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OF AVIATION AND AEROSPACE SYSTEMS
processes, models, experiment

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EMBRY-RIDDLE AERONAUTICAL UNIVERSITY
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АКТУАЛЬНЫЕ ПРОБЛЕМЫ АВИАЦИОННЫХ И АЭРОКОСМИЧЕСКИХ СИСТЕМ
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СОДЕРЖАНИЕ

CONTENTS

Казань, Дайтона Бич
Вып. 1(36), том 18, 1-164, 2013

A C T U A L   P R O B L E M S   O F   A V I A T I O N   A N D   A E R O S P A C E   S Y S T E M S

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Main goals of this Journal -

- to inform the specialists of appropriate fields about recent state in theory and applications; about global problems, and actual directions;
- to promote close working contacts between scientists of various Universities and Schools; between theorists and application oriented scientists;
- to mathematize the methods in solving of problems, generated by engineering practice;
- to unite the efforts, to synthesize the methods in different areas of science and education...

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Kazan National Research Technical University of A.N.Tupolev's name - Kazan Aviation Institute, (collective member of International Federation of Nonlinear Analysts and Cosmonautics Federation of Russia) and Embry-Riddle Aeronautical University (Daytona Beach, USA) in accordance with the agreement about collaboration initiated the foundation of Russian-American scientific Journal on a broad spectrum of problems in aviation and aerospace systems. It is interdisciplinary bilingual scientific Edition, presenting the papers in areas of dynamics and flight control; theory, design and technology of aircrafts, engines; sciences on materials; information and computing systems, experimental investigations; economic and humanity problems of operation; Earth remote sensing; information satellite technology; the problems of Higher Engineering Education in area of Avia-, Aerospace systems; nanotechnology problems for Avia-, Aerospace systems,…

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"…we value cooperation with Russia…
since **in Russia it is World Sharpest Engineers,**…",
Josef Byden, Vice President, USA, (2011).

If to be, it is necessary to be ***the First***
V.P.Chkalov

From International Editorial Board

New issue of the International scientific journal "Actual problems of aviation and aerospace systems", *No.1(36), Vol.18, 2013*, is another special issue devoted to the greatest events of the history of Mankind associated with the beginning of Space exploration Era.

This epoch is associated with distinguishing achievements in space exploration, implemented on the basis of fundamental science and thought-out engineering practice: from the *first*, Soviet, Earth satellite (4 October 1957) – to the *first* Man on space orbit (Yu.A.Gagarin, 12 April 1961), to the satellite constellations and International space stations, to the space flights and lunar landing, to the interplanetary missions…

Great Russian scientist **Konstantin Eduardovich Tsiolkovsky** was the originator of the Epoch of Space exploration, with profound development of all the areas of basic and applied astronautics. Scientific theories and approaches that became a basis for the first space calculations, theoretical and applied research, including the problems of dynamics of celestial bodies and artificial satellites and engineering problems of space flights, are associated with the names of outstanding specialists in mechanics and mathematics, with *Russian* scientific and design Schools, which have been recognized all over the world. They are the Academicians: **Leonard Euler**; **Alexander Mikhailovich Lyapunov**, founder of the motion stability theory; **Nikolay Guryevich Chetaev**, who interpreted A.M.Lyapunov's concepts and theory to the whole scientific and engineering world, who founded Kazan Chetaev's School of stability and Kazan Aviation Institute (A.N.Tupolev KAI-KNRTU); **Sergey Pavlovich Korolev**, Chief Designer of rocketry; **Mstislav Vsevolodovich Keldysh**, scientific supervisor of the USSR Space Program, theorist in astronautics – a brilliant specialist in *mechanics and mathematics*…

This was an event of paramount importance for the history of Mankind that logically resulted from the efforts of the USSR people, who had managed to join the achievements of basic and applied science, engineering, socio-political system.

Contribution to that notable breakthrough, the projects and creativity of the outstanding scientists and designers of that time – M.K.Tikhonravov, V.P.Barmin, M.S.Ryazansky, G.Ye.Lozino-Lozinsky, V.P.Glushko, V.N.Chelomey, M.K.Yangel… – are the subject of special scientific research.

It was the basic higher engineering education, powerful scientific schools, lofty ideas, boundless loyalty and inexhaustible enthusiasm that provided the Soviet Union with the chance for such a brilliant breakthrough in science, technology and ideology. These positive results were provided by professional heroism of the Soviet representatives of science and engineering and policy of the country's top leadership who made the fantasy come true and the Soviet Union win the Victory (*in the struggle for Peace*…)

The city of Kazan and Kazan Aviation Institute is directly relevant to the development of aviation and astronautics; the world-famous names – Nikolay Guryevich Chetaev, Valentin Petrovich Glushko, Sergey Pavlovich Korolev, Andrey Nikolaevich Tupolev,..., as well as Andrey Vladimirovich Bolgarsky, Yuri Georgievich Odinokov, Vyacheslav Yevgenyevich Alemasov, Georgy Sergeevich Zhiritsky (one of the lunar craters was named after him), Vladimir Mefodyevich Matrosov (minor planet – Object 17354 – "**Matrosov**")… – all of them are associated with Kazan and Kazan Aviation Institute (which celebrates its 80th Anniversary in 2012), alma mater of engineering personnel for aviation and rocket-and-space engineering.

It was in 1945 in Kazan where the first in the country department of rocket propulsion engineering was founded in Kazan Aviation Institute (Head of department – V.P.Glushko, Professor of department – G.C.Zhiritsky, Lecturers – S.P.Korolev, D.D.Sevryk,...).

Among the famous designers of rocket-and-space hardware there were also the following graduates of KAI: B.I.Gubanov, Chief Designer of Energiya-Buran Space System; V.I.Lobachev, Head of Mission Control Center,...

Close interdisciplinary link between the basic and applied spheres of science, between its separate disciplines is of vital importance for successful development of the whole aviation and rocket-and-space engineering, for space exploration. This was established as a basis for the entire scientific, educational, engineering and design work aimed at the training of specialists in Kazan on N.G.Chetaev's initiative and according to the innovative ideas of the "fathers of Russian aviation" **N.E.Zhukovsky, S.A.Chaplygin**, aiming at extension of traditions of advanced scientific and educational School (**P.L.Chebyshev – A.M.Lyapunov– N.G.Chetaev**).

The papers published in this special issue describe the developments of the leading specialists in aerospace; they contain the historical analysis of the way that led to the positive results of the beginning of Space Era. Scientific research, analytical reviews on these events and relevant problems, analytical and information articles, polemical ideas and prospects of further development of Astronautics in Russia and in the World, reflections on the meaning of space scientific and engineering heritage for the whole world society and results in the sphere of aviation and aerospace systems are presented.

The special issue was prepared with support from our Partners, among them: Cosmonautics Federation of Russia Central Scientific Research Institute for Machine Building, Federal Space Agency, K.E.Tsiolkovsky Russian Academy of Cosmonautics, Academy of Aviation and Aeronautics Sciences, A.A.Maksimov Scientific and Research Institute of Space Systems, N.E.Bauman Moscow State Technical University, Moscow Aviation Institute (National Research University), International Academy of Astronautics, Institute of Control Sciences of RAS, …

Our authors are the specialists, researchers, representatives of the Academies of Sciences, design bureaus, scientific and research institutes, universities, space agencies, who work in the spheres theoretical and applied aviation and astronautics.

A.A.Barenbaum (Institute of problems of oil and gas of the Russian Academy of Science, Russia), the specialist in area of problems of geodynamics, cosmogony and astronomy, – with the survey of main principles of Galaxy centric paradigm revealing physical mechanisms of influence of space processes in the Galaxy and Solar system on Earth evolution (part II).

E.V.Gorbenko (Dnepropetrovsk National University named after Oles Gonchar, Ukraine), the post-graduate student (Physics and Technical Department, Technical mechanics, specialty “The history of science and technology”), – with scientific research work on topic related to the schemes development for air launching and rocket engineering complexes (Scientific supervisor is **Galina I.Sokol**, Professor of Dnepropetrovsk National University).

A.V.Danilenko, K.S.Elkin, S.C.Lyagushina, S.B.Fedorov (TsNIIMash, Russia), the specialists in dynamics of flight and control of spacecrafts motion, – with discussion on statements and results in problems of designing orbital tethered systems for nano-satellites of scientific purpose.

M.V.Levskiy (Research Institute of Space Systems, Khrunichev State research and production Space Center, Russia), the specialist in the domain of attitude control systems, navigation and stabilization, – with interesting problem of the combining regimes of orientation and orbit correction for a spacecraft motion control.

Z.Wang, A.S.Kretov (Nanjing University of Aeronautics and Astronautics, PRC; Tupolev Kazan National Research Technical University-KAI, Russia), the specialist in area designing of high-temperature structures of flying vehicles, – with analytical survey of scientific engineering and philosophic aspects of Space exploration from point of “Columbia” Space Shuttle tragedy analysis.

K.K.Klionovska (Moscow Aviation Institute-NRU, Russia), the student (4-th year, Dept. «the System analysis and control», a specialty: – flight dynamics), – with scientific research of asymmetries influence during opening stabilizer on the accuracy of uncontrolled aircraft motion (scientific supervisor is **Stanislav Alekseevich Gorbatenko**, Dr., Prof. of Moscow Aviation Institute, Dept.604)

E.E.Escultura (Institute for Advanced Studies, University, India), the specialist in area qualitative modelling of complex systems and Cosmology problems, – with survey article on Universe evolution problems on base of author premises and hypothesis.

V.Yu.Rutkovskiy, (V.A.Trapeznikov Institute of Control Sciences of RAS, Russia), the specialist in the theory of nonlinear non-stationary objects and its application to aircraft and spacecraft control, – with memorial paper, devoted to the 100 Anniversary of Academician B.N.Petrov, brilliant specialist and Founder of control theory important chapters.

Galaxy Centric Paradigm in Natural Science, part II

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Basic issues of galactocentric paradigm [1] are stated, which relates the repeatability of geological processes on the Earth to the space events in the Galaxy and Solar System. New view of the physical nature of the structure of spiral galaxies is substantiated. Consistent solutions of a number of basic problems of astronomy and Earth sciences have been elaborated on the basis of unified methodology. The required basis for the closing-in of geological and space fields of knowledge has been created, with survey of many results [1-160]. In this Journal issue ("APAAS", No.1(36), v.18, 2013) it is presented the second part of article (part II, figures 19-25, tables 5-7). First part (part I, fig.1-18, tabl.1-4) is published in past issue of Journal ("APAAS", No.2(35), v.17, 2012, pp. 56–111). The figures and tables are given in end of article part, after the reference list.

14. Utilization of space substance

More than 60 years ago V.I.Vernadski wrote that "a part of biosphere substance, maybe the largest one, comes to the Earth from outside, from space". However, geologists could not find any irrefutable proofs for this until recently. They used to believe that all the main geological events on the Earth, including the formation of mineral deposits, were caused only by internal endogenous reasons. The effects caused by space were admitted but considered at best only as a trigger [105].

Discovery of galactic comets has changed the situation dramatically. Falls of $\sim10^6\div10^7$ of such comets on the Earth, when the Sun was staying within the jet flows and Galaxy's spiral arms, is equal to our planet getting up to $\sim10^{20}\div10^{21}$ g of water, an order less amount of carbon and all the other heavier chemical elements according to their amount in space. This amount of substance is enough to explain the similarity [106] among an average isotope composition of H, He, C, N, O, and inert gases on the Earth and the substance of carbonaceous chondrites.

The analysis shows [72] that water, carbon and other chemical elements incoming with comets are immediately included into a global geochemical cycle of substance, breaking the well-established geochemical balance established on the planet. According to Le Chatelier principle this promotes a number of natural processes on the Earth intending to return the system to the equilibrium state.

Return of the system to a stable state is performed at the expense of getting rid of "useless" substance, and primarily of the excess of water and carbon, which are taken out of the active cycle by the system. The main part of water gets into the ocean, which explains the stepwise behavior of its level [107]. Carbon and the rest of space material are carried away into the ocean by the water. Therefore the content of P, Ca, Fe, Cu, U, Ir, Os, etc. in water becomes 10-100 times as much at the boundaries of periods and divisions of geochronologic time scale [63]. After the comets cease to fall, the composition of ocean water returns to normal, and relatively thin interlayers of rocks, which are carbonaceous or rich of other space substance and transform into black shale, are deposited in inland seas [108]. Besides, the deposits of many other minerals are formed: uranium, bauxite, ferriferrous manganese ores, phosphorus and salts [5, 109].

15. Origin of phosphates and salts

Phosphates and salts belong to a small group of minerals that take up large territories and depict global events associated with their formation [110]. Formation of large phosphate-bearing provinces on the Earth took place only during some relatively short (<10 million years) periods: Vendian Period – Early Cambrian, Permian and Late Cretaceous – Early

Paleogene. The planet's main phosphate-bearing basins belong to these three epochs. There are much fewer or even no phosphorus deposits outside these periods.

Despite the fact that the process of salt accumulation has been almost continuous "since Cambrian and till now", like in the case of phosphorus, the periods of global halogenesis [111] are distinct. The periods of formation of main volumes of salts and phosphorites are close (fig.19). Proximity of some phosphate and salt-bearing basins indicate the relationship between both processes.

For a long time there has been no explanation in geology for the reasons of intense accumulation of salts and phosphates in certain relatively short periods of the Phanerozoic, and the source of phosphorus and salts was unknown. In [112] this phenomenon is explained from the standpoint of the galactocentric paradigm. It is supposed that in addition to comets of jet flows the comets of spiral galactic arms also fell on the Earth in the epochs of comet bombardments. They were particularly numerous at the corotation radius of $R^* = 13.0\pm1.0$ kpc from the Galaxy center. The composition of spiral arms' comets differs from the substance of jet flows' comets in increased content (up to ~0.1-1 %) of chemical elements of average atomic weights. Therefore the deposits of rocks and ores of appropriate composition correspond to the epochs of such comets falling on the Earth.

Table 5 gives the chemical elements of so-called "calcium peak". All these elements are synthesized only in reaction of combustion of carbon, oxygen and silicon inside giant planets or result from the explosions of ordinary stars [113]. Comparison of nuclides in table 5 with the chemical composition of salts (table 6) shows that all of them (excluding phosphorus and silicon) are observed in salts. Moreover, the ratio of volumes of some classes of salts deposited during the Paleozoic is controlled by the content of these elements in space substance [112].

One more regularity is characteristic of the Paleozoic: volumes of deposited rock salts and prospected resources of phosphates summed for the whole globe reveal linear dependence (fig.20). From the standpoint of our hypothesis this fact leads to three conclusions: 1) weak change of average composition of galactic comets that fell on Earth; 2) proportional burial of its phosphate and most soluble components in sedimentation process; 3) there was no significant erosion and redeposit of existing accumulations of phosphorites and salts in later epochs. If at least one of these conditions was broken, the plot linearity would have been violated.

The described results sufficiently explain the times and volumes of deposits of phosphorites and salts during the Phanerozoic, but do not answer another important question: why the enhanced formation of minerals on the Earth started at the very boundary between Vendian and Cambrian periods. Besides, this period corresponds to an abrupt change in the pattern of calcium and calcium-magnesium carbonates accumulation, and limestones become widespread. The answers to these questions are linked to another fundamental problem, which we are going to consider.

16. Biotic revolution in Vendian-Cambrian

It is well-known that 570-545 million years ago, at the end of Vendian – beginning of Cambrian, the fauna of our planet developed rapidly. Earlier the living organisms of the Earth were primitive: archaebacteria, cyanobacteriae, (procaryotes) and unicellular planktonic organisms (eukaryotes). At the end of Vendian, the multicellular ediacaran fauna emerges. At the beginning of Cambrian, it is replaced by almost all the main types of organisms, which already had hard shells or skeletons and have survived to the present day [105]. Later, marine animals acquire blood-vascular system, and dermal respiration is replaced by more advanced lung respiration [118].

Galactocentric paradigm has no problems here, too. The thing is that in calculations given in fig.19 the effect of the Galaxy evolution on parameters of the Sun's orbit was neglected. However, the estimates show that the orbital period of the Sun has increased by 3.6% in 600 million years that passed since the beginning of the Phanerozoic, and an average radius of the Sun's orbit has grown by approximately 2%. Although these changes are not significant, we are to account for them in our case.

Account for this factor leads to the conclusion [119] that at the boundary between the Vendian and Cambrian the Sun reached the apogalacticon section of the orbit ~20 million years later than the initial calculation showed. The calculated time boundaries of Cambrian system should be reduced by the same value. By the way, these values are in better agreement with the recently reconsidered time boundary between the Vendian and Cambrian periods [59].

An average radius of the Sun's orbit and, possibly, its eccentricity decreased as well. In the end, the apogalacticon of the Sun's orbit was closer to the Galaxy center in Precambrian than at present. Evolution of the Galaxy also influences the corotation radius, which is to reduce with time (fig.21).

Due to the evolution of our stellar system the Sun's orbit in the apogalacticon reached the Galaxy corotation radius for the first time only about 570 million years ago. The Sun's orbit lay within the corotation radius formerly. Therefore the sufficient amount of chemical elements of calcium peak was not delivered to the Earth by galactic comets. Due to this very reason the large accumulations of these elements that form the industrial deposits of phosphorites, salts, sulphates, etc. began to form on the Earth only in the Phanerozoic.

The same reason explains the emergence of highly advanced organisms on the Earth. The largest amounts of "chemical elements of life" – phosphorus and calcium – were supplied to the Earth at the bounds of Vendian-Cambrian, Carboniferous-Permian and Cretaceous-Paleogene, when the Sun was one corotation radius away from the Galaxy center. Therefore these three epochs were the time of the largest reorganizations of the organic world of our planet. The first one marks the beginning of the Paleozoic Era – the era of ancient life; the second one – the Mesozoic Era – the era of middle life; the last one – the Cenozoic Era – the era of new life.

Thus, according to the galactocentric paradigm, the rapid development of the Earth fauna of the last 570 million years is caused, first of all, by space influence. Since then, the orbit of the Sun has reached the Galaxy corotation radius for the first time ever, causing the galactic comets rich of phosphorus, calcium and other vital chemical elements fall on the Earth. These elements were supplied to the ocean with comet water, and the ocean became the main arena for the fauna evolution on our Earth in the Paleozoic Era.

One should note that the idea that living organisms emerged on the Earth owing to the Sun locating close to the Galaxy corotation radius was submitted earlier [42], but this association was not described in detail.

17. Geochemical cycle of carbon

Unlike phosphorus and salts, large amounts of which were supplied to the Earth relatively rarely, the most popular components of comet substance – water and carbon – were delivered by the comets of Galaxy jet flows every 25 million years on the average. And while phosphorus was utilized as early as in the epochs of falling comets, and salts – millions – tens of millions of years later (fig.20), carbon actively participated in the cycle of substance on the planet between the epochs of comet bombardments too [72].

