space laboratory on x-axes (**Figure 3**) and  $I = I_0 + (\frac{1}{3}\mu l^3 + \mu s^2)$ —inertia moment of space laboratory. At that, beam is considered to be homogeneous.  $I_0$  is inertia moment of central body. Then, the general inertia force of elastic element is:

$$\Phi_{\tau}(l) = \mu \frac{M}{2I} (x+s)^2 = \frac{\mu}{2} \frac{M(l+s)^2}{I_0 + \left(\frac{1}{3}\mu l^3 + \mu s^2\right)}. \quad (4)$$

When length of elastic element decreases in two times, this formula has the following appearance:

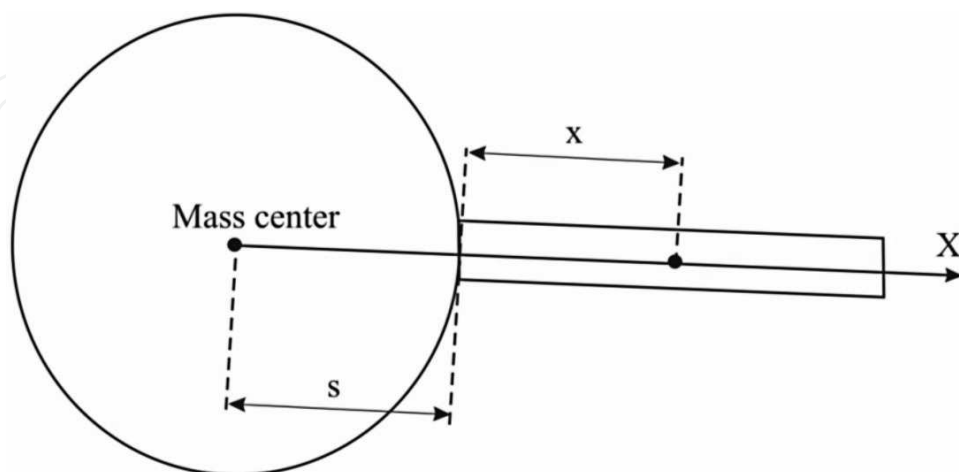
$$\Phi_{\tau}\left(\frac{l}{2}\right) = \frac{\mu}{2} \frac{M\left(\frac{l}{2}+s\right)^2}{I_0 + \left(\frac{1}{24}\mu l^3 + \mu \frac{l}{2}s^2\right)}. \quad (5)$$

Equations (4) and (5) give more than double decrease of the real tangential inertia force of spacecraft “NIKA-T” [13] after substitution of basic parameters of the spacecraft. At that, energy losses are not taken into account there. It means the reduction of amplitude of reaction force of embedding. The reaction force to the spacecraft’s body and causes microaccelerations by its moment around the spacecraft’s center of mass.

Losses of energy in the attaching lug of elastic element are not taken into account. It means reduction of the amplitude of reaction force of embedding. The reaction force transmits to the body of spacecraft and causes microaccelerations, because it creates momentum around center of mass of spacecraft. Mass and size of spacecraft should be reduced so as angular accelerations from tangential inertia forces are similar to get initial amplitude of microaccelerations. It is considered to be a condition of constancy of the form of constructive component caused by vibrations of elastic element (**Figure 2**). Thus:

$$\varepsilon(l) = \frac{M[\Phi_{\tau}(l)]}{I} = \frac{\Phi_{\tau}(l)s}{I} = \frac{\mu}{2} \frac{M(l+s)^2 s}{\left(I_0 + \frac{1}{3}\mu l^3 + \mu s^2\right)^2}, \quad (6)$$

$$\varepsilon\left(\frac{l}{2}\right) = \frac{M[\Phi_{\tau}(\frac{l}{2})]}{I_1} = \frac{\Phi_{\tau}(l)s_1}{I_1} = \frac{\mu}{2} \frac{M\left(\frac{l}{2}+s_1\right)^2 s_1}{\left(I_{10} + \frac{1}{24}\mu l^3 + \mu \frac{l}{2}s_1^2\right)^2}. \quad (7)$$



**Figure 3.** Circuit of space laboratory.



Inertia moment of central body is  $e$  according to the formula:  $I_{i0} = \frac{m_i R_i^2}{4}$ , where  $m_i$  and  $R_i$ —mass and radius of central body for  $i$ -iteration accordingly.