The studied pattern of geochemical cycle of carbon on the Earth allowing for the repeated arrival with comets is theoretically shown in fig.22.

Three interacting circles of carbon circulation are highlighted in the scheme. The first one lasting 10^8-10^9 years is associated with immersion of carbon-bearing rocks into the Earth mantle during the subduction of tectonic plates. The second one ~10^6-10^7 is caused by transformation of buried organic substance during the accumulation of sediments. And the third one – biospheric, the shortest cycle, - is caused by transfer of biospheric carbon to the depths of the Earth crust by meteoric waters during their climatic cycle.

The Earth surface acts as a geochemical barrier in the cycle. Movable carbon circulates in its oxidized form above the Earth surface (CO_2) and – mainly in its reduced form – under the surface (CH_4). Due to their weak solvability in water, the hydrocarbons of the Earth crust stand apart and form their own deposits in favorable environment – oil and gas.

Different arrow length stresses the known imbalance between “upward” and “downward” currents of carbon owing to natural processes. While $(2\div6)\times10^{14}$ g of carbon are buried annually in the sediments of continents and oceans, $(1\div5)\times10^{15}$ g/year are taken out of the interior [120]. And oxidized carbon consisting of carbonates (~2/3) and dead organic matter (~1/3) gets under the surface. Meanwhile the reduced carbon (methane and its homologues) is supplied to the atmosphere out of the interior.

This imbalance is even aggravated if annually extracted oil, gas and coal making 7.6 billion tons of oil equivalent (7.6×10^{15} g of carbon) are taken into account. When this fuel is burned, almost thrice as much CO_2 gets into the atmosphere, increasing the total amount of carbon dioxide there. Some climatologists believe that this can be responsible for the global warming on the Earth.

Large amount of calculations has been carried out aiming at the study of fuel consumption effect on the Earth climate. Carbon cycle in the biosphere, including the atmosphere, ocean and soils-sludges, has been investigated. It appeared that if the problem is stated this way, the current emission of CO_2 is excess for the circle of carbon on the Earth. Even the most optimistic evaluation admits that about 30% CO_2 cannot be removed from the atmosphere using the currently known mechanisms of its solution in ocean waters and consumption by flora and fauna [121].

We show [122] that these difficulties are caused by incorrect consideration of biospheric carbon cycle through the Earth surface with participation of hydrosphere water.

According to fig.22, carbon cycle on the Earth can be described by the system of equations

$$\frac{dn_1}{dt}+\frac{n_1}{t_1}=a_{12}n_2+a_{13}n_3+Q(t)\,,\ \frac{dn_2}{dt}+\frac{n_2}{t_2}=a_{21}n_1+a_{23}n_3\,,\ \frac{dn_3}{dt}+\frac{n_3}{t_3}=a_{31}n_1+a_{32}n_2 \qquad (3)$$

where n_1, n_2, n_3 and t_1, t_2, t_3 – amount of carbon and its lifetime in each of three cycles; $Q(t)$ – function of space carbon arriving to the Earth; a_{ij} – parameters of carbon exchange between the cycles.

The first equation defines geochemical cycle of carbon in the biosphere (above the Earth surface), the second one – in underground lithosphere, the third one allows for binding of carbon with rocks, i.e. its long-term elimination from active interchange.

Solution of equations (3) for pulse arrival of comet substance to the Earth leads to the conclusion that the total mass of carbon and the speed of its burial in biosphere cycle grew exponentially in the Phanerozoic. This conclusion is fully confirmed by actual facts (fig.23). However, the measurements show that such growth was disturbed by strong perturbations that reduced the rate of carbon deposition by several times. The strongest perturbation corresponded to the boundaries between the Triassic and Ordovician, when the most intense comet bombardments took place. The actual data, in our opinion, can be comprehended and interpreted, if we admit that the amount of space substance arriving to the Earth varies significantly meeting the galactic periodicity. It should be admitted [123] that the largest amount of water (majority of comets) fell on the Earth at the beginning of the Mesozoic Era. Further redistribution of this water between the ocean and underground hydrosphere obviously took several tens of millions of years and eventually led to the strongest transgression in the Jurassic [124].

There is every reason to say [72] that the fast rearrangement of the whole system of substance cycles on the Earth took place at the boundaries between the Mesozoic and Paleozoic Eras and was accompanied by the change of the main geochemical processes. The system being under the influence of the Galaxy jumped to a new equilibrium state. The noted feature resembles the behavior of systems with so-called unstable equilibrium state [126, 127], when an open system under the external influence jumps from one local equilibrium state to another.

Let us consider some other important consequences of galactocentric paradigm based on the solution of the set of equations (3) by two examples: formation of hydrosphere and origin of oil and gas.

18. Formation and evolution of hydrosphere

In the current statement of the problem of hydrosphere formation a consistent explanation of at least three problems should be given: 1) reasons for the formation of the global ocean; 2) accumulation of water in the global ocean; 3) periodicity of abrupt oscillations of the ocean water level in the planet history.

It is rather difficult to answer these questions on the basis of the idea [128-130] that the hydrosphere was formed owing to degassing of deep substance of the planet and elevation of volatile elements to the Earth surface. It is not even clear how this process ran and changed with time. Some believe [131] that water mainly reached the Earth surface during the first billion of years after the Earth had formed, others consider [123] this accumulation as an abrupt increase at the boundary between the Mesozoic and Paleozoic Eras, still others [132, 133] assume that the water accumulated more or less gradually.

According to the galactocentric paradigm, the water in the global ocean and oscillations of its level were caused by the comets and asteroids that fell on the Earth accompanied by its cooling resulted from powerful galactic impacts. At that, the amount of free water on the Earth surface changed significantly. The periods of ocean existence were replaced by the periods of its shallowing or even evaporation during the Archean and Proterozoic. Hence, incompatible opinions on large or small amount of water relate just to different segments of this long time interval. We divide the formation and evolution of hydrosphere into 4 stages [134].

The Archean. This eon is notable for an extremely intense falling of large astronomical bodies on the Earth. The processes of cratonization and volcanism caused by these impacts spread globally and were very powerful [105]. The processes of magma outflow and hydration of Earth crust rocks took place frequently during this period. They significantly reduced the lifetime of free water in lithosphere ($t_1 < t_2 << t_3$). As long as t_1 time remained less than the period of comet bombardments ($t_1 < T$), the water in the Earth surface could possibly exist only in the epochs of comet falls.

Around 4-3.8 billion years ago, the temperature close to the Earth surface fell, and t_1 grew to such values that conditions for accumulation of water on the Earth surface became favorable. The obtained data demonstrate that there was not much water at first. And it collected mainly in relatively narrow (~10 km) and stretched (~n·100 km) basins, which set off the neighboring cratons and served as a place for sediment ablation. The basins could be 1.5-2 km deep. Water temperature in sea basins was ~70ºC, air temperature 70-100ºC [135].

We believe that the Archean water was mainly included into magma melts; in the case of $t_2 > t_3$ it took part in volcanic processes and magma outflows; in the case of $t_2 < t_3$ it was bound in minerals at rock hydration.

The Proterozoic. Behavior of hydrosphere in the Proterozoic is clearer despite strong variability and complexity of its regimes. We distinguish two main regimes in the Proterozoic: significantly "water" and "waterless".

The first regime (periods of loaded carbonate carbon correspond to this regime (see fig.13d, part I, «APAAS», №2(35), v.17, 2012, p.108) was notable for large amount of water on the surface ($t_1 \geq t_2$). This regime was triggered by mass falling of large asteroids on the Earth, which made the water bounded in rock transform into mobile condition and get into the ocean. Simultaneously, due to the formation of a cloud layer that shielded the solar beams, near-surface temperature became so low that ice covered the surface [136]. Judging by rapid growth of biota [73, 74] during that period on the Earth, these conditions were rather comfortable for it.

The second regime of hydrosphere life was, unlike the first one, notable for high temperatures and almost completely dried water basins ($t_1 \leq t_2$). This regime can be considered using the data on conditions of formation of ferruginous quartzite's (jaspilites). We develop hypothesis [137] assuming that these ores emerged from asteroid substance, large amount of which fell on the Earth (~10^{23} g) after regular interactions of Sun and stars.

Since ~90% of asteroids consist of olivine and pyroxene [138], i.e. they consist of iron and silicon in 1:3 proportion, these oxides got into seas in the same proportion. Large deposits of jaspilites were formed in shallow water basins owing to the products of land rock weathering that accumulated in them and transition of large amount of iron and silica in colloidal form into solution [139]. Formation of ores usually took place in an undisturbed tectonic situation in ~10^6 years. Streak pattern of ores resulted from mutual coagulation in the solution of gels of oxidized iron and silica [140]. Water temperature was ~100ºC [141] during the period of active coagulation. Water was fresh [77], and the partial pressure of oxygen in it was low <0.2 atm. The value of pH in water did not exceed 2-6 [142, 143]. The water composition changed at the final stage. At diagenesis stage, which was often caused by drying of the basin, the substance was heated up to 150ºC and more [144].

So, hydrosphere regime changed repeatedly in the Proterozoic. The epochs of flower of life and seas filled with water ($t_1 \geq t_2$) were replaced by long periods of drying of water basins and depression of living organisms ($t_1 \leq t_2$), when the share of biogenic carbon in precipitations fell almost to zero (see fig.13, part I, «APAAS», №2(35), v.17, 2012, p.108).

The Paleozoic and Mesozoic Eras. Unlike the Archean ($t_1 < t_2 << t_3 \sim T$) and Proterozoic ($t_1 \approx t_2 > T$), the planet lithosphere was cooled by the beginning of the Phanerozoic to such extent that the largest share of water constantly remained on the Earth surface ($t_1 > t_2$, $t_3 >> t_1$), filling the global ocean.

Solution of the system of equation (3) for these conditions for a simplified problem statement is the following [134]. After each comet bombardment the most part of comet water flows to the global ocean, and in about t ~2 million years it penetrates into the underground hydrosphere. In ~ 10 million years the system reaches its equilibrium state, when the most part (2/3 Q_0) of incoming water remains on the Earth surface, and the rest (1/3 Q_0) – under the surface.

The intensity of comet bombardments of the Earth varied significantly. In particular, at the boundary between the Ordovician and Triassic, our planet suffered much more comet falls than in other epochs. Water supplied with the comets caused an intense washing out of the Earth surface rock. However, it accumulated not in the global ocean, but mainly in underground hydrosphere, where it was included into magma melts. This circumstance is possibly associated with increased tectonic and magma activity of the Earth in the Triassic and Ordovician periods and with small amount of biogenic carbon in sediments of that time (fig.23).

Apparently, the subsequent redistribution of water between the underground hydrosphere and global ocean happened faster than in the Triassic. During the latter it took tens of millions of years, causing strong transgression in the Jurassic and Cretaceous periods [124]. According to some estimates, the level of global ocean became twice as high at that time. We believe that such water rise and its long supply to the ocean indicate the release of this water in the process of Earth crust dehydration.

The Cenozoic Era. Unlike the earlier periods, the cycle of hydrosphere water in the Cenozoic Era was rather stable. Comparison of our calculations to reliable empirical data on the growth rate of an average depth of global ocean [144] leads to the conclusion that the sea level in the Cenozoic Era grew mainly not due to the incoming comet water, but owing to dehydration caused by the heating of lithosphere rock under the impact of falling comets. This conclusion [145] agrees well with the growth of global ocean level.

And finally, one more useful calculation. Assuming that comets in the Earth history fell with the period typical for the Phanerozoic, we obtain the mass of comet water supplied since the Earth origin (4.6 billion years) equal to $\sim 10^{24}$ g. This value is comparable to the actual mass of hydrosphere water. Thus, repeated bombardments with galactic comets should be considered as a main supplier of free water to the Earth, Mars, Moon and other Solar System's planets.

19. Oil and gas

Origination of oil and gas is one of the crucial problems in geology, being at the same time a problem of applied significance. Scientific statement of this problem dates back to the 18th-early 19th centuries, when it was proved that oil and gas can be obtained both in biogenic (organic) and abiogenic (mineral) way.

According to galactocentric paradigm, oil and gas are inherent products of carbon and comet water circulation through the Earth surface. These carbon and water accumulated in the past geological epochs and participate in geochemical substance cycle taking place on the Earth at present [146].

Theoretical analysis shows that when large amounts of space substance are repeatedly supplied to the Earth, stable operation of the system requires obligatory withdrawal of excessive carbon and water and their capture in some "reservoirs" for some time. Such reservoirs that accumulate movable carbon on the Earth surface are global ocean, living substance, atmosphere and soils, and under the Earth surface – rock of the Earth crust and upper mantle.

Solution of (3) for biosphere cycle yields that under dynamic equilibrium of the system the carbon is distributed between the reservoirs meeting the following rule:

$$C = n_i / t_i = \text{const} \tag{4}$$

where C - speed of geochemical cycle, n_i and t_1 – mass of movable carbon and time of its residence in main reservoirs of the system.

If relation (4) is satisfied, then the decrease of carbon in one part of the system is compensated by its supply from other parts; if not, then cross flows take place in the system returning the latter to its equilibrium.

Carbon cycle in the biosphere is now close to equilibrium (fig.24). Constant value (4) defined using the plot in fig.24 and recomputed for carbon dioxide is given in table 7 together with the estimated speed of the cycle of atmosphere oxygen [5] and current circulation of the global ocean water across central ocean ranges [147].
One can see that all the three processes form a single system of cycles with C=2.7·10^{17} g/year. This result confirms fundamental correctness of V.I.Vernadsky at least in two issues: 1) cycle of substance on the Earth is a global geochemical phenomenon that covers mainly the upper shells of the planet and supplies them with water, carbon and oxygen; 2) living organisms play a crucial role in this phenomenon taking an active part in redistribution of the substance on the planet and matching the speed of carbon and oxygen cycle in biosphere with the speed of underground water cycle.
Current distribution of water over the hydrosphere basins is shown in fig.25. The water of main planet's basins participates in two different cycles in certain proportion. About 90% of water is formed by surface climate cycle with the speed of 5.2×10^{20} g/year [148] (upper inclined line), about 10% - by lithosphere water circulating with the speed of 2.7×10^{17} g/year (table 6) (lower line). Thus, an average cycle speed is $(2.0\pm0.5)\times10^{19}$ g/year.
Water involved in climate cycle is called "meteoric", water of lithospheric cycle – "sea water". The former one is of local origination; it is formed in the atmosphere in the form of rain and snow and infiltrates through the Earth surface, reaching the basins' recharge areas. The latter one is deeper and relates to the common circulation system of underground water. It is called "sea water", because its composition is close to the one of global ocean water. Both types of water differ in their isotope composition of hydrogen and oxygen, which allows their reliable identification [149].
Meteoric water flowing along the faults and other soft regions of the Earth crust can penetrate rapidly to the depth of several km. This can be observed everywhere on the Earth [149]. Moreover, it is able to provide about 10^{15} g of carbon [122] mainly in the form of hydrogen carbonate (HCO_3) and carbon dioxide dissolved in water (CO_2). Allowing for this fact, one can eliminate the first balance contradiction of carbon cycle through the Earth surface shown in fig.23 with the arrows of different length.
The second imbalance consisting in "downward" supply of oxidized carbon and "upward" supply of reduced carbon is also eliminated if the possibility of catalytic synthesis of hydrocarbons from carbon oxides and hydrogen oxides in the Earth crust is allowed for [150, 151].
Thus, it becomes obvious that the most rapid biosphere cycle of carbon is not restricted to carbon circulation above the Earth surface, as climatologists believe, but involves the whole biosphere, including sedimentary cover of the Earth crust, where the main deposits of oil and gas are concentrated.
Oil-and-gas accumulations act as natural traps that accumulate movable carbon, which circulates through the Earth surface and is excessive for the system of its regional geochemical cycle. Due to active participation of meteoric water in this process, the traps are supplemented with hydrocarbons not in geological time, but much faster. Besides, the traps themselves, first, are located within large catchments sediment basins that drain huge areas, second, they are drawn towards large faults in the Earth crust [152]. From the one hand, the faults make it easier for the meteoric water to get into the Earth crust rock, from the other hand they promote withdrawal of carbon from the water that transport it.
The most essential is the conclusion on involvement of carbon cycle into the processes of "current" oil-and-gas formation. This results in partial recovery of oil and gas in producing wells [153] and discovery of cosmogeneous isotope C^{14} with the half-life of 5730 years in oils

[154]. The facts show that oil-and-gas deposits are formed under both geological conditions of genesis and accumulation of hydrocarbons in the Earth interior (existing source rocks, faults and rocks, thermobaric conditions, etc.) and the pattern of carbon cycle above the planet surface, which is defined to a large extent by the economic activity. Current production and consumption of oil and gas can not only significantly influence the planet climate, but also have a considerable effect on the distribution of movable carbon in its interior [155].

Transportation of oil and gas for many thousands of kilometers from the place of their production leads to redistribution of world resources of hydrocarbons, and not in geological time. Industrially developed countries that actively consume oil and gas accumulate the latter on their territories, while the countries that produce and export oil and gas can exhaust their resources relatively quickly.

Another predictable consequence of this process is the trend towards the shift of the largest industrial accumulations of oil and gas to the basin of global ocean. Due to the fact that at the continents' edges there are no required geological conditions for the accumulation of hydrocarbons in the Earth interior, and the main part of the Earth population actively consuming oil and gas live on the surface, the excessive carbon in the course of regional cycle is withdrawn by the underground water to the global ocean [156, 157] on deep-sea shelf and continental slope. The author considers this fact as a reason for rich reserves of hydrocarbons of our planet concentrated right here and represented not only by oil and gas, but also by aquamarine clathrate hydrates [158].

On the basis of galactocentric paradigm one can assume that oil and gas reserves in producing deposits are being constantly recovered with a certain rate. Therefore, if production is reasonable and the rate of oil and gas extraction does not exceed the rate of their natural replenishment, there are some prerequisites for the operation of oil-and-gas deposits as renewable sources of hydrocarbons.

Conclusions

The second century AD can be considered the time of birth of the modern science. It was the time when the foundations of general vision later called a geocentric paradigm were laid by Ptolemy. According to this vision, everything that took place on "celestial" and "earth" spheres was associated with our planet. Hence, the Earth was self-sufficient to explain all the observed phenomena.

In the Middle Ages, owing to N.Copernicus (1473-1543), G.Galileo (1564-1642) and J.Kepler (1571-1630), the investigations of celestial sphere were finally distinguished as an independent science area – astronomy. Concerning the earth sphere, which remained the subject of geology, geocentric vision had dominated there until recently. All geological, climatic, biological and other planetary phenomena were considered as caused by endogenous processes deep in the Earth interior. At the beginning of the 20th century, V.I.Vernadsky, A.L.Chizhevsky, M.Milankovich, etc. demonstrated that the endogenous factors are not sufficient to explain the processes taking place on the Earth. The effect caused by processes in the Solar System should also be taken into account: variation of solar activity, revolution of the Earth and planets around the Sun, Moon rotation, asteroids falling on the Earth, etc.

Little was known about the influence of physical processes of the Galaxy, i.e. in deep space, on the Earth. Hence, this factor was not considered when tackling geological problems.

Discovery of jet outflow of gas-and-dust substance from the center of spiral galaxies and development of galactocentric paradigm on the basis of this discovery has completely changed the situation.

It appeared that the main geological events from the Earth history, concerning which there were unsuccessful attempts to explain them using a geocentric paradigm, are actually a result of powerful space processes of galaxy scale. Moreover, a cause-and-effect relationship between the events on the Earth and in the Galaxy appeared to be so close that it becomes possible to use geological data for the study of structure and physics of galaxies and use astronomical observation data to solve urgent geological problems.

Thus, it seems obvious that the galactocentric paradigm after a 2000-year break once again allows methodological combination of knowledge about the "sky" and "earth" in the framework of single vision concept, but at new scientific level.

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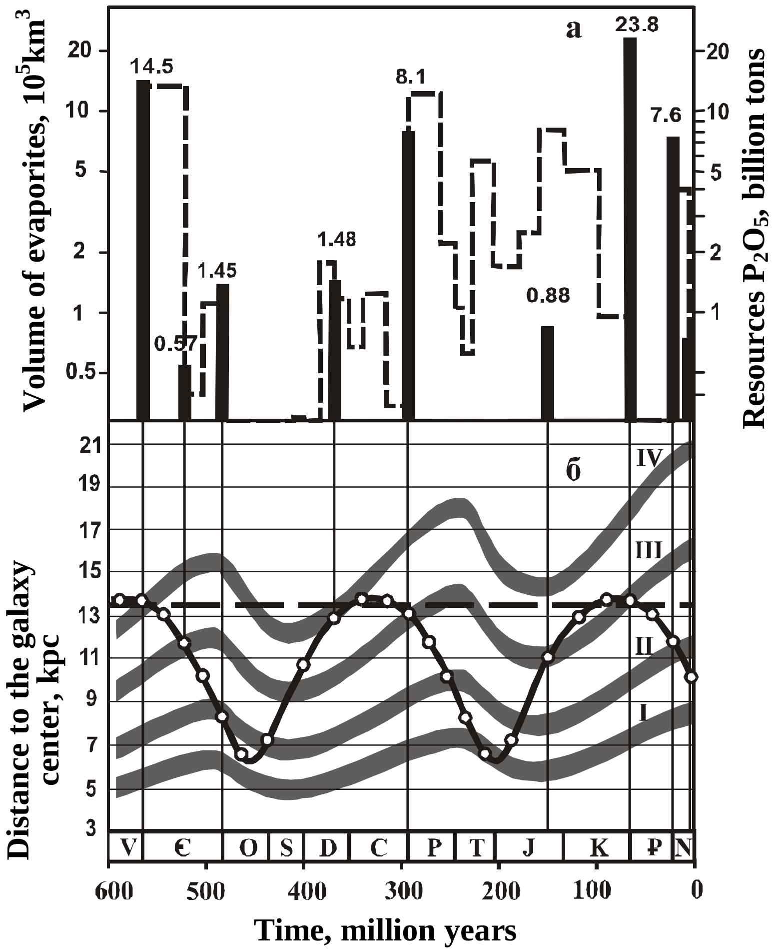

Fig.19. a) prospected deposits of phosphorus (columns) – right scale, and salts (dashed) – left scale, in comparison б) with position of the Sun along the galactic orbit (periodical curve) and distance from the Galaxy center to its four spiral arms (figures I-IV). Circles – moments of comet bombardments. Dashed – corotation radius of the Galaxy.

Table 5. Abundance of some elements in space substance relative to silicon according to A.Cameron [114]

Isotope	Content in natural mixture, %	Combustion process	Abundance in space substance
$_{11}Na^{23}$	100	C	6.0×10^{4}
$_{12}Mg^{24,25,26}$	100	C	1.06×10^{6}
$_{13}Al^{27}$	100	C	8.5×10^{4}
$_{14}Si^{28,29,30}$	100	O	1.0×10^{6}
$_{15}P^{31}$	100	O	6.5×10^{3}
$_{16}S^{32,34}$	99.22	O, Si	4.96×10^{5}
$_{17}Cl^{35,37}$	100	O, Si	4.74×10^{3}
$_{19}K^{39,41}$	100	O, Si	3.5×10^{3}
$_{20}Ca^{40,44}$	99.03	O, Si	6.19×10^{4}

Comment: abundance of Si is accepted equal to 10^{6}

Table 6. Classification of salts according to E.A.Baskov et al. [115]

Systematics of salt-forming minerals			Geochemical types of salts						
Class	Subclass	Mineral, formula	1	2	3	4	5	6	7
chlorides	sodium	halite NaCl		xx	x	x	x	x	x
	magnesium-potassium chlorides	sylvite KCl			xx				
		carnallite $KCl\cdot MgCl_2\cdot 6H_2O$			xx				
		bischofite $MgCl_2\cdot 6H_2O$			xx				
		tachhydrite $CaCl_2\cdot 2MgCl_2\cdot 12H_2O$			xx				
sulfates	calcium sulphates	plaster stone $CaSO_4\cdot 2H_2O$	xx				x		x
		anhydrite $CaSO_4$	xx	x	x	x			
	magnesium-potassium sulfates	polyhalite $K_2SO_4\cdot MgSO_4\cdot 2CaSO_4\cdot 2H_2O$				xx			
		kainite $KCl\cdot MgSO_4\cdot 3H_2O$				xx			
		langbeinite $K_2SO_4\cdot 2MgSO_4$				xx			
		kieserite $MgSO_4\cdot H_2O$				xx			
		epsomite $MgSO_4\cdot 7H_2O$				xx			
	sodium sulfates	thenardite Na_2SO_4					xx		
		mirabilite $Na_2SO_4\cdot 10H_2O$					xx		
		glauberite $Na_2SO_4\cdot CaSO_4$					xx		
		astrakanite $Na_2SO_4\cdot MgSO_4\cdot 4H_2O$					xx		
		glaserite $Na_2SO_4\cdot 3K_2SO_4$					xx		
carbonates	sodium carbonates	Trona $Na_2CO_3\cdot NaHCO_3\cdot 2H_2O$						xx	
		nahcolite $NaHCO_3$						xx	
		Natron $Na_2CO_3\cdot 10H_2O$						xx	
		northupite $Na_2CO_3\cdot MgCO_3\cdot NaCl$						xx	
		shortite $Na_2CO_3\cdot 2CaCO_3$						xx	
		gaylussite $Na_2CO_3\cdot CaCO_3\cdot 5H_2O$						xx	
		Dawsonite $NaAlCO_3(OH)_2$						xx	
		hanksite $2Na_2CO_3\cdot 9Na_2SO_4\cdot KCl$						xx	
	Calcium - magnesium carbonates	magnesite $MgCO_3$							
		dolomite $CaMg(CO_3)_2$	x	x	x	x	x	x	
nitrates	potassium - sodium nitrates	sodium nitrate Na_2NO_3							xx
		potassium nitrate KNO_3							xx

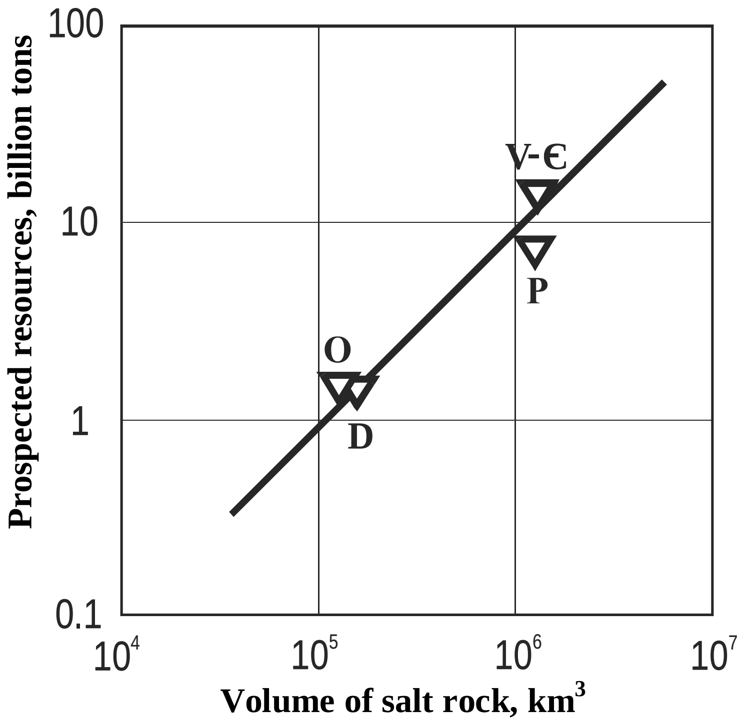

Fig.20. Comparison of prospected deposits of phosphorites and rock salt in the Paleozoic according to data published in literature [112]

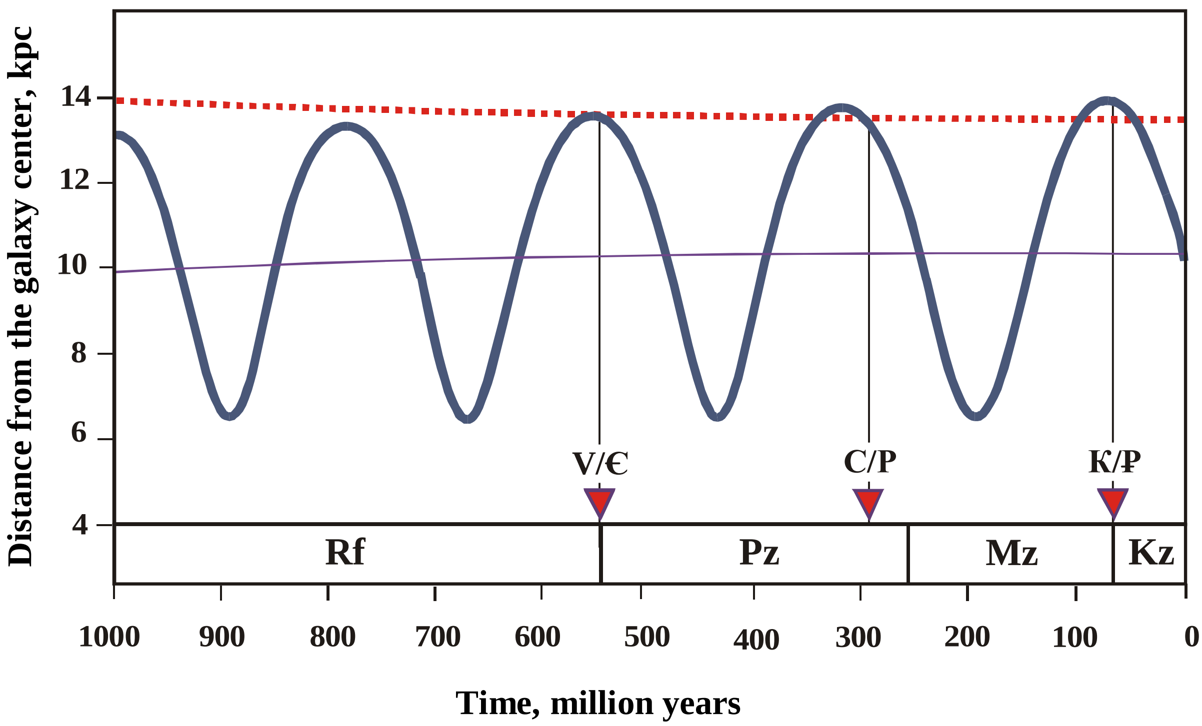

Fig.21. Time variation of the distance from the Sun to the galactic center (periodical curve) and to the Galaxy corotation radius (dotted line) allowing for the evolution of our star system. Triangles at the bottom – main epochs of accumulation of phosphates and salts in the Earth at the boundaries between Vendian period and Cambrian (V/Є), Carboniferous and Permian (C/P), Cretaceous and Paleogene (K/P). Positions of the Paleozoic (PZ), Mesozoic (Mz) and Cenozoic (Kz) eras and late Riphean are shown at the bottom.

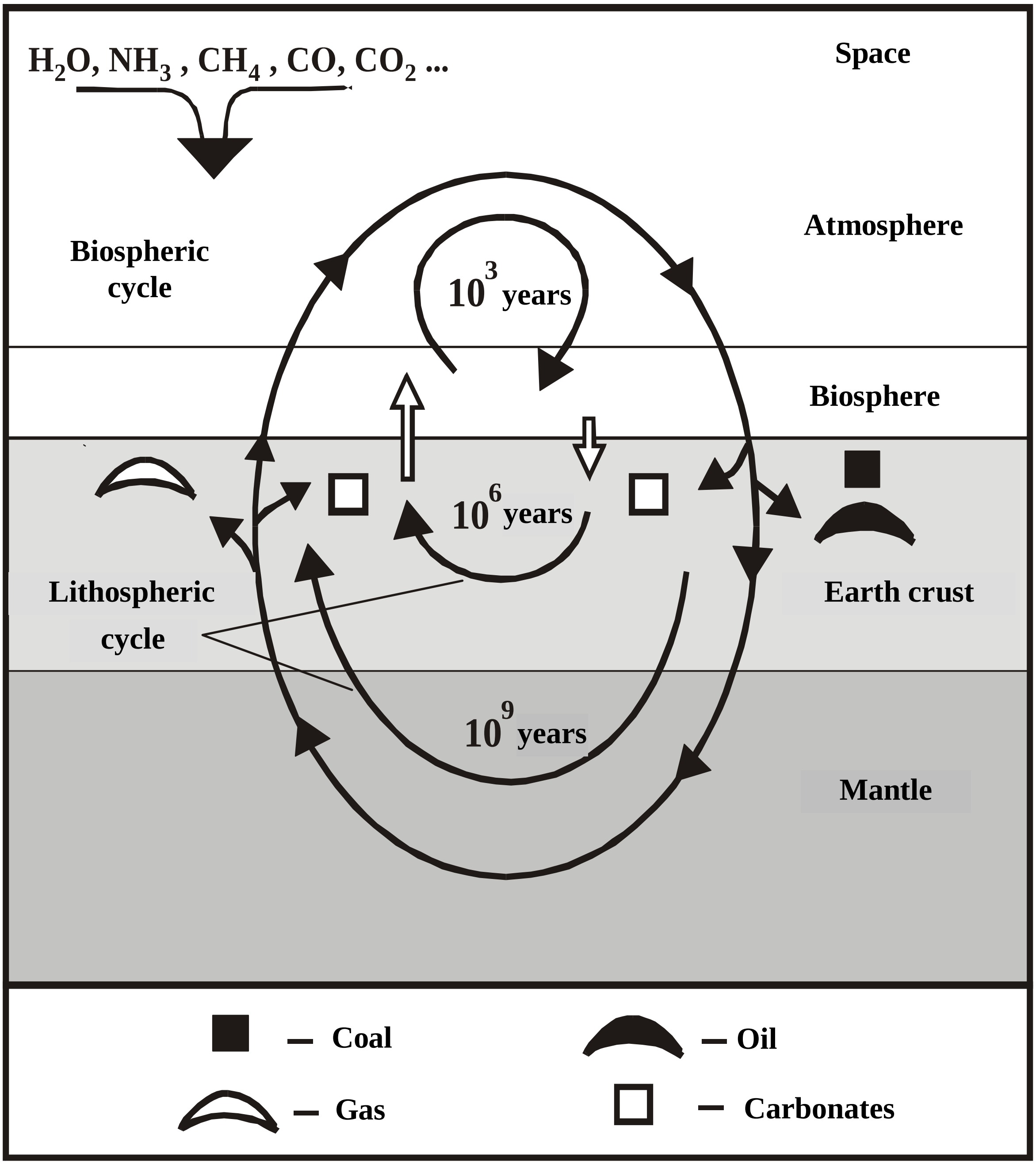

Fig.22. Schematic of carbon cycle. See explanation in text.

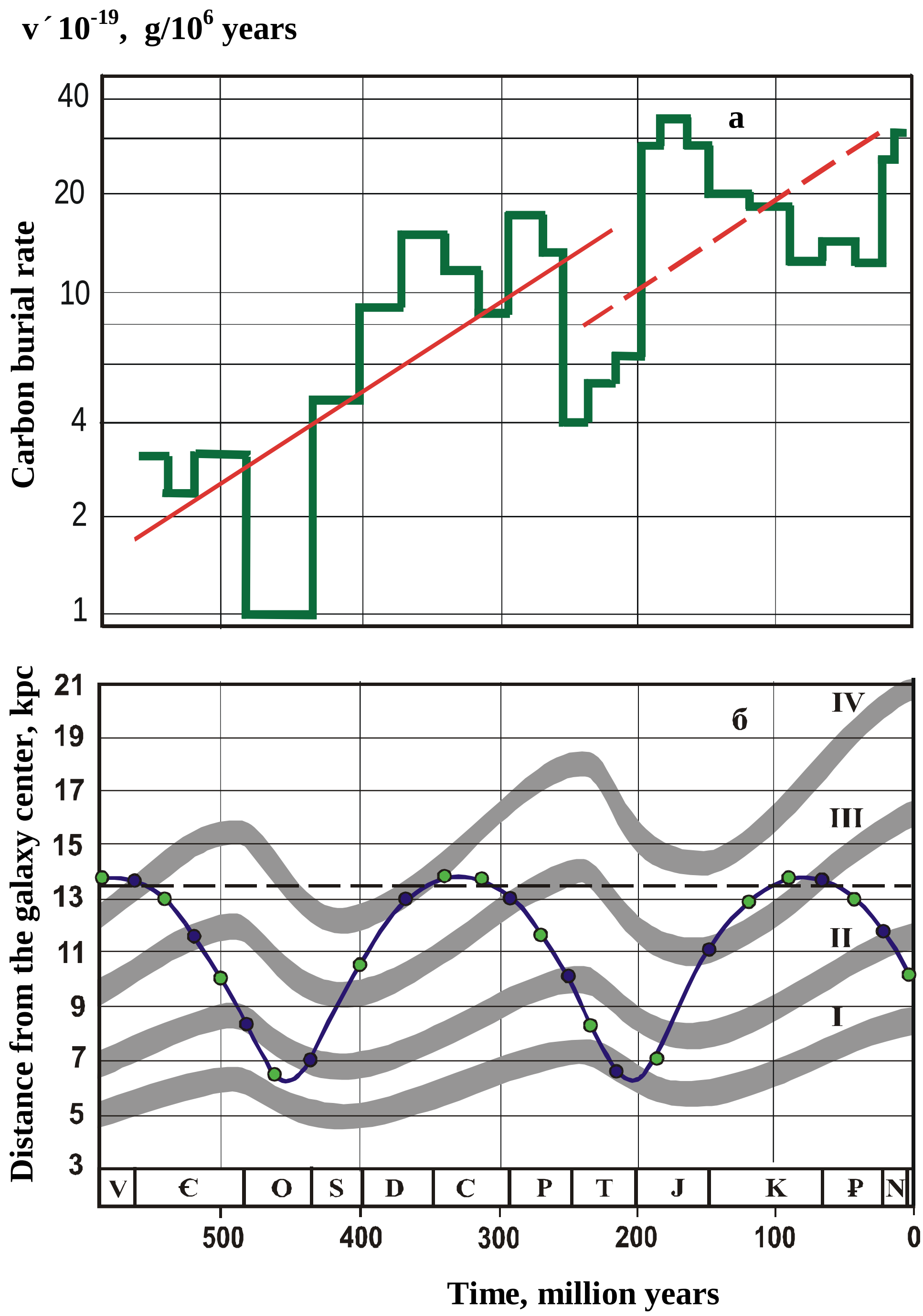

Fig.23. Variation of intensity (a) of biogenic carbon burial in the Phanerozoic [125] in comparison to the calculated distance from the Sun to the Galaxy center (b). Inclined lines correspond to the exponential growth of the rate of carbon burial