The initial spacecraft determined by scheme on **Figure 3** is considered to be the zero iteration ( $i = 0$ ). The spacecraft with elastic element length of which is less than two times the initial length ( $l_1 = (0.5)^1 l_0$ ) and inertia-mass parameters and sizes are matched so as angular accelerations in Eqs. (6) and (7) are equal ( $\varepsilon(l) = \varepsilon(\frac{l}{2})$ ) is considered to be the first iteration. The spacecraft with length of elastic element which is more than two times the initial length ( $l_{-1} = (0.5)^{-1} l_0$ ) and inertia-mass parameters and sizes are matched so as angular accelerations in Eqs. (6) and (7) are equal ( $\varepsilon(l) = \varepsilon(\frac{l}{2})$ ) is considered to be the minus first iteration. Thus, there is view that the following change is lower than the elastic element while iterations:

$$l_i = \left(\frac{1}{2}\right)^i l_0. \quad (8)$$

Besides, the values of  $i$  can be positive (reduction of spacecraft's sizes relatively to initial) as well as negative (increase of spacecraft's sizes relatively to initial).

It is necessary to question: Would inertia-mass parameters of spacecraft change as synchronously so length of elastic element does? Is formulation of changing low of these parameters in the form similar to Eq. (8) possible? If the answers to the questions are positive, there are quality which is similar to the self-affine property of the cosine part Weierstrass-Mandelbrot function Eq. (1). Oppositely, if parameters will change disproportionally and angular accelerations would not be equal after each iteration, the analogy with fractal properties would be inapplicable. So, it is impossible to apply fractal functions for study and modeling of microacceleration field.

To search answers for these questions, the generalized parameter that characterizes inertia-mass features of spacecraft was formed [14]:

$$z = \frac{\sum_{i=1}^N m_i}{m_0 + \sum_{i=1}^N m_i}, \quad (9)$$

where  $m_0$  is mass of central body;  $m_i$  is mass of  $i$ -elastic element and  $N$ , is number of elastic elements of spacecraft.

The generalized parameter in Eq. (9) has the following form for investigated situation:

$$z = \frac{m_1}{m_0 + m_1}. \quad (10)$$

In fact, generalized parameter  $z$  characterizes mass percent of elastic elements to the total mass of spacecraft. The equality of angular accelerations is the condition of constancy of appearance of time-dependence of microaccelerations which correspond to **Figure 2**:

$$\varepsilon(l_{-1}) = \varepsilon(l_0) = \dots = \varepsilon(l_i). \quad (11)$$

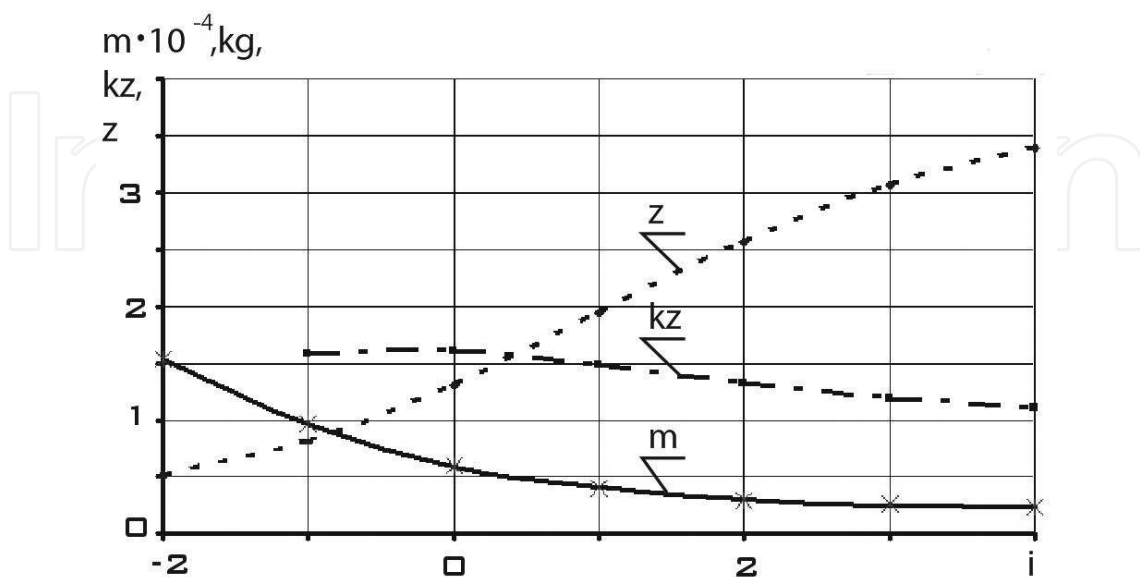
The value  $l$  obeys the law in Eq. (8). It is necessary to provide equality of Eq. (11) without changing of geometrical parameters of central body of spacecraft (radius and coordinates of fixing points of elastic element). In fact, it means multiple changing of elastic element's length and mass of central body to provide in Eq. (11) independently from sizes of spacecraft's body. Results of these actions for basic parameters of spacecraft "NIKA-T" ( $l_0 = 2$  m,  $\mu = 10$  kg/m,  $M = 1$  H m,  $m_0 = 6000$  kg) are shown in **Figure 4**. The following equation plays the role of coefficient, which determines multiplicity of changing of generalized parameter  $z$ :

$$kz_i = \frac{z_{i-1}}{z_i}. \quad (12)$$

According to **Figure 4**,  $kz_i$  coefficients significantly differ for different iterations. However, it is absolutely predictable, because changing of mass was conducted while permanent size of spacecraft's central body. Only length of elastic element was changed accordingly to the law in Eq. (8). It is hard to imagine significant changing of mass of spacecraft without changing of radius of central body. Thus, search of answers to be mentioned above questions after conducted in which the analysis will be leaded to the following. Is it possible to realize such changing law of central body's radius to achieve the following:

- values of  $kz_i$  do not significantly differ for different iterations;
- values of analogical coefficient for radius changing  $kR_i = \frac{R_{i-1}}{R_i}$  do not significantly differ for different iterations;
- changing of mass and radius are connected to each other, it means that they do not contradict to each other (reduction of mass leads to reduction of radius and vice versa).

According to the investigations, conducted for spacecraft, shown in **Figure 3**, such law exists. The sample dispersion of values  $kz_i$  was analyzed for different values  $kR_i = \text{Const}$ , using the



**Figure 4.** Changing dynamic of spacecraft's mass and generalized parameter if Eq. (11) is prominent for iterations  $-2 \leq i \leq 4$ .

same quantitative data, which correspond to basic parameters of spacecraft “NIKA-T.” The results of quantitative analysis are shown in **Figure 5**.

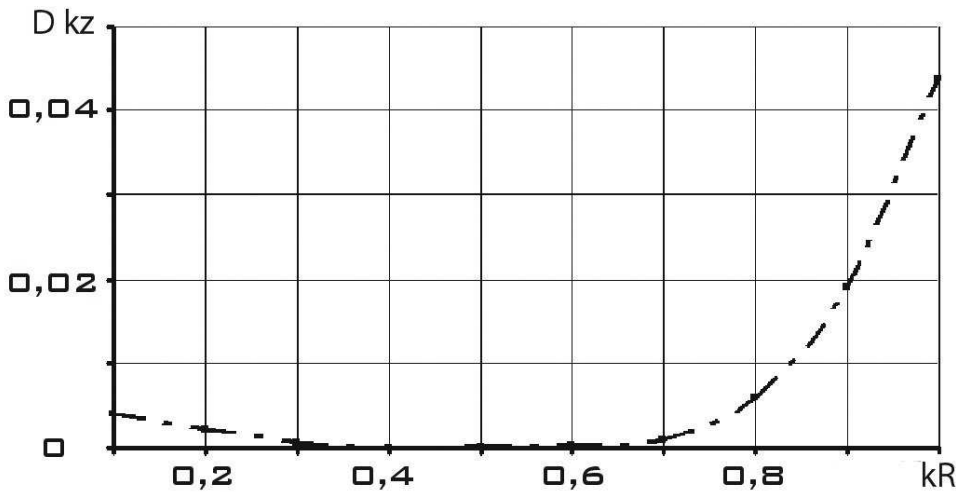
Minimum of the dispersion is achieved closely to the value  $kR = 0.4$ . Thus, changing law of radius of spacecraft’s central body, which is analogical to Eq. (8), has the following form:

$$R_i = (0.4)^i R_0. \tag{13}$$

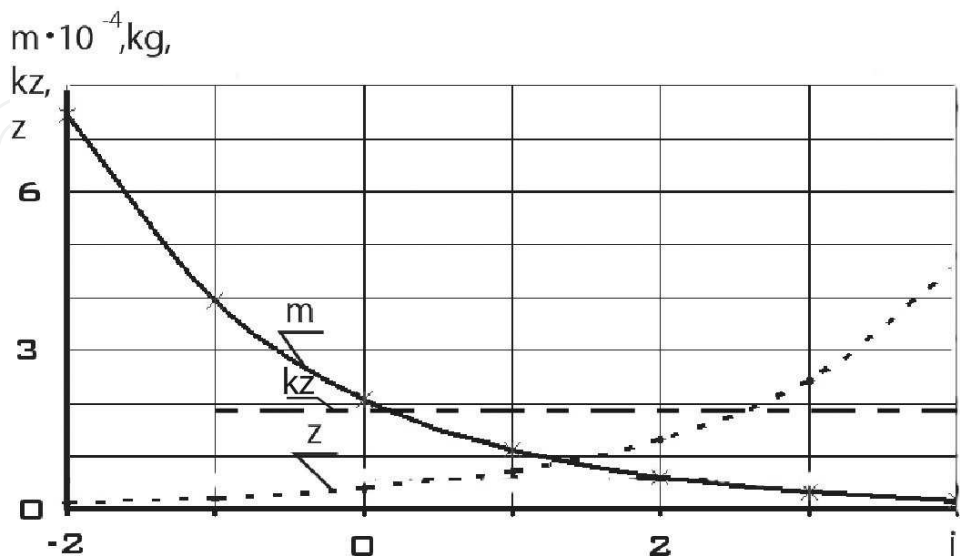
At that, generalized parameter  $z$  changes accordingly to approximated law:

$$z_i = (1.873)^i z_0. \tag{14}$$

Then, changing dynamic of the parameters with taking into account radius’s changing, which is analogical to **Figure 4**, has the form shown in **Figure 6**.



**Figure 5.** Sample dispersion of values  $kz_i$  in dependence on  $kR$ .



**Figure 6.** Changing dynamic of spacecraft’s mass and generalized parameter when Eq. (11) is right taking into account changing of spacecraft’s radius for iterations  $-2 \leq i \leq 4$ .

Consequently, we can confirm that constant scaling coefficients of central body's radius and generalized parameter  $z$  are found for viewed example of spacecraft. These coefficients provide invariance of appearance of dependence of constructive component of microaccelerations on time (**Figure 2**). The laws in Eqs. (8), (13) and (14) are realized simultaneously.

In this case, the fractal quality of constructive component of microaccelerations can be determined as *invariance of the form of time-dependence of microaccelerations' module whole scaling of spacecraft on generalized parameter  $z$* .

Scaling coefficients among axes of graph of time-dependence of microaccelerations are equal to 0.25 among time-axis and one among microacceleration-axis. Thus, the graph does not change its appearance as well as values of microaccelerations. It is very important for providing of required microacceleration level in the area with technological equipment. Graph compression among time-axis is explained by fourfold increase of frequency of proper oscillations of a beam while double reduction of its length.