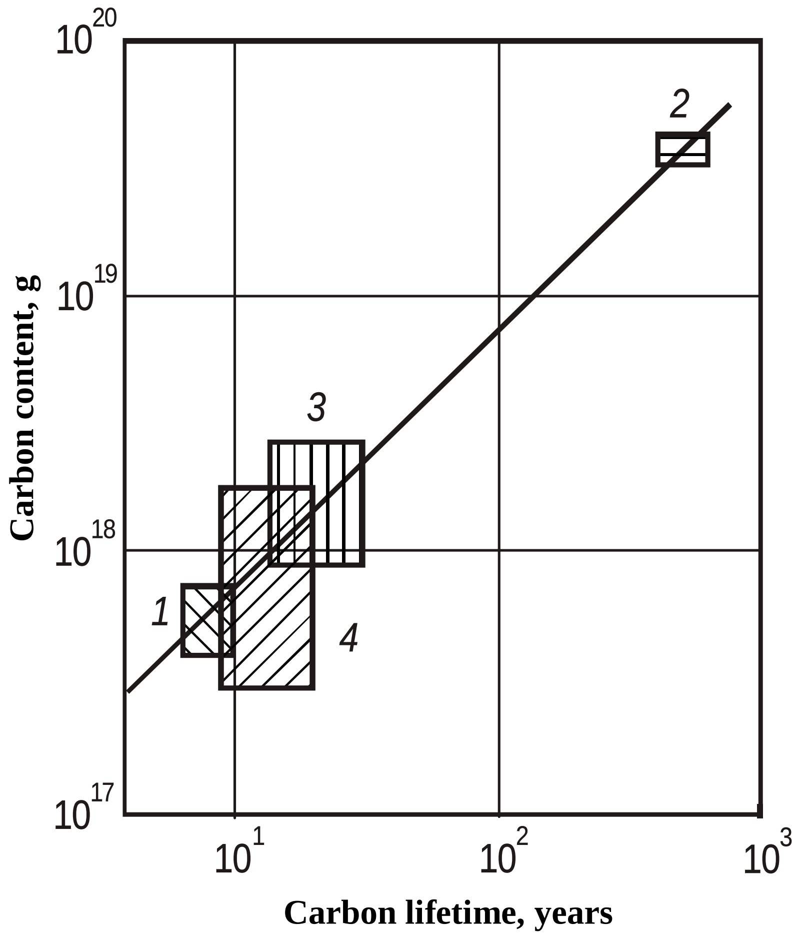

Fig.24. Comparison of carbon content and its lifetime in the atmosphere (1), global ocean (2), living substance (3) and soils-sludge layer (4); rectangles – scatter of literature data

Table 7. Constants of cycle of carbonic acid, oxygen and water in current epoch [72]

Cycle type	Geochemical constant of cycle, $C\times10^{-17}$ g/year
Biosphere cycle of CO_2	2.56±0.51
Atmosphere oxygen cycle	2.75±0.05
Geological cycle of global ocean water	2.64±0.53

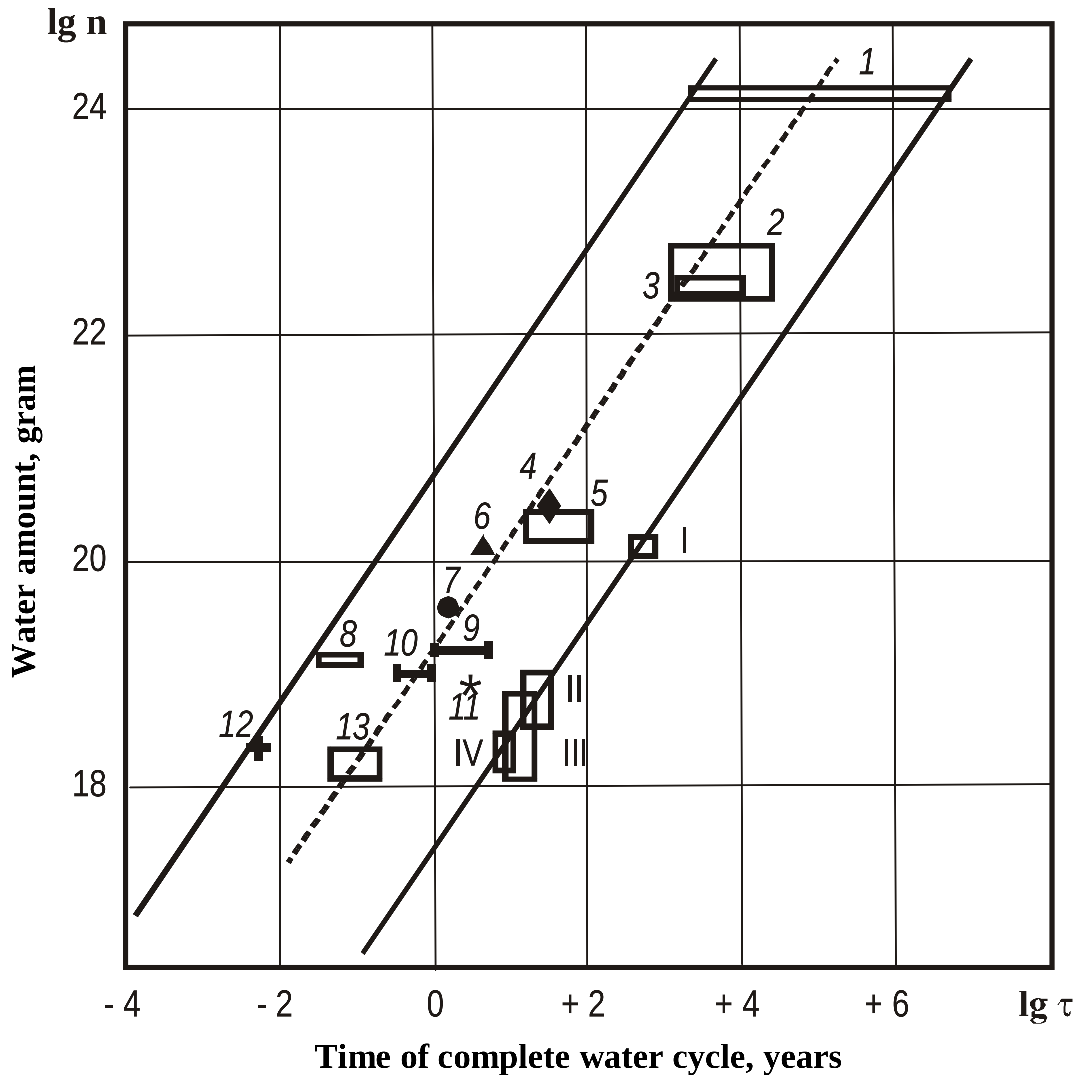

Fig.25. Comparison of the amount of water and time of water cycle for main water basins: 1 – global ocean; 2 – underground water; 3 – glaciers; 4 – lakes, storages and swamps; 5 – lakes; 6 – swamps; 7 – sea ice; 8 – atmosphere water; 9 – soil water; 10 – snow cover; 11 – icebergs; 12 – atmosphere ice; 13 – rivers. Roman figures – data on carbon (see fig.24). Dashed line – average speed of water cycle on the Earth surface.

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About new scheme development for air launching

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Introduction

Establishment and development of aviation, launcher technology and outer space exploration took the leading position among the outstanding scientific and technological achievements of the 20th century.

Theory of rockets flight came into being at the turn of the 19th and 20th centuries. The fundamentals for the investigations were developed by I.V.Meshchersky (1859 - 1935), outstanding scientist-mechanicist [1], who obtained the motion equation for the bodies with variable mass (rockets belong to this type). The works of K.E.Tsiolkovsky [2], F.A.Tsander, U.V.Kondratyuk, A.P.Mandryka [3] were written during this period.

One of the first air launching schemes was shown by the project of launching the space launch vehicle Orel from aircraft An-124-100 Ruslan [4]. One of the types of air launching carriers was so used airlift aircraft An-225-100, the modification of An-225 Mriya developed by Antonov Aeronautic Scientific-Technical Complex. This aircraft has special equipment mounted over the fuselage in order to fix the launch vehicle; inside the hermitic cockpit, there is also on-board equipment to perform launching and the crew to release the vehicle.

Along with the developments of Shuttle Aviation and Space System, held in the USSR, the work on establishing of the own HOTOL complex space plane was carried out in Europe. When aircraft An-225 Mriya was produced in the USSR, the idea of bringing the two projects together was expressed by the joint project which intended space plane Interim HOTOL to be launched from carrier aircraft An-325 Mriya.

During many years, Yuzhnoye Design Bureau named after M.Yangel has been working out various projects to develop the air-launched space rockets to be released from carrier aircrafts. The rocket launching was made over the area of the neutral zone waters out of the Ukrainian borders (Svityaz and Orel projects).

In early years of the 21st century, Yuzhnoye Design Bureau and Antonov Aeronautic Scientific-Technical Complex initiated developments of aerial and space rocket complex Svityaz. During the work over this project, “Method to Evaluate the Influence of Liquid Propellant Oscillation on Dynamic Characteristics of Airspace System with Respect to Damping Oscillations” (2005) and control over multimode airspace rocket complex (2008) were elaborated. In 2010, the project was on the stage of concept development. Its implementation has been molded due to the shortage of funds.

Launching of space vehicles via aviation in the air is one of the most promising ways of development. It provides several advantages over ground launching and allows not only to enjoy considerable reduction in operation costs and proper object insertion into the orbit but also elimination of the conventional ground launching inconveniences of complexity and high costs of earth-based facilities and necessity to have the restricted zone. It makes possible vehicle launching from anywhere around the globe, for example, from the water area over the Indian Ocean.

Nowadays, approximately 30 projects of air-launched systems are being developed in the USA, Russia, Ukraine, France, Germany, Japan, China, etc. [6, 7].

Among all the systems existing in the world, only Pegasus XI (USA) has been implemented. It is a 3-stage solid rocket with the weight of 23 tons, tucked under the fuselage of carrier aircraft L1011, and released when the aircraft reaches the height of 11.5 km.

Yuzhnoye Design Bureau named after M.Yangel has developed aerial launch complex with movable airlift and launching platform [8]. N.S.Kozin [9] designed the complex which incorporates an aircraft with twin fuselages and a container for a launch vehicle. Launch vehicle bay is placed between the aircraft twin fuselages by means of hinges to permit the container rotation around transversal horizontal axis. This bay is equipped with fairing, devices to turn, fix and push out the launch vehicle and the attachment points for fixation in a given position. Touching the question of the invention disadvantages, it should be noted that there is a limitation for a launch vehicle size not to be over that of the platform. Furthermore, this complex is designed to launch only solid propellant vehicles and is unsuitable for ones with liquid fuel.

A new scheme development of air launching for the vehicle with liquid propellant is the objective of the present paper.

Development of a New Aerial Launch Platform

In order to provide reliable and safe launching of the vehicle with liquid propellant as well as to ensure safe conditions for the crew, we have developed an aerial launch platform [10].

The present aerial launch platform and air launching are developed in order to achieve the following goals: to make it possible to have a reliable and safe airlift of dry launch vehicle, to ensure its filling with fuel constituents, to elaborate the detachment for the fuel constituents filling system from the launch vehicle, to find the way for a release of the launch vehicle with the mass of between 30 - 100 tons and that which is heavier than this range, and finally to provide the vehicle air launching.

Along with all above mentioned, the construction should be simple in operation and all the operations are to be performed automatically.

Principle Scheme of Aerial Launch Platform

The mentioned goals are reached through the aerial launch platform in which the launch vehicle container is installed rotating around its transversal horizontal axis by means of hinges between the aircraft twin fuselages. This complex incorporates fairing with drainage slots, devices for tuning, attachment points for fixation of the launch vehicle container in a given position, devices to fix and push out the vehicle, systems to transport, fill, release, slow down the horizontal travel, guide and stabilize the vehicle, systems to control vehicle launching and flight, systems to control fuel tank (P) and oxidizer tank (O), and flexible tubes for launch vehicle filling.

Application of twin fuselage aircraft within aerial launch platform enlarges air-launched vehicle capability both in terms of sizes (more than 3 meters in diameter and more than 20 meters in length) and mass (more than 100 tons).

Location of the container with a dry launch vehicle between twin fuselages provides the conditions for the vehicle transportation in the standard horizontal position. Moreover, in order to ensure the turning of the container with the dry launch vehicle, mass center of system of “container with the dry launch vehicle + fairing” should be on the axis where rotation of the container occurs by means of hinges. For supplying the filling components to the launch vehicle after its turning into the vertical position, the flexible tubes are used. They connect tanks “P” and “O” with the launch vehicle. Hinges and opportunity to turn of the launch vehicle container from horizontal into the desired position, for instance into the vertical one, allows launch vehicle filling with the fuel and oxidizer components, the detachment of the

filling system from the vehicle as well as launch vehicle release out of the container into the vertical direction due to the own weight influence.
A new scheme of aerial launch platform is shown in fig.1, fig.2 and fig.3. The main advantage of the introduced scheme is in equipping fuselages with the tanks for fuel and oxidizer which are connected by flexible tubes designed for the launch vehicle filling. In order to improve the performance of the fuel line, the flexible tubes are put running through the journals of the container hinges.
The link between the constructional elements of the system of new air launching is presented in fig.1, fig.2 and fig.3. Aircraft (1) is designed with twin fuselages (2). Each fuselage (2) is equipped with a bearing (3) and its cap (4). The journal (5) of the container (6) with the launch vehicle (7) is installed on the bearings (3) and fastened with the caps (4).
The bearing (3), cap (4) and journal (5) make up the hinge (8). In the area of hinges (8), the container (6) may rotate around its transversal axis which passes through the hinges. Fixation of the container (6) in a required position is provided by the hydraulic rod (9), its body (10) is fixed on the aircraft (1). The rod (11) enters the hole of the bracket (12) of the container (6).
The container (6) is equipped with the fairing (15). This fairing (15) has the lower cover (16) and the upper cover (17) both of them are with the drainage slots to open when the vehicle release, and the hatch (18). The container is connected with launch vehicle (7) by control pyrorods (19) and the springs of pyropusher (20). The launch vehicle (7) has the rings (21) to create the required rigidity of the construction. Each of the twin fuselages (2) is accompanied with fuel tank “P” (22, 23) and the oxidizer tank “O” (24, 25). The fuselages and tanks are connected by tubes for fuel filling (26, 27) and oxidizer filling (28, 29).
Aerial launch platform operation is described bellow.

Performance

Container (6) with launch vehicle (7) is placed by means of hinges in a transportation position on the twin fuselages (2) of the aircraft (1). They are fixed to prevent turning by the hydraulic rod (9). Then, jet engines (13) and fairing (15) are installed. Tanks (22, 23, 24 and 25) are filled with the corresponding components. Aircraft (1) drives to the launch position.
After coming into the start area, the aircraft reaches the required height and moves at the constant speed. The container (6) is freed from the hydraulic rod (9), which is used only during transportation. Jet engines (13) turn the container (6) into the vertical position. Filling followed by release begins. The hydraulic rod (9) fixes the container (6) in the vertical position before the release. In this position, launch vehicle filling is carried out, then the constituents of the filling system are shut off, the hatch (18) opens for the release. The command to disunite the rods is issued and activates spring pyropushers (20).The launch vehicle goes downwardly out of the container (6). The launch vehicle (7) leaves the rings (21), which detach and undock.
The cruise engine of the launch vehicle is switched off and the vehicle is released. After the launch vehicle (7) leaves the container (6), the hatch (18) shuts and the hydraulic rod (9) frees the vertical position fixation of the container (6). The engines (13) back the container (6) into its transportation position and it is fixed by the hydraulic rod (9). After placing the container into its transportation position the aircraft returns to the base aerodrome.
The aerial launch platform developed by the present work is able to transport the launch vehicle to its release point over the water area of the World Ocean. The presented construction allows putting the container with the launch vehicle into the position for filling in order to introduce the components of the fuel and oxidizer, ensuring reliable and safe vehicle release, removing the elements of the filing system away from the vehicle. After these operations, the aircraft leaves the area of air launching.

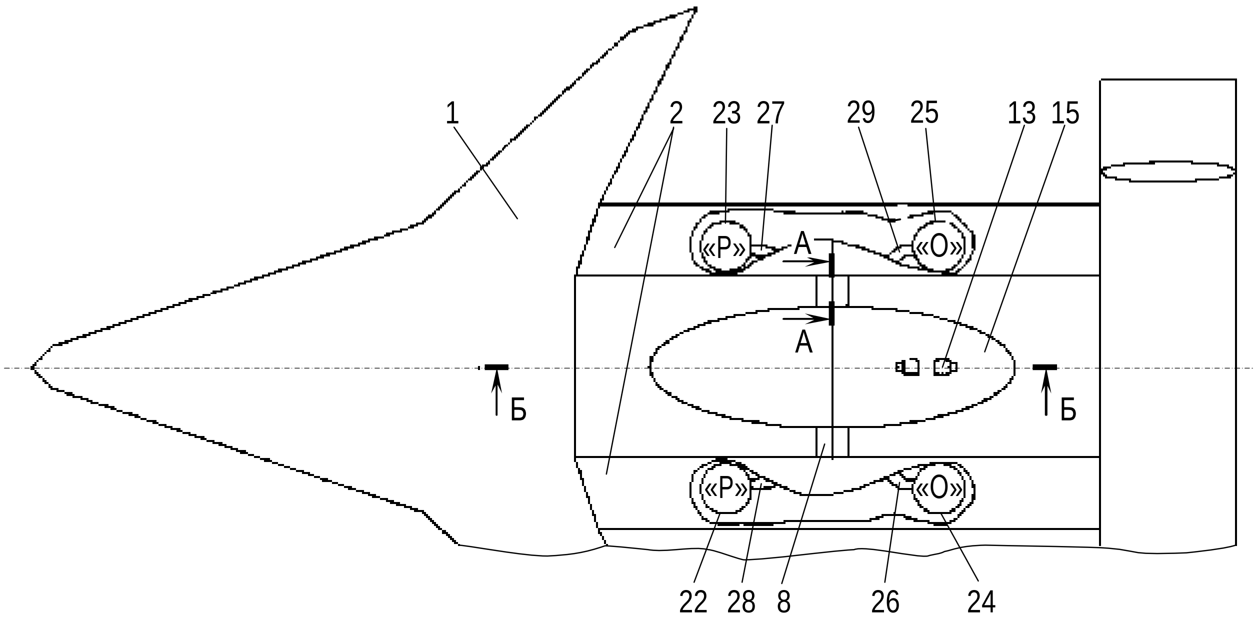

Fig.1. General view of aerial launch platform.