There is used the simple scheme of spacecraft to show scaling property without hard computing in mentioned case. The same situation would be for more complicated scheme which is close to real spacecraft.

Scaling coefficients of mass  $km$  and radius  $kR$  are determined accordingly to the chosen scaling coefficient of length  $kl = 0.5$  in such a way as generalized parameter  $z$  was changed according to the law:

$$z_i = kz_i \cdot z_0, \quad (15)$$

where  $z_0$  is value of spacecraft's generalized parameter while  $i = 0$ , i.e., for basic spacecraft, which is the base for the future different types of spacecraft.

Application of another changing law of the length in place of Eq. (8) also does not change anything fundamentally. In this case, scaling coefficient of time-dependence of microaccelerations among time-axis will differ from 0.25.

It is worth to mention that only constructive component of microacceleration field has this property. Neither metastable even more nor random components according to classification [8] meets the fractal property. Metastable component is determined by the sphere of cosmic space where spacecraft operates. The component forms the part of microacceleration field, which is caused by outer disturbing factors. This disturbance, such as aerodynamic drag and light pressure, can change when spacecraft is scaled and can remain unchanged, such as magnetic disturbance. That is why metastable component has no scaling property.

The same thing is for random component. Appearance of emergency situations, failure of different equipment or random oscillations of basic parameters of outer disturbing impact on spacecraft is not connected with its scaling. On the other hand, probability of hitting of micrometeorite to spacecraft is connected with square of its outer surface and will change with scaling. Thus, we can claim that random component has no scaling property.

However, the remarks relatively to metastable and random components do not reduce the value of the found property of constructive component of microacceleration field. Actually, just

constructive component is determined already in early developmental stages of spacecraft. This component characterizes dynamical features of spacecraft's constructional layout and takes into account the algorithms and ways to orient its orbital motion. Only constructive component can be influenced by using of the total power of different methods to provide and control microacceleration level in the area with technological equipment. This power can be significantly strengthened by application of fractal analysis as well as classical.

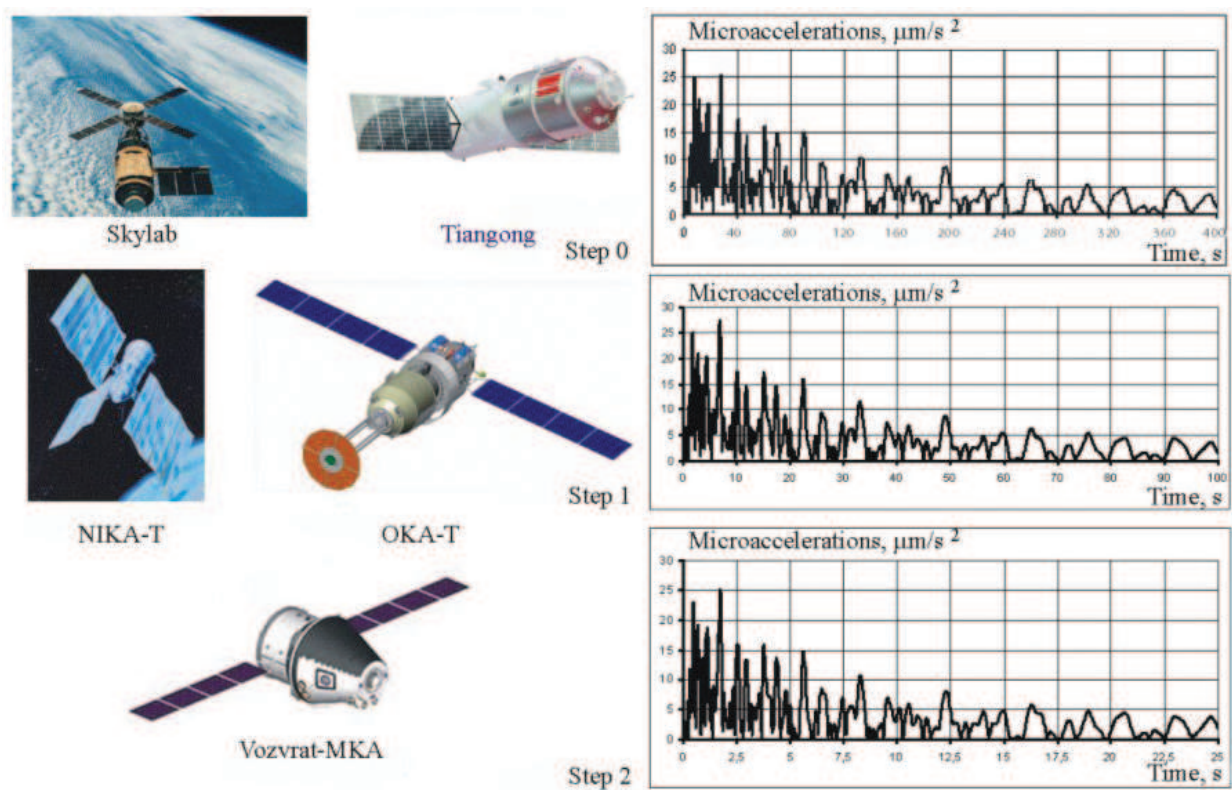
Scaling property of constructive component of microacceleration field allows application of methods of fractal analysis for designing of technological spacecraft as well as for correct data processing of microacceleration measurements, finding of failures of gauges and recovery of lost measuring data. It is very hard to do all of these only on the base of classical methods of analysis. The perspectives of addition of classical methods described by fractal property of constructive component of microaccelerations are mentioned below.

The launchings of spacecraft with specialized technological purposes happen with big intervals on the modern stage of space technologies' development. For instance, spacecraft "FOTON – M" No 3 was launched in 14 September 2007 and the following spacecraft "FOTON – M" No 4—only after almost 7 years in 19 July 2014. Thus, it is evident that it is impossible to arrange space experimental batch manufacturing only on the base of specialized space technic. One of the perspective ways to solve the problem is the wide application of small spacecraft. One start of carrier rocket of middle class is able to provide launching of tens small spacecraft to their orbits. Series-produced homotypic spacecraft can provide meeting of similar conditions for realization of concrete gravity-sensitive process. Continuous production can be organized using project launchings with small spacecraft as additional load. However, only application of small spacecraft would significantly limit production value. Limits on mass would not allow placement on spacecraft's board more than 100 kg of technological equipment and materials for production.

The approach, which includes advantages of spacecraft with specialized technological purposes and small spacecraft, is necessary to meet requirements of experimental batch production in space. This approach should integrate opportunities of these ways of space technic's development: regularity of launchings and significant scales of production while maintenance of equal favorable conditions for realization of gravity-sensitive processes. It is evident that such task statement leads to necessity to create line of spacecraft from different classes which meet these equal conditions. The scaling property of constructive component of microaccelerations should be applied to solve this task. For this purpose, the mathematical model of microaccelerations should be built using fractal function. Fractal model of microaccelerations worked out in the articles [15, 16] on the basis of cosine part of Weierstrass-Mandelbrot function in Eq. (1) can be example of such model. Behavior of an average value of microaccelerations as a random process was compared with behavior of cosine part of Weierstrass-Mandelbrot function with usage of statistical analysis. At that parameters of the function were identified with spacecraft's characteristics. So, functional fractal dimension  $D$  is identified with moment from orientation engine of spacecraft and scaling parameter  $b$ —with generalized parameter  $z$ .

Such line approximately can be presented in the form of scheme shown in **Figure 7** [13], where "NIKA-T" is the base spacecraft and actually created space objects are used.





**Figure 7.** Line of spacecraft from different classes, which realize equal microacceleration level in the area with technological equipment.

The line developed using fractal property would guarantee a correspondence of microacceleration levels on the spacecraft from different classes. It would allow conducting of the same process on the spacecraft and taking a step toward full-scale experimental batch production in space.