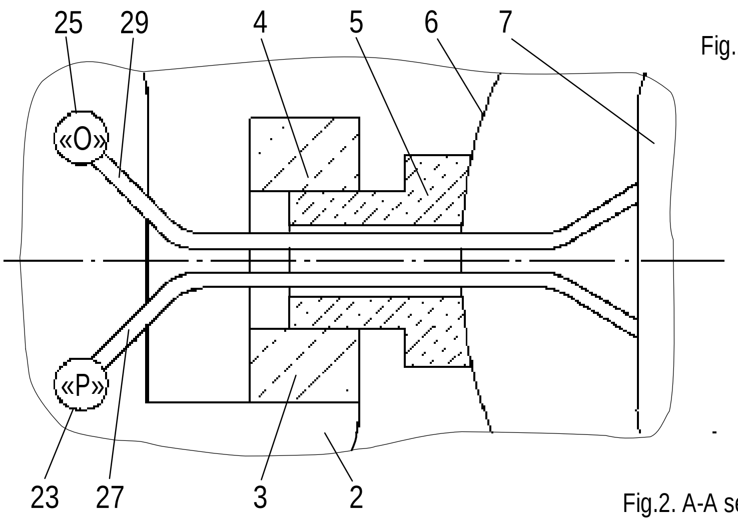

Fig.2. A-A section.

Main elements of ALP

1. Twin-fuselage aircraft
2. Fuselages
3. Bearing
4. Cap
5. Trunnion
6. Container
7. Launch vehicle
8. Joint
9. Hydro-pin
10. Hydro pin casing
11. Pin
12. Bracket
13. Jet thruster
14. Bracket for thruster
15. Fairing
16. End cap of fairing
17. Top cap of fairing
18. Hatch door
19. Pyro-linkage
20. Spring type lifter
21. Stiffening ring
22, 23. Fuel tanks
24, 25. Oxidizer tanks
26–29. Pipes

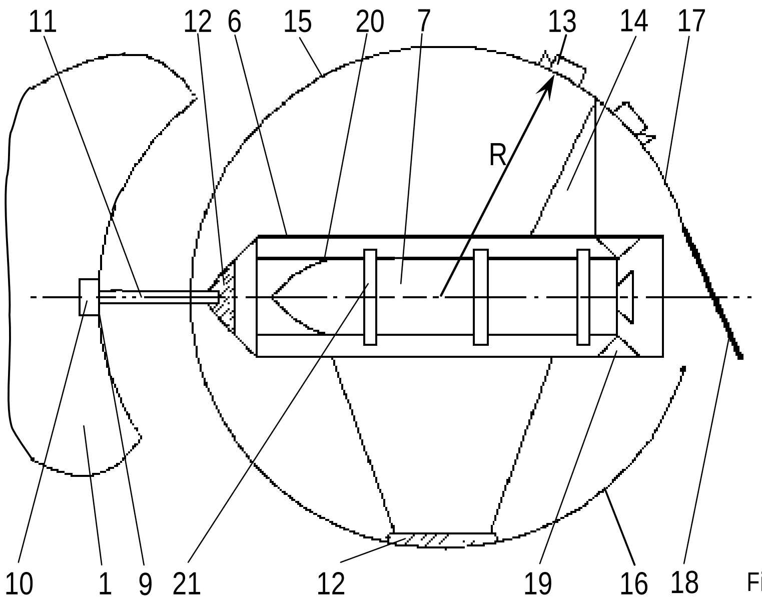

Fig.3. Б-Б section.

Conclusion

1. The new scheme of air launching for the launch vehicle with liquid fuel is developed. This permits to implement the new type of air launching.
2. The paper describes the interrelated work of all the elements of the new air launching system.
3. The technological results feasible with the new aerial launch platform are presented.

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Elizabeth V.Gorbenko. Post-graduate (Dnepropetrovsk National University named after Oles Gonchar, Physics and Technical Department, Technical mechanics, specialty 07.00.07 “The history of science and technology”). The scientific interest area:
rocket science and engineering; the research of works of scientists in rocket production in Dnepropetrovsk region. Scientific supervisor is **Sokol Galina I.**, Professor of Dnepropetrovsk National University.
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Orbital tethered systems in nano-satellites of scientific purpose

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At present time there are trends of space vehicles miniaturization, that connected with small-sized scientific devices development (magnetometers, spectrometers, and so on) and with their power consumption lowering. Possibility to solve complicated scientific tasks has been proved by missions MUNIN (2000), QuakeSat1 (2003), RAX1 and 2 (2010 and 2011).

Scientific nano-satellites are often designed for operations in the cluster. As a rule their lifetime is not long. That is why the task to put these objects in an entry trajectory after end of their missions is the actual one, because it is the task to avoid additional space debris. One of version to execute the task is use of a tethers system.

Orbital tethers are systems from two spacecrafts (SC) connected with flexible tether. Different modes of the orbital tethered system (OTS) are feasible: stationary balanced mode (position along radius-vector), libration mode (oscillations relatively equilibrium position) and rotational mode. To control the system, the tether should be in tension.

These systems applications are diverse [1, 2]:

- transport operations;
- repair and inspection of a spacecraft and SC systems;
- carrying out synchronous multi-component measurements of Earth fields parameters;
- artificial gravity;
- small trust modes and electric current generation by electrodynamics tethered system (EDTS) and so on.

Figures 1-3 depict several versions of OTS applications.

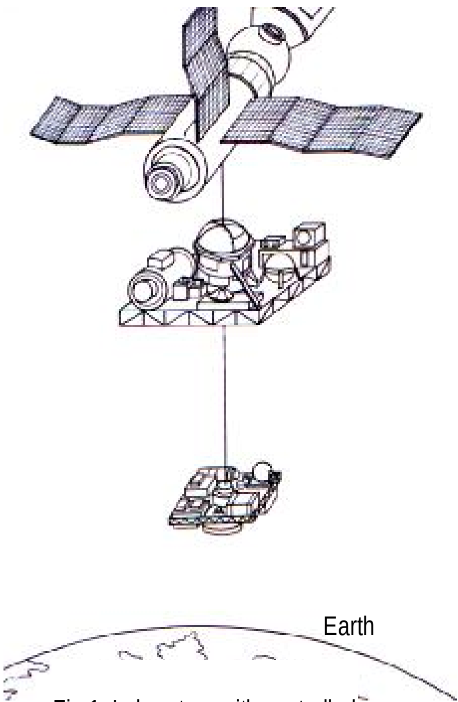

Fig.1. Laboratory with controlled mini-gravity.

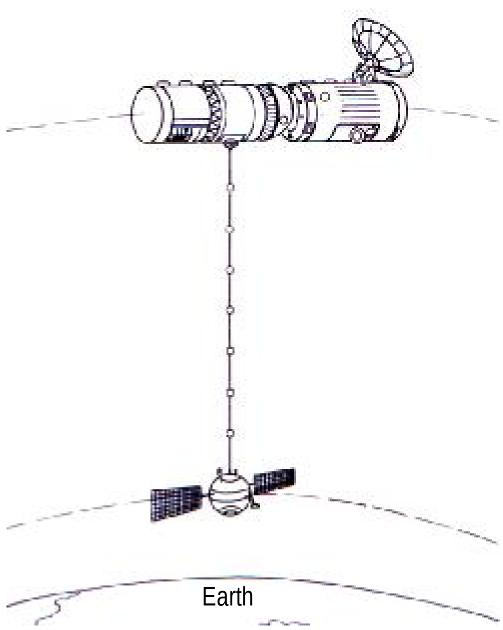

Fig.2. Measurements in the Earth upper atmosphere.

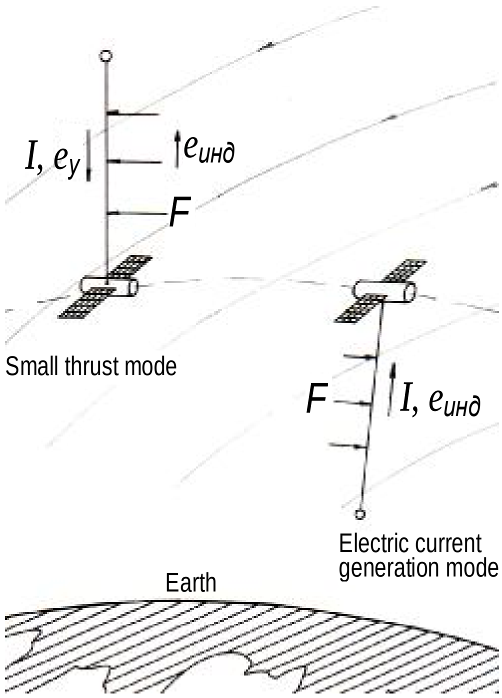

Fig.3. Interaction between electric current in tether (cable) and terrestrial magnetic field.

Another version of OTS applications is space debris cleaning. Recently this problem has obtained significant value. About 16 thousands catalogued debris with sizes more than 10 cm are in near-Earth orbits, risk of collision with them is estimated as one event per three years [3]. Space infrastructure threats from debris are constantly growing. That is why the projects to decrease rate of space debris growth (and in ideal case – to space debris full elimination) are developing (such as BETs, DEORBITSAIL, Clean Space One) - [3, 4].

At present prospective projects ROY and PS-2 are under development (phase A). These projects imply nano-satellites (with masses up to 10 kg) [5, 6] to study near-Earth space.

The projects ROY and PS-2 are based on clusters from many nano-satellites, which would be injected in orbits by groups. The nano-satellites lifetime is small, about several days. That is why the task to de-orbit these SC, which is necessary to decrease space debris. The problem is urgent for objects in low orbits – nano-satellites PS-2 designated for our planet ionosphere study. It is proposed that the nano-satellites PS-2 will be placed in near-circular orbits with heights *H*=300÷400 km. These orbits are close to the International Space Station (ISS). It is known that the ISS orbit should be corrected often to avoid collision with space debris. It is desirable to decrease growth of such objects number and, in ideal case, to zero level.

Figure 4 shows a tethered system, based on nano-satellite PS-2. The tethered system will be operated here as antenna and drag-control facility (ADCF).

The drag-conrol facility will be operated in most effective manner in case of electric current flow along the tether (EDTS case). Evolution of a circular (near-circular) orbit of the PS-2 base object will be under influence of atmospheric drug and, mainly, of Ampere force (F_A), acted on conductor with electric current in motion through magnetic field [1].

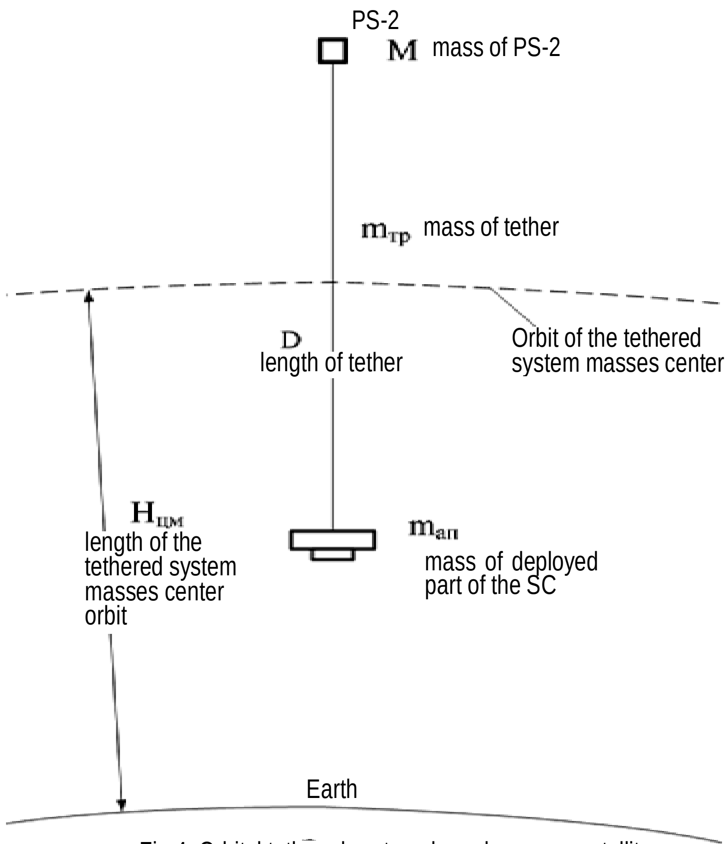

Fig.4. Orbital tethered system, based on nano-satellites.

The Ampere force $F_A = I \cdot D \cdot B_0 \cdot \cos i$, where
I – current value,
D – tether length,
i – inclination of tether system masses center orbit,
B_0 – magnetic induction vector, $B_0 = m_m \cdot R_0^{-3}$;
$m_m = 8 \cdot 10^6$ Tl · km^3 – magnetic momentum of the terrestrial dipole.
Generator mode of the EDTS (fig.3) would increase drug of the system.
Movement of the system masses center and its' basic object will be along curving spiral with decreasing radius, that is characterized by subsequent lowering of the orbit' major semi-axis (or its focal parameter).

Focal parameter per a rotation is determined as: $\dfrac{dp}{dn} = 4p \cdot I \cdot D \cdot \cos i \cdot m_m (m \cdot M)^{-1}$

$\mu = 398600{,}5$ km^3/s^2 – the Earth gravitational constant.
Values of lifetime for nano-satellite with ADCF on base of OTS are in table 1 (for height of center masses orbit H = 300 km) and in table 2 (for H=400 km). It is considered tether lengths D – up to 2 km and masses of the basic object from 3 to 5 kg.
Table 1.

OTS lifetime: H=300 km, i=51°									
	M=3 kg			M =4 kg			M =5 kg		
D, km	I=1A	I=2A	I=3A	I=1A	I=2A	I=3A	I=1A	I=2A	I=3A
0.5	7.56	3.78	2.52	10.1	5.04	3.36	12.6	6.3	4.2
1	3.78	1.89	1.26	5.04	2.52	1.68	6.3	3.15	2.1
1.5	2.52	1.26	0.84	3.36	1.68	1.12	4.2	2.1	1.4
2	1.89	0.95	0.63	2.52	1.26	0.84	3.15	1.57	1.05

Table 2.

OTS lifetime: H=400 km, i=51°									
	M =3 kg			M=4 kg			M=5 kg		
D, km	I=1A	I=2A	I=3A	I=1A	I=2A	I=3A	I=1A	I=2A	I=3A
0.5	11.34	5.67	3.78	15.12	7.56	5.04	18.9	9.45	5.25
1	5.67	2.84	1.89	7.56	3.78	2.52	9.45	4.73	2.63
1.5	3.78	1.89	1.26	5.04	2.52	1.68	6.3	2.63	1.75
2	2.83	1.42	0.95	3.78	1.89	1.26	4.73	1.97	1.31

In process of analysis for case nano-satellites, measured Earth magnetosphere, operated in a high-elliptic orbit (e > 0,02) and included ADCF, which is based on OTS, it has been concluded that influence of the ADCF leads to the orbit change: perigee height is the same, but apogee height is decreased, the orbit will be "more" circular one. This stage will elapsed longer than SC lifetime for case of a circular orbit with initial height equal to perigee value of the high-elliptic orbit. That is why efficiency of such drag system implementation for SC orbits with high apogee is little. In this case orbital tethered system could be operated as antenna.

Wide range of the OTS possible in-space applications are implied necessity to verify and use this technology in step-by-step manner. Up to now there are about 30 space experiments with tethers. Russian specialists took part only one space experiment with tethered system - YES-2 in 2007 during mission Foton-M2. Now the Russian space experiment "Tros-MGTU" is under development. It is envisaged to deploy in un-controlled mode tether with length D=5 km and to register its subsequent flight in librations mode with amplitude ~ 30° during several rotations.

It is expedient to develop and fulfill national program of space tethers applications in different spheres, such as space debris de-orbiting; in-orbit injection and re-entry; SC support, re-pair and inspections; EDTS moving and generation modes and others. Final part of the program will be use of OTS in service systems of robotic, manned and serviced SC.

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The combining regimes of orientation and orbit correction in a spacecraft motion control

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Problems of combining the regimes of attitude control and correction in optimal way during control of spacecraft motion are considered. It is supposed that basic means of control when changing a spacecraft position are jet engines. Concrete control algorithm of spacecraft reorientation combined with orbit correction, in application to orbital stations, is presented. High efficiency of combining the regimes of attitude control and correction of spacecraft orbit altitude is shown. Data of mathematical simulation for two patterns of mounting the engines are presented, and estimations of efficiency indices and the values of correcting velocity that can be obtained by executing a fixed number of turns are given.

Introduction

Angular stabilization and reorientation of a spacecraft are the most frequently used dynamic regimes. The research programs conducted during a flight and the related stringent requirements for precision and efficiency of control over spacecraft angular motion heighten interest in the problem of optimization of spacecraft reorientation process. Significant increase in size, mass and active lifetime of modern spacecraft equipped with systems of attitude control and correction leads to a sharp increase in the relative propellant load necessary for operation of the executing devices of motion control system. Concept of motion control as a center of mass, as well as of motion with respect to spacecraft’s center of mass by means of non-central jet power is successfully used in designing the control devices of rockets. Using and developing the above idea, one can economize a significant amount of fuel when designing control systems of spacecraft motion. Such economy can be achieved by combining the regimes of attitude control and correction, accomplished through applying a noncentral force produced by jet engine of attitude control system whose thrust vector does not pass through spacecraft center of mass to a spacecraft.