Described property also can be effectively applied for study of microacceleration field of inner environment of spacecraft. Correctness of the gauges' run after launching overloads can be estimated by comparison of experimental data with results of on-board measurements. There is worked out an algorithm of measuring equipment efficiency check on the basis of fractal property of constructive component of microaccelerations in Ref. [13]. The algorithm is effective when constructive component dominates in microacceleration field of inner environment. Significant differences between the fractal model and measuring data can be explained by following factors:

- There is no dominance of constructive component in microacceleration field.
- An additional source of microaccelerations presents, for instance, as the result of emergency situation.
- The gauge is failed.

Thus, checking of efficiency of all gauges after launching overloads is possible. It is unachievable by classical methods of analysis.



For instance, failed gauge was found in the result of such checking. It is possible to avoid significant mistakes while forming of model of microacceleration field of inner environment of spacecraft by neglect of measuring data from the gauge. However, accuracy would be reduced along with loss of measurement channel from failed gauge. In this case accuracy can be raised using fractal analysis. Well-known method of majority control [13] can be applied for replacement of the measurement channel by fractal mathematical model of microaccelerations, which was used for measuring equipment efficiency check. Undoubtedly, accuracy of such estimation would be lower in comparison with valid effective measurement channel. On the other hand, it would be higher than without application of majority control.

One of the possible algorithms of majority control with the aim to find out failed gauge and to smooth results of measuring data processing is shown in **Figure 8** [2].

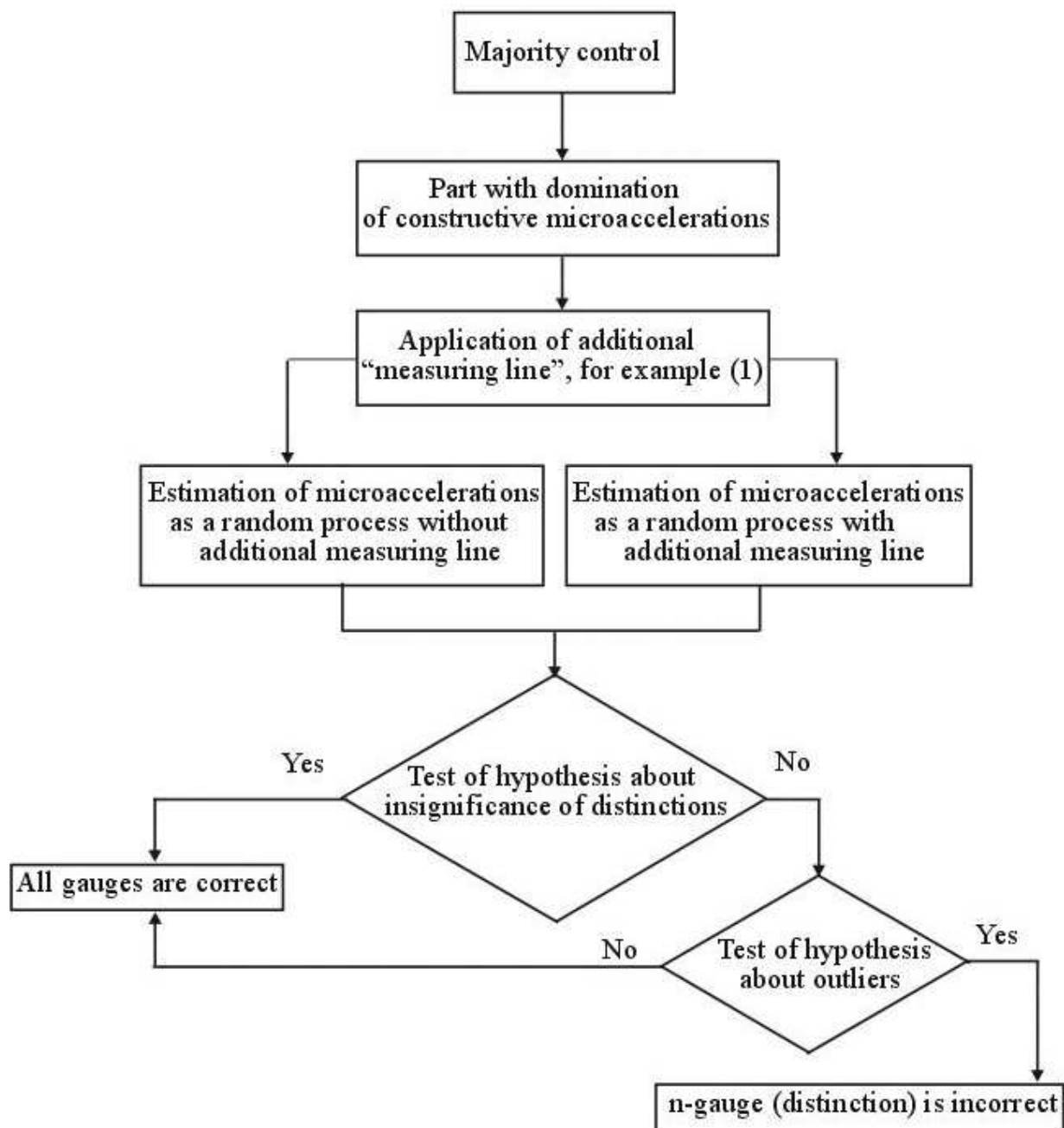
At that, fractal mathematical model plays the role of additional measurement channel. The presence of significant statistical differences between measurements with additional channel and without ones can be evidence of failed gauge. If the differences will be considered to be random, we can claim that all gauges run correctly. It increases the reliability of measuring data which leave much to be desired on the present developmental stage.

Thus, invention of scaling property of constructive component of microacceleration field which is similar to self-affine property of fractal functions allows application of methods of fractal analysis for creation of a line of spacecraft from different classes. At that, these spacecraft should realize the equal microacceleration level in the area with technological equipment.

The application of the scaling property of constructive component of microaccelerations gives the ability to select the row of values of generalized parameter  $z$ , which provides invariance of the form of time dependence of microaccelerations. The generalized parameter will allow a choice of corresponding inertia-mass characteristics of spacecraft and creation of the family of spacecraft (from orbital space stations to small spacecraft) which realize the identical microacceleration level.

Such result could not be achieved by classical methods because the fractal property is the base of supposed approach to creation of line of spacecraft from different classes. At that, it is worth to note that application of fractal analysis gives a significant practical result. Actually, creation of spacecraft line which realizes equal microacceleration level will have to be allowed in the beginning of pilot batch production in space already on the present developmental stage of space-rocket technic. The potential and advantages of spacecraft from all classes included in the line created on the base of scaling property of microaccelerations will be applied in the production. It is a large step forward in comparison with separated irregular experimental investigations with technological purposes, which are conducted in separated spacecraft today. On the other hand, creation of line of spacecraft on the basis of scaling property of microaccelerations is one of a few ways which lead to pilot batch-space-production on the present stage.

In spite of the main aim of designing of the spacecraft line, fractal model of microaccelerations, built, for example, on the basis of Weierstrass-Mandelbrot function, combined with classical methods of analysis allows solution of other tasks. These tasks include increasing of reliability



**Figure 8.** Algorithm to realize majority control over gauges during exploitation stage.

of data from on-board measuring equipment for microaccelerations; increasing of efficiency of control over microaccelerations during conducting of gravity-sensitive technological processes and also taking the decisions about possibility and advisability to realize some or another gravity-sensitive process on the board of concrete spacecraft.

We can claim that fractal analysis significantly widens opportunities of classical methods for conducting of majority control of microaccelerations, for recovering of lost measuring data and also for taking the decisions about realization of active control over microaccelerations on the exploitation stage of spacecraft.

Evidently, significant complications of spacecraft's model are necessary for effective application of fractal analysis and achieving required accuracy of estimations. The model described in the chapter was chosen only for approval of existence of scaling property of constructive component of microacceleration field and its illustration.

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