A goal of optimally combining the regimes of correction and attitude control is advisable only for a certain class of spacecrafts for which the condition $G\text{c} \approx G\text{a}$ holds true; here $G\text{c}$ and $G\text{a}$ are the propellant loads intended for orbit correction and spacecraft attitude control, respectively. If inertial executing devices (power gyroscopes) are used, then $G\text{a}$ represents fuel consumption necessary to compensate inadmissible increase of angular momentum of gyro system. The considered class of spacecrafts includes primarily long-term orbital stations. For the stations, combining maintenance of station flight orbit in the prescribed spherical layer with following regimes of attitude control is of practical importance: adjustment of spacecraft reorientation to a prescribed angular position; spacecraft stabilization and spin-up; maintenance of prescribed attitudes and off-loading of inertial executing devices. For a spacecraft of long-term orbital station type, combining the controls over spacecraft angular position and over position of its center of mass is of current interest because of the following circumstances: (a) mean altitude of flight is (h = 350 – 400 km), where the atmosphere is rather dense; (b) a spacecraft itself is of large size, and solar batteries have extensive surfaces; and (c) the period of the active lifetime of the spacecraft is extended. The first two factors make aerodynamic drag significant; therefore, continuous maintenance of orbit altitude is requited. As a result, fuel expenditures on orientation and on increase of flight altitude become commensurable. Last factor leads to an increase of the mentioned fuel expenditures in absolute value. In this paper, the problem of optimal programmed turn of a spacecraft combined with correction of its orbit is considered in general form. Let us assume that jet micro-engines are used as main executing devices of motion control system. In this case, possibilities to increase an efficiency of spacecraft turn are related to three basic ways: (1) efficient arrangement of attitude control engines on spacecraft body; (2) synthesis of optimal laws of spacecraft reorientation control, with respect to fuel consumption, and (3) combining process of turning with correction of spacecraft orbit altitude. Development of first way leads us to transition from control with respect to the principal central axes of a spacecraft to control with respect to the axes bound to its angular momentum vector. For this type of control, provisions must be made for shifting the point of attachment of control engines with respect to spacecraft body, which requires some special features of construction. Second way is well known, and largest number of publications and works on optimization of spacecraft rotations (though without requiring the simultaneous correction of an orbit) has been dedicated to it. In particular, problems of solid body rotation, optimal for response time and for minimum energy expenditures, were considered in [1]. Analytical solution was obtained by Pontryagin's maximum principle. Combined control of motion around a center of mass and of motion of spacecraft center of mass itself permits us to reduce significantly total propellant load necessary for all dynamic regimes of attitude control of a spacecraft and correction of its orbit. This method is relatively new, but seems to be very promising nevertheless.

In this paper, numerical realization of the algorithm with a prognostic model [2] is proposed. The peculiarity of the model in use is prediction of "free" motion in the class of spacecraft rotations along the trajectories where angular momentum vector of spacecraft body is constant in inertial coordinate system. This allows us to change over from a continuous synthesis of controls to their determination at discreet instants of time.

1. General formulation of optimization problem

Let, in the course of the combined control, correcting velocity V_c increment in the required direction be transmitted to a spacecraft's center of mass; in the process, an amount of working fuel G_{COM} is consumed for the turn and correction. Had the processes of spacecraft reorientation and correction of its orbit been independent, total fuel consumption would have been G_r+G_c. To estimate the control efficiency, we introduce the function $E=(G_{r\ min}+G_c\ )/G_{COM}$. Here, $G_{r\ min}$ denotes minimum fuel expenditure for independent turn of a spacecraft, Gc is fuel expenditure for orbit correction, and G_{COM} is fuel expenditure for the combined control. Absolute fuel economy is determined by the value

$$\Delta G_{COM} = G_{r\ min} + G_c - G_{COM}$$

It is obvious that the turn that is optimal for fuel expenditure corresponds to maximal value of target function E. Only in this case is the effect of combining the regimes of control revealed to the fullest extent. Thus, when optimizing laws of the combined control of spacecraft motion, one must first determine the value of minimum fuel expenditure for rotation independent of orbit correction, which requires in its turn a prior solution of traditional problem, i.e., optimization problem of control of spacecraft reorientation. Therefore, we formulate the problem of combined control of spacecraft reorientation as follows: one should determine a control providing, with the prescribed accuracy Δj, spacecraft turn from arbitrary initial position Λ_{in} to the required final position Λ_f within the fixed time T, with minimal fuel expenditure; the increment of velocity ΔV transmitted to spacecraft center of mass during a turn should be maximum. It is assumed that initial and final angular velocities are equal to zero. When solving the formulated problem, we made some assumptions: (1) a spacecraft is considered to be a perfectly rigid body, (2) possible misalignment of the principal central axes of spacecraft ellipsoid of inertia with the axes of the bound coordinate system is ignored; (3) the time of action of the controlling moment is small compared to the time of spacecraft turn;

(4) angular momentum imparted by attitude control engines to spacecraft body significantly exceeds angular momentum acquired during a turn from external disturbances; (5) influence of a projection of thrust impulse of attitude control engines on the normal to spacecraft orbital velocity is negligible.

2. Planar spacecraft rotation

Let us consider the problem of optimal combining of control of a center of mass motion with spacecraft rotation around the principal central axis of inertia. Let the force **P** (which produces spacecraft motion in the plane fixed in inertial space orthogonal to one of the principal central axes of inertia, i.e., orthogonal to the axis of control) act on a spacecraft. To describe spacecraft motion in the plane of rotation, we introduce rectangular coordinate systems with the origin at spacecraft center of mass: the orbital system OX_OY_O (axis OX_O is aligned with the given direction **V** of the correcting impulse of velocity) and the system OXY, bound to spacecraft body; Z axis of the bound coordinate system is the axis of the programmed rotation of a spacecraft. Let us suppose that, during a motion, jet force **P** can be applied at one of two points situated on OX-axis, A_1 or A_2 (the distances from rotation axis Z to these points of application of engine thrust A_1 and A_2 are assumed to be equal). This allows us to create the controlling moment M_y of the prescribed value and sign with the simultaneous fulfillment of the following condition

$$|(\mathbf{P}, \mathbf{V})| < p/2 \qquad (1)$$

For the sake of definiteness, we assume that a time of spacecraft rotation is considerably smaller than a period of its orbit. Hence, orbital motion of a spacecraft can be neglected, and the coordinate system OX_OY_O can be considered to be inertial. Let the engine producing the vector **P** have one degree of freedom (it can rotate in plane OXY through the prescribed angle g). At initial instant, velocity vector **V** forms the angle α with positive direction of the axis Y. Mutual position of the vectors **F** and **V** in the plane of rotation is illustrated in Figure 1, where l denotes an arm of engine position; j is the angle between axis OY and vector **V**, determining current attitude of a spacecraft; and g is the angle between engine thrust **P** and axis OY. Spacecraft rotates around axis Z. Denoting the angle of spacecraft rotation by y (i.e., of the bound axes X and Y) in the plane, we obtain the relationship $j = a + y$. Maximum value of the controlling moment is $M = Pl$; and maximal acceleration additionally imparted to spacecraft center of mass is $d = P/m$, where m is spacecraft mass. Thus, the correcting velocity value is equal to

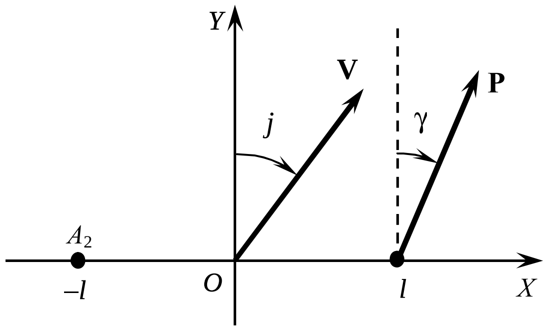

Fig.1. The scheme of mounting the attitude engines and the action of the controlling force.

$$V_C = \int_0^T d\cos(j - g)dt .$$

Control of rotation combined with orbit correction is considered optimal if $V_C \to$ max with the simultaneous fulfillment of the condition $G \to$ min. The time t_f of this maneuver termination is limited by the fixed value T, i.e. $t_f \le T$, where T is the given time of completion of dynamic operation.

Total fuel expenditures for control of spacecraft motion comprise:

1) for independent control of the motions of spacecraft center of mass and around center of mass, $G_\Sigma = kV_C + G$, where G is value of fuel expenditures for rotation, and k is

proportionality coefficient depending on an efficiency of the correcting propulsion system of a spacecraft; and
2) for combined control of translational and rotational motions of a spacecraft,

$$G_\Sigma = kV_C + G.$$

Let us now determine fuel expenditures for complete combining of the regimes of control (when vectors **P** and **V** are collinear):

$$G = kV_C,\ G_{ind} = G_\Sigma = 2G\ \ (G \to \min),\ G_{max} = 2G.$$

It is natural to take a difference between fuel expenditures G_Σ for rotation and orbit correction under independent control and minimum possible expenditures $2G_{min}$ for complete combining of the regimes as an efficiency of control method E; it should also be required that $E \to \max$, i.e. $E = kV_C - G \to \max$.
Note that, for independent control of spacecraft angular and translation motions, efficiency of control over a center of mass is determined by the index $E_{CM} = kVc \to \max$, and efficiency of control of motion around a center of mass is determined by the index $E_O = -G \to \max$ (or $G \to \min$). Hence, the optimized functional assumes the form:
$E = km^{-1}\int_0^T P\cos(j - g)dt - c\int_0^T Pdt \to \max$, where c=const is the coefficient of expenditures.
It is known that minimum fuel consumption for rotation is achieved for maximal acceleration of spacecraft at the phases of acceleration and braking. Allowing for this, one can take the value $E = \int_0^T (k_v\cos(j - g) + k_w\cos g)dt$ as the index of efficiency.
In particular case $k_v = k_w$, solution can be found in analytical form. For arbitrary values of coefficients k_v and k_ω (and, respectively, of constants k and c), solution can be found through mathematical simulation only.
If the controlling engine is movable, two essentially different formulations of the problem of combined control of spacecraft motion are possible. First formulation implies that fuel expenditure for the control of spacecraft rotation is subjected to unconstrained optimization (that is, absolute optimization), and maximization of value of the correcting velocity obtained in process of rotation is conditional, since it is performed within the framework of the obtained solution. Second formulation implies that value of the correcting velocity is maximized first of all, and control of rotation is constructed on the basis of available resources of control (of value of the controlling moment). It is obvious that, in first case, the controlling moment M_y should be maximal; therefore, $g = 0$ throughout rotation time. In second case, the angle between engine thrust **P** and velocity vector **V** is equal to zero (or close to zero if $a + y = 90°$ at initial moment of time), i.e., $j - g \approx 0$.
In the case of the fixed engines ($g \equiv 0$), second formulation of optimization problem of the combined control of attitude and orbit correction makes no sense. In this case, solution of the problem of the combined control is reduced to determination of optimal control over spacecraft angular position in traditional formulation (when $G \to \min$), and control over a center of mass is accomplished through the choice of engines whose thrust vector **P** forms acute angle with orbital velocity vector **V**. Of practical interest is a compromise variant, which, when subjected to optimization, is distribution of the controlling forces produced by the system of jet engines on regulation of motion of a center of mass and of angular position of a spacecraft.
Let us formulate the problem of optimal combination as follows: to find the control satisfying differential equations

$$\dot{j} = w\,,\;\; \dot{w} = Pl\,\mathrm{sign}\,l \cos g \,/\, J_z$$

and, providing maximum of the functional

$$F = \int_0^T |c| P\cos(j - g)dt - mck^{-1}\int_0^T |c| Pdt$$

for the prescribed time of relation T = const and given boundary conditions:

$$j(0) = j_0 = a\;,\; w(0) = w_0 = 0\,,\; j(T) = j_T\,,\; w(T) = w_T = 0\,,$$

and with limitations on rotation velocity $|w| \le w_{max}$, where j is the angle of spacecraft rotation (the angle between velocity vector **V** and positive direction of axis Y); w is rotation velocity; g is the turn angle of engine; u is the angle between vectors **V** and **P**; $u = j - g$; J_Z is spacecraft moment of inertia with respect to the axis of rotation; and χ is the parameter determining the switching on of the thrust **P** and a point of its application:

c = 1, if the thrust **P** is applied at the point A_1;

c = 0, if the thrust **P** is absent;

c = –1, if the thrust **P** is applied at the point A_2.

Let us bound the domain of variation of rotation time T by the inequality $T_{\min} \le T \le T_{\max}$, where $T_{\min}$ and $T_{\max}$ are values of time T for $u = j$ and $u = 0$, respectively (for $u = 0$, the value $j_o = p/2$ is not considered, since $T_{\min} \to \infty$ in this case).

The bounded ness of spacecraft rotation velocity by the value w_{max} follows from the requirement for minimization of fuel expenditure for rotation with independent control of spacecraft angular and trajectory motions. Taking into account that, for independent rotation of a spacecraft, optimal motion consists of an acceleration up to the required angular velocity, spacecraft rotation with constant angular velocity, and its subsequent deceleration, one can easily find the relation between the expenditure G and maximum angular velocity w_{max}. Using the fact that the value of G is uniquely determined by the value w_{max} in this case, we substitute optimality criterion $E = km^{-1}\int_0^T P\cos(j - g)dt - G \to \max$ by the requirement

$$\int_0^T |c| \cos(j - g)dt \to \max$$

with simultaneous fulfillment of the condition $|\dot{j}| \le w_{\max}$; meanwhile, the value of G remains fixed and is not subjected to optimization, $G = \mathrm{const}$.

The posed problem was solved using personal computer by the method of parameterization of controls family [3]. Analysis of results of numerical experiments showed that, for all $T_{\min} \le T \le T_{\max}$ and arbitrary boundary conditions, the condition $f = u_{\mathrm{opt}} / j_{\mathrm{oopt}} \approx$ const holds true during spacecraft turn. This means that, for optimal program, the controlling resources are distributed proportionally between the requirements for spacecraft rotation and for correction of motion of its center of mass. We will estimate efficiency of optimal control by the value: $S = \int_0^T |c| (\cos(j - g) + k_w \cos g / k_V)dt$.

For $k_\omega = k_v$, index S attains its maximum when proportionality coefficient f = 0.5 (i.e., when $g = j - g$). It follows here that, for optimal control, engine thrust **P** is directed along the bisector of the angle formed by axis Y and velocity **V**. Since maximum fuel economy is provided by equal sharing of engine thrust **P** between linear and rotational motions of a spacecraft (f = 0.5), we will consider this case in more detail. Let us write the equation of motion: $\ddot{j} = e\cos(j/2)$, where $e = Pl\,\mathrm{sign}\,l / J_z$.

Introducing new variable, $J = (j - p)/2$, we transform this equation to the form

$$\ddot{J} = -k_b \sin J\ ,\quad k_b = e/2 \tag{2}$$

Let us obtain the dependences determining $\operatorname{sign} l$ and $\operatorname{sgn} c$. Let us denote the angle between **V** and OY by φ_+ and the angle between **V** and $-OY$ by φ_-. Then, taking (1) into account, we have $\operatorname{sgn} l = \operatorname{sgn} M_y$, and

$$\operatorname{sign} c = \operatorname{sign} M_y \text{ at } j_+ \in [-p/2, \pi/2] \text{ or } \operatorname{sign} c = -\operatorname{sign} M_y \text{ at } j_- \in [-p/2, p/2] \tag{3}$$

For $|\varphi_+| = |j_-| = p/2$, we chose the angle for which the condition $\operatorname{sign} j_{+(-)} = -\operatorname{sign} M_y$ holds true as j. From (3), we find the angular coordinates of the stages of acceleration and braking:

$$J_a = \arccos(w_{max}^2 / 4e + \cos J_0)\ ,\quad J_b = \arccos(\cos J_T - w_{max}^2 / 4e)\ .$$

Introducing $d_a = J_a - J_0$ and $d_b = J_T - J_b$ we linearized (2), assuming that e, J_0, J_T, w_{max} are such that d_a and d_b are small values.

During the period of acceleration: $\ddot{d} = -k_{0o} - k_1 d$, where $k_0 = k_\beta \sin J_0$ and $k_1 = k_\beta \cos J_0$.

The form of solution of last equation depends on the angle J_0. Omitting the intermediate calculations, we write the relationships for t_a and S_a for different J_0, where t_a and S_a are, respectively, the time and value of S at the stage of acceleration.

1. $-p < J_0 \le -p/2$:

$$t_p = \ln\left(1 + d_a \cot J_0 + \frac{\sqrt{d_a \cot J_0 (d_a \cot J_0 + 2)}}{\sqrt{|k_1|}}\right),\quad S_p = \left|\sin J_0 \frac{\exp\left(t_a\sqrt{|k_1|}\right) - \exp\left(-t_a\sqrt{|k_1|}\right)}{\sqrt{|k_1|}}\right| \tag{4}$$

2. $J_0 = -p/2$:

$$t_p = \sqrt{\frac{2d_a}{k_b}}\ ,\qquad S_P = 2t_a \tag{5}$$

3. $-p/2 < J_0 \le 0$:

$$\text{for } J_0 \le -p/4 \qquad t_p = \frac{\arccos(d_a \cot J_0 + 1)}{\sqrt{|k_1|}},\quad S_p = 2\left|\frac{\sin J_0 \sin t_a \sqrt{k_1}}{\sqrt{k_1}}\right| \tag{6}$$

$$\text{for } J_0 > -p/4 \qquad t_p = t_1 + t_2 = \frac{\arccos\left(1 - (J_0 + p/4)\cot J_0\right)}{\sqrt{|k_1|}} + \frac{\ln\left|A + \sqrt{A^2 - q}\right|}{\sqrt{|k_2|}},$$

$$S_P = 2\left|\frac{\sin J_0 \sin\left(t_a\sqrt{k_1}\right)}{\sqrt{k_1}} + \left[\left(\omega_{max} - \sqrt{|k_2|}\right)\exp\left(t_2\sqrt{|k_2|}\right) + \left(\omega_{max} + \sqrt{|k_2|}\right)\exp\left(-t_2\sqrt{|k_2|}\right) - \frac{2\omega_{max}}{\varepsilon}\right]\right|;$$

$$A = \frac{J_0 + 1 + p/4}{1 - \frac{w_{max}}{\sqrt{|k_2|}}};\quad q = \frac{\sqrt{|k_2|} + w_{max}}{\sqrt{|k_2|} - w_{max}};\quad k_2 = -\frac{k_b}{\sqrt{2}} \text{ or } k_2 = -\frac{e}{2\sqrt{2}}\ .$$

At the stage of braking, the controlling moment M_y changes its sign. This affects the form of $\delta(t)$ only; cases 1, 2, and 3 for acceleration phase correspond to cases 3, 2, and 1 for braking.

Let us now compare fuel expenditures G for the separate and combined controls of attitude and orbit correction. For the combined control, $S_{p/2} \le S \le S_0$, where $S = S_{p/2}$ for $j_0 = \pm p/2$, and $S = S_0$ for $j_0 = 0$; then $G_o < G < G_{p/2}$.

Analyzing (4), (5), and (6), one can conclude that, for separate control, in order to attain the values $S_{p/2}$ and S_0, it is necessary to spend $\sqrt{2}\,G_{p/2}$ and $2G_0$, respectively, which correspond to the interval of possible values of the efficiency index I of combining: $\sqrt{2} \le I \le 2$.
Therefore, even by an example of this particular case, i.e., of planar rotation of a spacecraft around the principal central axis of inertia, one can clearly see that the use of the idea of regulation of spacecraft angular position by means of non-central jet force allows us to gain significant fuel economy.

3. Solution of the problem of combined control of spacecraft spatial motion

At first, let us solve the problem of optimal control of spacecraft three-dimensional reorientation independent of orbit correction. The method proposed below belongs to a group of algorithms of combined synthesis of optimal control with predicting [2]. As prognostic model, we take the model of rotational motion of dynamically symmetric spacecraft. Prediction of "free" motion corresponds to regular precession of a spacecraft. We chose the parameters of prognostic model on the basis of the condition of maximum similarity of predicted motion to actual motion of a spacecraft. Rotational motion of a spacecraft is described by the following system of equations:

$$J_1\dot{w}_1 + (J_3 - J_2)w_2w_3 = M_1, \qquad 2\dot{l}_0 = -l_1w_1 - l_2w_2 - l_3w_3, \qquad 2\dot{l}_2 = l_0w_2 + l_3w_1 - l_1w_3$$
$$J_2\dot{w}_2 + (J_1 - J_3)w_1w_3 = M_2, \qquad 2\dot{l}_1 = l_0w_1 + l_2w_3 - l_3w_2, \qquad 2\dot{l}_3 = l_0w_3 + l_1w_2 - l_2w_1$$
$$J_3\dot{w}_3 + (J_2 - J_1)w_1w_2 = M_3.$$

Here, w_1, w_2, and w_3 are the projections of spacecraft angular velocity on the bound axes; J_1, J_2, and J_3 are the principal central moments of inertia of a spacecraft; M_1, M_2, and M_3 are the moments of external forces; l_0, l_1, l_2, and l_3 are components of the quaternion Λ describing relative orientation of the bound and inertial coordinate systems. For the sake of definiteness, we assume that the axis OX is the longitudinal axis of a spacecraft, $J_2 > J_3$, and J_2, $J_3 > J_1$. Note that the chosen spacecraft class satisfies the condition of quasi-symmetry: $J_2 \approx J_3$, but $J_2 \ne J_3$, and $\min\{\, |J_3 - J_1|, |J_2 - J_1| \,\} > |J_2 - J_3|$. Hence, the moment $(J_2 - J_3)w_2 w_3$ is small, and we can consider it as a perturbation. Further, we select the moment of inertia J with respect to the transverse axis on the basis of the condition of invariance of characteristic equation of dynamic system:

$$J = (1+h)/(J_2+J_3-J_1)$$

where $|h| = \sqrt{(J_2 - J_1)(J_3 - J_1)/J_2J_3}$, $|h| < 1$.

In this case the dynamics of real spacecraft motion will be described by the system:

$$J_1\dot{w}_1 = (J_2 - J_3)w_2w_3 + M_1,$$
$$J\dot{w}_3 + (J - J_1)w_1w_2 = [J_1(J - J_3) + J(J_2 - J_3)]w_1w_2 / J_3 + M_3J / J_3,$$
$$J\dot{w}_2 + (J_1 - J)w_1w_3 = [J_1(J_2 - J) + J(J_3 - J_2)]w_1w_3 / J_2 + M_2J / J_2.$$

In determination of motion by prediction, the controlling moments are taken to be zero. Therefore, M_1, M_2, and M_3 include only the perturbing moments. Analysis of this system shows that the right-hand sides of the equations are small values (we accept them as the perturbations); thus, in prognostic model, we neglect them. Finally, the equations of prognostic model assume the form:

$$J_1\dot{w}_1 = 0, \quad J\dot{w}_2 + (J_1 - J)w_1w_3 = 0, \quad J\dot{w}_3 + (J - J_1)w_1w_2 = 0.$$

Solving the boundary value problem $\Lambda(0) = \Lambda_{in}$, $\Lambda(t_f) = \Lambda_f$ with allowance for the last system, we obtain the required angular velocities:

$$w_{10}=Jbn_1/(J_1T)\,, \quad w_{20}=Jbn_2/(J_2T)\,, \quad w_{30}=Jbn_3/(J_3T).$$

The angles b and q and vector $\mathbf{n}$ are determined by the following system of relationships:

$$\cos(b/2)\cos(q/2)-n_1\sin(b/2)\sin(q/2)=n_0,$$
$$\cos(b/2)\sin(q/2)+n_1\sin(b/2)\cos(q/2)=n_1,$$
$$n_3\sin(b/2)\sin(q/2)+n_2\sin(b/2)\cos(q/2)=n_2,$$
$$n_3\sin(b/2)\cos(q/2)-n_2\sin(b/2)\sin(q/2)=n_3,$$
$$\theta=n_1b(J-J_1)/J_1,$$

where n_0, n_1, n_2, n_3 are components of the quaternion of the turn $\Lambda_r = \tilde{\Lambda}_{in} \circ \Lambda_f$; $0 \le b \le p$.
Taking into account the fact that true motion of a spacecraft differs only slightly from the predicted motion, we will use the method of iterative guidance in order to form the control commands in the process of rotation. According to this method, the trajectory is divided into several segments where control is absent ($\mathbf{M} = 0$). Transition from one segment to another segment is accomplished by the correcting impulses. There is only one requirement for the segments: they must pass through $\Lambda(t)$ and $\Lambda(T)$. The objective of the control consists in providing such initial conditions for the segments without control that the motion by prediction passes through final position Λ_f . To do this, for the beginning of each segment t_i , the quaternion of a turn is determined, $\Lambda_r^{(i)} = \tilde{\Lambda}(t_i) \circ \Lambda_f$, by which the required initial conditions for next segment, w_{1i} , w_{2i} , and w_{3i}, are determined. Spacecraft motion at the stages of acceleration and braking coincide with the predicted trajectories (since $M_b << M_C$), and their duration t is determined by the prescribed time T of a turn, available value of the controlling moment $\mathbf{M}$, and rotation angle j_0=2arccos(squal($\tilde{\Lambda}_{in} \circ \Lambda_f$)), by which it is necessary to rotate a spacecraft. Duration of a motion along the segments of spacecraft free motion is determined from condition of minimization of fuel expenditure G and depends on logic of formation of the commands for execution of angular momentum correction. Usually several impulses of correction of angular momentum are sufficient (up to 4–6, depending on rotation angle). Optimization is reduced to determination of the durations of gain and cancellation of spacecraft angular velocity. The controlling moments M_1 , M_2 , and M_3 during the segments of acceleration and braking are determined by two conditions: $\mathbf{M} = r\,\mathbf{K}$ and $|M_j| \le U_j$ for all $j = 1, 2, 3$, and at same time, (a) for acceleration stage, $r > 0$ and $\mathbf{K}$ is the calculated value of angular momentum, $K_j = J_j\,\omega_{j0}$; and (b) for the braking stage, $r < 0$ and $\mathbf{K}$ is actual angular momentum of a spacecraft at the beginning of the braking. During both phases, $\mathbf{M}$ is constant in inertial coordinate system.
Thus, control of spacecraft reorientation is reduced to execution of following operations:
1) calculation of the turn quaternion $\Lambda_r = \tilde{\Lambda}_{in} \circ \Lambda_f$ and determination of initial conditions for free motion segment w_{10}, w_{20} and w_{30}; determination of calculated value of angular momentum $\mathbf{K}^*$ and the controlling moments M_1 , M_2 , and M_3 ;
2) spacecraft acceleration with maximal controlling moment to the required value of angular momentum $L=(J_1^2\omega_{10}^2+J_2^2\omega_{20}^2+J_3^2\omega_{30}^2)^{1/2}$, during this process, the controlling moment direction being constant in inertial space: $\mathbf{M} = \tilde{\Lambda} \circ \mathbf{M}_A \circ \Lambda$, $\mathbf{M}\cdot\mathbf{K} > 0$;
3) free rotation of a spacecraft, $\mathbf{M}$=0, up to the instant t_i of spacecraft motion correction;
4) at time instant t_i, determination of error signal quaternion $\Lambda_E = \tilde{\Lambda}(t_i) \circ \Lambda_f$, and calculation of the boundary conditions corresponding to it (for new hitting trajectory), w_{1i}, w_{2i}, and w_{3i},

for next segment of motion without control. Determination of the required impulse of angular momentum $\Delta\mathbf{K}$: $\Delta K_j=J_j(w_{ji} - w_j)$ for j = 1, 2, 3.
We calculate the controlling moments basing on the requirement $|M_j|\le U_j$ for all $j=\overline{1,3}$, according to expression $M_j=J_j(\omega_{ji} - \omega_j)/\Delta t$, where $\Delta t = \max\limits_j(|\Delta K_j|/U_j)$.
Then, one should assume that $t_0 = t_i$, and repeat operations 3) and 4) until time instant when spacecraft can be rotated through the remaining error angle j_{rem}=2arccos(squal($\tilde{\Lambda}\circ\Lambda_{\text{f}}$)) within the time t necessary to cancel angular velocity.
5) damping of spacecraft angular velocity with maximal controlling moment:

$$\mathbf{M}=\tilde{\Lambda}\circ\mathbf{M}_{\text{T}}\circ\Lambda,\ \mathbf{M}\cdot\mathbf{K}<0,\ K_j = J_j w_j\ (j=\overline{1,3})$$

(the controlling moment is directed strictly opposite to actual angular momentum).
Correction of the trajectory of spacecraft motion can be made at regular intervals ΔT or at regular decrements of the remaining error angle Δj_{rem}. Time instants t_i can be formed by logarithmic scale as well, in the direction of lowering Δt_i or Δj_{rem} as time passes. The smaller the remaining angular distance to the prescribed position Λ_f, the more frequently are corrections of spacecraft angular moment made. The choice of particular program for determination of a sequence of the times t_i during spacecraft rotation (the cyclorama of the output of the correcting impulses of spacecraft angular momentum) depends on the priorities of accomplishing the planned tasks. The proposed algorithm is based on the method of iterative guidance with the use of prognostic model. Therefore it needs no continuous formation of the controls and is reduced to moderate correction of the trajectory of spacecraft rotational motion at certain instants of time. The obtained method of control is invariant to external as well as to parametric disturbances and provides high efficiency and accuracy of spacecraft reorientation.
Efficiency index of the synthesized law of control of a single spatial turn of a spacecraft can be naturally represented in the form $I = (G_r + G_{\text{C}})/G_{\text{COM}}$. We form control commands for attitude control engines on the basis of assumption that the main purpose of control is to minimize fuel expenditures for spacecraft reorientation, $G_{\text{r}}\to\min$, and orbit correction is the consequence of this process. Hence, it is reasonable to assume that $G_{\text{COM}} = G_r$; i.e., fuel is not consumed specially for increase of orbit altitude. According to this approach, G_C represents fuel expenditures necessary to provide the same effect of orbit altitude increase for independent control: $G_{\text{C}} = k_v V_{\text{C}}$, where V_{C} is spacecraft velocity increase obtained as the result of reorientation; $k_v = m/W = \text{const}$; m is spacecraft mass, and W is gas exhaust velocity of altitude control engines.
The values G_r and G_C depend on the pattern of mounting attitude control engines. As was shown by example of spacecraft planar rotation, optimal combining of the regimes of attitude and correction require a possibility to rotate jet engine thrust in arbitrary way. It is obvious that, for the case of spacecraft spatial rotation combined with orbit correction, optimal control also necessitates orienting engine thrust **P** in the required direction with respect to the bound spacecraft axes. However, such a method of control implies setting attitude control engines in gimbals mounts, which involves some constructive difficulties. Because of this, two expedient patterns, from practical point of view, of rigid mounting of attitude control engines were considered (fig.2; the schemes with 16 and 32 attitude control engines). Reorientation control law appears to be rather simple: in order to create the prescribed controlling moment **M** providing spacecraft transition from initial angular position Λ_{in} to required final position Λ_{f} within prescribed time T, we switch on only those engines whose thrust makes acute angle with velocity vector **V**. It can be easily seen that this is always possible, since, in order to

create the required controlling moment, one of two oppositely directed attitude control engines can be chosen.

In the realized calculations the following simplifications were accepted: the engines are situated at equal distances from the longitudinal axis *OX* and are symmetrically located with respect to the plane *YOZ*, and point *O* coincides with a center of mass of a spacecraft.

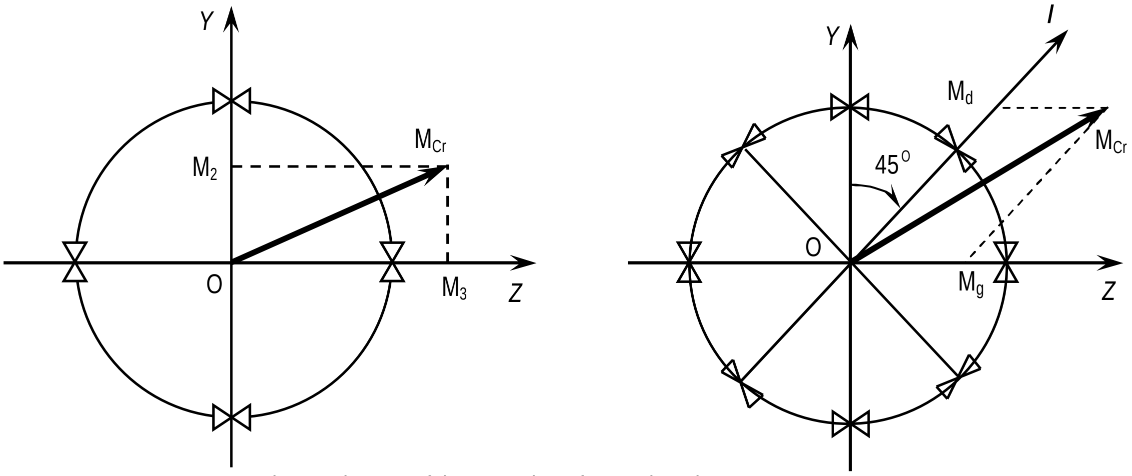

Fig.2. Schemes of the mounting of control engines.
I – is the direction along the diagonal, II – is the direction along one of the transverse axes *Y* or *Z*.
$\mathbf{M} = \mathbf{M}_{Cr} + \mathbf{M}_1$, $\mathbf{M}_{Cr} = \{M_2, M_3\}$ or $\mathbf{M}_{Cr} = \{M_d, M_g\}$.

The final logic and the calculations of Δm and ΔG_C for both patterns of the mounting of attitude control engines were made by author (here it is do not shown).

4. Data of mathematical simulation

As an example, we present results of mathematical simulation for a series of turns of a spacecraft of orbital station type, which has k_V = 36.32 kg·s/m, and the coefficients of expenditure by channels $C_j = J_j/(Wl_j)$ are equal: C_1=8.74 kg·s, C_2=11.59 kg·s, and C_3=7.09 kg·s. This simulation was accomplished for large number of the turns, while initial and final angular positions of the spacecraft were chosen at random and reorientation time was assumed to be proportional to a turn angle. Mathematical simulation gives us the estimations of average fuel consumption per one maneuver *G* and location accuracy, as well as of the performance of combining the regimes of attitude and orbit correction for two considered patterns of installation of control engines. For the pattern with 16 engines, we have average fuel consumption per one turn maneuver G = 2.62 kg, the index of combining control I = 1.59 and orbit correction velocity V_C = 1.37 m/s (per 30 turns). For the pattern with 32 attitude engines, we obtained G = 2.28 kg, I = 1.72, and V_C = 1.44m/s. Reorientation precision was equal to x = 0.2. The values of the optimized functional G_r and of the index of combining 'I' were determined by the method of mathematical shooting using personal computer [3]. When investigating the problem of combining the regimes of orientation and correction, we make one important assumption: velocity vector **V** is constant in inertial space (we have neglected orbital motion of a spacecraft during rotation time *T* and have not taken into account rotation of orbital coordinate system with respect to inertial basis). For new generation orbital stations where rotation time *T* is large, this simplification might be too restrictive (and even inadmissible for exact estimations of efficiency index 'I' of combining). Hence, at mathematical simulation, we take account of all factors of spacecraft actual flight, including the spatial variation of velocity **V** direction during reorientation maneuver.

For the purpose of comparison, we present the results of simulation of spacecraft reorientation process by two-impulse control method, which provides absolutely minimum fuel consumption for a turn, independent of orbit correction. For the pattern with 16 attitude control engines: G = 2.57 kg, I = 1.43, and V_C = 0.99m/s; and for the pattern with 32 attitude control engines: G = 2.24 kg, I = 1.51, and V_C = 1.01 m/s.

Conclusion

An algorithm of control of reorientation combined with orbit correction for the spacecraft of the long-term orbital station type is synthesized in this paper. High efficiency of combining of the regimes of orientation and maintenance of spacecraft orbit altitude is shown. Numerical simulation of spatial rotations of a spacecraft of orbital station type by the obtained algorithms of control was accomplished. As a result, the practically attainable values of the efficiency indices of combining the regimes and the correcting velocity value, which can be reached by executing the prescribed number of turns, were obtained. Practical application of proposed method of spacecraft spatial motion control allows us to lower significantly fuel consumption for dynamic operations as a whole. The results of mathematical simulation show that this economy reaches no less than 60%. For sufficiently frequent changes of spacecraft attitude, value of velocity impulse necessary to maintain orbit altitude can be achieved through control over spacecraft angular position only. The operating experience of orbital scientific complex “Mir” shows approximate equality of actual fuel consumption for attitude control and orbit altitude maintenance. Ratio of the noted consumptions G_C/G_a varies between 0.68 and 0.75, which corresponds to the range of variation of the combining index within an interval $I\in[1.68, 1.75]$. These data confirm actual possibility of practical use of the combined regimes of control over motion of orbital spacecraft by means of jet micro engines. It may be possible in future to abandon executing special corrections of an orbit in order to increase its altitude (or, at least, to reduce sharply a number of such corrections).

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Space Shuttle "Columbia" with seven astronauts on board was lost 10 years ago …

About tragedy of Space Shuttle "Columbia" in the context of Space explorarion

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Introduction

Рис.1а. «Space Shuttle»; the aerospace plane «Columbia»

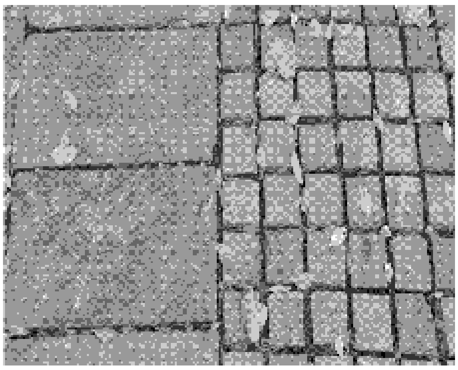

Fig.1б. Tiles on park alleys …

Ten years ago, on 1 February 2003, shortly before successful completion of the 107th Space Shuttle mission, Columbia spacecraft carrying seven astronauts disintegrated within a few seconds. The tragedy resulted from the damage of the thermal protection system sustained during the launch of the spacecraft (pieces of thermal insulation foam made of ceramic fiber withstand temperature up to 1250°C, and carbon-carbon panels on the leading edge of the wing – up to 1650°C).

These thermal protection tiles of airspace planes resemble the tiles that cover park alleys. Magic phrase "Space Shuttle" has been being mentioned by specialists and those who are fond of astronautics when discussing the outstanding achievements of humanity for 40 years already. And reflections inevitably take us back to events that happened ten years ago…

We imagine how the glowing flow with the temperature of several thousands degrees is forcing its way through the damaged thermal insulation tile of the leading edge of the left wing panel, and the load-carrying structure made of aluminum alloys is losing its load-carrying capability at 300°C and starts melting and disintegrating at 650°C. The spacecraft is turned, and the pieces of thermal insulation some of which were designed to withstand 350°C and other 750°C are absolutely unable to sustain the heat several times exceeding the allowed temperature. The temperature in landing-gear section is quickly growing; pressure inside two tires with the diameter of 110 cm is growing (before launch they were filled with nitrogen under a pressure of ~25.5 atm). Thermal protection tiles and panels attached to the load-carrying structure now detach due to high temperature and load and uncover the details and units designed to operate adequately up to just +175°C. And there are seven astronauts inside the cabin, who having felt the increased temperature and inadvertent motion of the spacecraft flying at the altitude of 60 km with the speed of 20160 km/h (5.6 km/s), realize their hopeless plight…

These reflections are also induced when reading the Report of Columbia Accident Investigation Board, which was sent to NASA on 26 August 2003 and was laid open to the public. Burnout of the leading edge of the left wing at the reentry phase was called an official version of the disaster cause. The burnout resulted from damage of the wing caused by the insulating foam shed from the external tank during launch.

Ten years passed since the disaster, and now it is possible to make reasonable conclusions on this one of the most complicated and costly programs, which was completely terminated in July 2011, - Space Transportation System. To answer the questions associated with this Program, it is necessary to consider the event from many sides and standpoints. The complete information is certainly needed, and as the authors do not have it at their disposal, they can give only some facts and their own attitude to the subject.

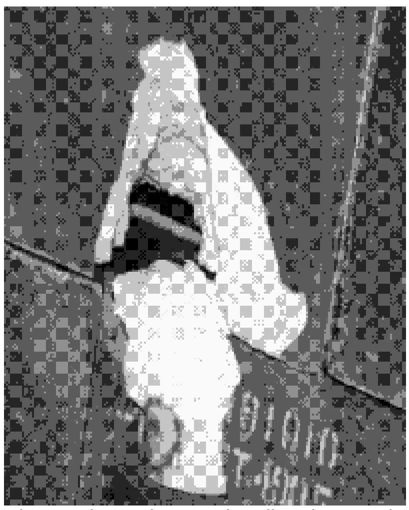

Fig.1в. Thermal protection tiles damaged by the foam insulation piece.

Few words about the history of astronautics, space shuttle systems on the whole and Space Shuttle orbiters in particular

After the first steps on the lunar surface made by Neil Armstrong and Edwin Aldrin on 21 July 1969 and Apollo-11 return to the Earth, it became clear that the American program of manned lunar landing proposed by Kennedy immediately after Yuri Gagarin's successful space flight performed on 12 April 1961 had been successfully accomplished. Unlike all the previous ones, this program headed by the designer of the first ever combat ballistic missile V-2 Wernher von Braun tackled solely civil problems. The United States took the lead over the Soviet Union at this stage of technical and political competition. The USSR declared the development of an orbital station its main task. The cost of the manned lunar program was huge. But ordinary taxpayers soon got tired of these outstanding scientific and engineering achievements, and only Apollo-13 disaster, which kept everyone who followed these events on their toes once again stirred up interest in space, and the broadcasts from the Mission Control Center were resumed. Twelve representatives of the Earth, having left their footprints on the dusty surface of the Earth satellite, proved WHAT a man can do if only he wishes. The superpower's ambition were satisfied, political satisfaction was achieved, and what next? The cost of the lunar program, which was announced in the account to the Congress in 1973, was $25.4 billion (more than $150 billion at present).

Immediately after Apollo-11, National Aeronautics and Space Administration (NASA) being deprived of almost half of its budget reduced the number of lunar missions by two and on Wernher von Braun's initiative decided to use the now spare Saturn-V launch vehicles to create a huge Skylab space station with the crew of dozens of astronauts. It was obvious that it would need a shuttle to transport astronauts and cargo. It seemed obvious that future belonged to space stations, and it was time to switch from expendable vehicles to space shuttles. At first the project of a space shuttle looked rather advantageous and well-grounded. It was a booster carrying an orbital plane capable of delivering about 11 t of payload to the space station. Each of the two stages of this reusable spacecraft looked like a huge airplane. Having delivered the second stage to a high altitude, the booster with a two-man crew returned to its launch site. The orbital plane orbited by means of its own engines and fuel. Having accomplished its mission, it returned to the Earth and landed near the launch site. Considering the orbital plane to be prepared for the next flight in two weeks, NASA specialists expected each launch to cost about $10 million. However, the preliminary estimate of the development was as high as $10…12 billion. President Nixon's administration did not approve of this project and charged NASA with investigation of alternative projects associated with lower cost of the development even despite the increased expenditures on preflight preparation and limited functional capabilities of the system. The Department of Defense as a chief expert stated the payload requirements: diameter ~5 m, length ~18 m, mass 29.5 t. So far it has been unknown whether it was the matter of launching a new weapon system or possible stealing of USSR satellites and modules of space stations from the orbit. Besides, the spaceplane's predesigned crossrange when exiting the orbit of 600 km should be increased up to 2000 km, and 30% of the launches should be performed for the benefit of the US Department of Defense. The project was approved in January 1972, and the Department of the Treasury budgeted $5.15 billion for it. It was the moment when the magic words "Space Shuttle" first appeared. By that time NASA had managed to reduce the initial cost of the system due to switching over from manned to unmanned booster and due to scaling the manned orbital plane down, having located the fuel for main engines in a detachable expendable fuel tank. Thus, not much was left from the initial design. In the middle of 1972, NASA engineers finally chose the structural layout, in which the boosters and main engines operated together during ascent.

Solid rocket booster that appeared to be not quite reliable was chosen owing to less design risk and lighter modification of the system at late flight phases due to the boosters, if the required parameters in the main liquid-propellant engine were unattainable (the phrase “not quite reliable” is used here because the risk of operating solid-propellant boosters of such sizes is undoubtedly increased). Six largest US corporations started this ambitious project.
The project gave rise to unfavorable criticism from the environmental professionals. While hydrogen burning in oxygen in main liquid-propellant engines causes almost no effect on ozone layer stability, the burning of solid propellant is accompanied with the emission of products that act as an active catalyst for ozone decay process. Thus, Space Shuttle program would result in 400 ozone holes (4 space planes each performing 100 flights) to be naturally healed for years. Environmental specialists from NASA disproved such a danger threatening the protective layer, which is located at the altitude of 20 km and saves every living thing from the solar UV radiation.
It appeared soon that NASA had no funds and resources for Skylab, though $3 billion had already been invested into the project. The initially assigned budget of Space Shuttle program had increased half as much. Space Shuttle had to be supported with cogent substantiation, and its huge cargo bay (340 m^3) had to be filled somehow. Despite the fact that this system had been predicted to be in demand (it seemed the matter of 25-30 flights per year), its try-out and finish revealed the problems and inefficiency of the program. The natural and frequently asked question of how to rescue the crew in case of emergency was answered in such a way: the system reliability was close to unity (0.999).
An important strategic result of the US Space Shuttle Program was that there appeared “wise heads” in the USSR who managed to persuade the government of taking an adequate step. Those who took the decisions were absolutely convinced that when exiting the orbit the space plane with a cross range of 2000 km carrying 30 t of payload could fly over the Kremlin. The Soviet Union was involved in the “marathon” of the same space distance and the same “weight category” of payload. In fact, Energiya-Buran project attracted the whole cream of the Soviet science.
Even now, after many decades, one can not call the decision wrong. The merciless Cold War between two political systems made them find adequate solutions. And it appeared that when the enemy’s actions themselves were vague, the counteraction was indistinct, too. And nobody could clearly answer the question – what for? More than 1200 companies and factories were involved into this work. Comprehensive answer to this stalemate question was given by Georgy Grechko: such cooperation of scientists and industry was organized in the USSR that to be used for tackling any tasks in the future. The answer can be accepted if we neglect the price of this space marathon for the state economy, which unfortunately was already entering the period of “Perestroika”…
Soviet spaceplane was not plotted from scratch. The reusable systems were mentioned as far back as in K.E.Tsiolkovsky’s works. Romantic engineer F.Zander drew his jet space plane. S.P.Korolev also approached the subject in 1958. He instructed his future deputy S.V.Tsybin to develop a manned winged spacecraft. Competition of two projects of a small-size military space plane (American Dyne-Soar and Soviet Spiral) in sixties was a draw due to their early termination. It is interesting to note that the first cosmonaut Yu.A.Gagarin was concerned with the reusable systems. He presented his degree thesis dealing with such systems in the Air-Force Academy in 1967. The unique experiments successfully conducted in the USSR with the scale space plane models Bor-4 and Bor-5 were used later in Buran development.
Despite a 3-year lag behind the schedule of launches of American space planes, the first of the four scheduled planes named after the ship Columbia (this ship took part in exploration of

Pacific West at the end of the 18^{th} century) was successfully launched on the day remarkable for the world astronautics – 12 April 1981, i.e. 20 years after the first manned space flight.

There were many problems and difficulties during the first flights, but the most urgent one was probably the question of thermal protection system behavior. Only four orbital flight tests had been performed. During these flights the crew of two astronauts tested the space plane at each mode of the nominal mission. Insignificant damage of thermal protection tiles by the shock waves, ice and debris detached from the fuel tank at the launch phase was noted.

The reentry phase is the most difficult one for the space plane. Having performed the deorbit burn, the space plane starts descending. It reenters the atmosphere in 30 minutes at the altitude of about 100 km (Entry Interface), and here the most critical phase begins. The temperature of the fuselage fore body and the leading edges of wings behind the shock exceeds 10000°C. The large portion of heat dissipates into the atmosphere, but its minor portion causes significant heating of the spacecraft despite the reverberating effect of thermal protection. This critical in its heating level flight phase lasts 15-18 minutes. The tests demonstrated satisfactory performance of thermal protection at this phase. Thus, a new page in space exploration was opened.

Losses suffered in the course of space exploration

When speaking about the pioneering explorers, the word “tragically” is often used. New activities are almost always associated with problems, and given the extreme conditions, an enormous risk is inevitable. Unfortunately, space exploration is accompanied by heavy losses. Let us remind those who sacrificed their lives at the altar of His Majesty Space.

The first space flight of 12 April 1961. 20 days before Yuri Gagarin was launched, his colleague from the first team of cosmonauts Valentin Bondarenko burnt down during the chamber tests. This information was made public only 25 years later.

The first ever manned rocket plane X-15 developed in 1959 was very helpful in the development of Space Shuttle. X-15 accelerated up to hypersonic velocity which was five times the sonic velocity and performed suborbital flights. Two of 199 flights were performed at the altitude more than 100 km, which is the altitude from which Space begins according to the international classification. This was made by pilot Joseph A. Walker in 1963, who was killed in a plane crash while flying in formation three years later. Termination of X-15 program was significantly affected by Michael Adams’ death in 1967, when his space plane having performed its 191^{st} flight was returning from the altitude of 81 km (a record altitude for the pilot) and suddenly went out of control.

In January 1967, one month before the scheduled launch of Apollo-1, astronauts Virgil Grissom, Edward White, and Roger Chaffee burnt down in the spacecraft cabin within 15 seconds during the training. Oxygen atmosphere with the pressure of ~0.3 atm was maintained inside the cabin to reduce its mass.

April 1967. The first launch of spacecraft and rocket Soyuz, which later became one of the most popular “space carriers”. The problems with the not finished spacecraft were obvious for many specialists involved in the project. Yuri Gagarin warned the supervisors of the problems and even demanded permission to perform the flight by himself (!). Ultimately, he was left as a backup pilot on the Earth, and Vladimir Komarov was launched for his second, unfinished, time. The problems with Soyuz systems began from the very moment of orbital injection. At first, one of the spacecraft’s solar arrays did not deploy, then the attitude control system failed, and after the astronaut had managed to direct the spacecraft to the landing trajectory, both primary and backup parachutes of the reentry module failed. The touchdown speed of the module was 650 km/h… Yuri Gagarin, the first astronaut of the Earth, who became a symbol, died in a training flight in March 1968…

The crew of the first manned space station Salyut-1 suffered a disaster on 29 June 1971. Astronauts Georgi Dobrovolski, Vladislav Volkov and Viktor Patsayev, having successfully finished their 22-day mission at the station, died when the crew capsule depressurized at the reentry phase. The reason was plain: a breathing ventilation valve, which had been designed to open at the altitude of 4 km, opened as the descent module separated from the service module.

Fifteen subsequent years seemed to be a calm period of Space exploration. But it was deceptive quiet, because the faults of design and mistakes associated with human factor when controlling complex systems do not disappear on their own, if nobody works on their correction. They show up all of a sudden.

A “shot” rang out on 28 January 1986 at 11:39 EST above the Atlantic Ocean near the shore of the central part of Florida. Numerous spectators who gathered at Cape Canaveral observed how a beautiful “Challenger” became a huge fire whirlwind at the 73rd second of the 51st Space Shuttle mission. Francis R. Scobee, Michael J. Smith, Ellison S. Onizuka, Judith A. Resnik, Ronald E. McNair, Christa McAuliffe, and Gregory B. Jarvis… these astronauts were inside that spacecraft…

The reason for the catastrophe appeared to be simple: it was caused by the damage of a seal ring of right solid rocket booster. Hot gases under high pressure broke through the solid-propellant engine and did their dirty deed. The cause was also obvious. These units operate under extreme conditions. During the launch, when at first main liquid-propellant engines mounted on the space plane operate and reach 90% of design thrust, the spacecraft is pressed into the fuel tank, and the whole system is bent as a huge plane spring. The topmost point of the system (56.1 m) deviates by one meter at this moment. When the above mentioned rings are not sufficiently elastic, which may be the case at low temperatures, the tightness of solid rocket boosters with the internal pressure of tens of atmospheres and temperature of thousands of degrees is broken.

While analyzing reasons for the tragedy, a term of “corporate culture” emerged, which was born in the 19th century. NASA management was aware of potentially dangerous defects of solid rocket boosters’ seal rings supplied by Morton Thiokol from the very beginning of operation. However, they did not give due consideration to this problem. Not to break the mission schedule, the managers neglected warnings given by designers against the danger of launch of the spacecraft under low temperatures.

The crew cabin, which was more rugged, was not destroyed by the explosion at the altitude of 15 km. It hit the water with 200-g acceleration. Perhaps, someone inside the cabin was still alive…

Economic damage was estimated as ~ $8 billion, which included the space plane itself, the works on removal of collapse causes that showed up or remained potentially possible… But the cost of *human life…* it can not be estimated.

Both engineering and organizational aspects were considered when eliminating the cause of the catastrophe. Thus, new notice methods were introduced to encourage the staff, who informed the management of possible safety hazards. Such complex engineering systems required new approaches to everything. This was the first severe blow to the whole Space Shuttle Program, which had only started proving its great value. However, during the mission of 6-13 April 1984 the crew of the same Challenger successfully performed in-orbit repair of Solar Max satellite. The latter was designed to explore the solar activity and was launched in 1980. At first, Solar Max was towed by the astronaut with the help of personal translation equipment; then it was captured by the spacecraft’s manipulator and put into the cargo bay. After the out-of-service system of attitude control and some elements of telescope electronics had been replaced, the satellite was returned to its orbit for further operation.

Three remaining US space planes continued their missions after Challenger disaster, and the USSR was finishing its no less complex Energiya-Buran system. In the process of Soviet "Shuttle" development the designers did their best to allow for all the drawbacks that were widely discussed during the development and early operation of Space Shuttle. In our opinion, this major difference is associated with fact that this work was aimed at improvement of crew safety. The first characteristic feature making the difference: Buran was in its essence an autonomous system on a multipurpose launch vehicle Energiya. Such a configuration made it possible for the space plane to separate from the launch vehicle and make an emergency landing in case of any failure of the latter (this was the case on 28 January 1986). The second characteristic feature is an option of automatic flight mode. This is especially important at the initial stages of the system tryout and in the situations when the crew has to evacuate, and the automatic control system is charged with spacecraft recovery (something like that happened with the 107th mission of Space Shuttle).

Before the launch of Buran on 15 November 1988, a special Board insisted on an unmanned mission. Despite a collective letter signed by a group of astronauts, who considered this a mistake, as the space plane would be unable to perform the unmanned flight, the mission was successfully accomplished. The post-flight inspection proved the Board's decision reasonable – three neighboring thermal protection tiles were absent on the wing's bottom face (the operation conditions for Space Shuttle and Buran allowed only one tile to be lost).

Unfortunately, this was the first and only flight of the Soviet reusable spacecraft. The first Buran crew was supposed to consist of six astronauts headed by Igor Volk. By an unlucky train of events directly associated with the flights, five of this team, Oleg Kononenko, Anatoli Levchenko, Nikolay Sadovnikov, Rimantas Stankyavichus, and Alexander Shchukin have never flown in space on their tested Buran, ant the latter itself has never carried to space anybody of those, who had "taught" it to fly.

"Columbia" (107th mission of Space Shuttle; tragic one…)

After Challenger disaster the structure of the rest space planes was reinforced and hence became heavier. The payload capability decreased by 5 t. Production of one more space plane – Endeavour – was started using the spare parts and units prepared in advance for the emergencies. Endeavour started its mission in 1992. And on 2-13 December 1993 it was involved in a unique mission of in-orbit repair of one of the most expensive space tools - Hubble telescope ($1.5 billion). Four astronauts working in pairs spent about five days in outer space.

The catastrophe of 1986 resulted in termination of Space Station Freedom Program, which had been designed to be serviced by Space Shuttle. The space station development had already cost ~$10 billion.

Meanwhile, Soviet Space Station Mir had been successfully operating on the orbit since 1988, proving this sphere of astronautics to be important and always in demand. Its 15-year operation, instead of initially planned 5-year one, enabled to accumulate priceless experience, including the experience of 9 joint missions with Space Shuttle, which later was used in development of the International Space Station (ISS) of new generation.

The first segment of the ISS, Zarya Functional Cargo Block, was launched in November 1998 on Proton rocket. Later, Endeavour attached American Unity segment to Zarya. The station built with participation of 16 states started growing, its mass was supposed to reach ~450 t, length ~110 m. The schedule of ISS development was very strict. Reusable spacecrafts proved to be complex in their operation time by time: weather conditions and any minor failures made launches be delayed; there were also some problems with landing due to weather. Under such conditions, NASA had to take the risk of improper operation of the space transportation

system. Such behavior could theoretically result in a catastrophe at any stage and during any Space Shuttle flight. But it was the first one that had the bad luck.
The oldest Space Shuttle Columbia was not equipped with a manipulator and a docking unit, thus being unadjusted for operation with ISS. The docking unit had been scheduled to be mounted on this Shuttle, and the latter was to be launched to ISS by the end of 2003. Maybe this was the reason why little attention was paid to this Shuttle.
Columbia was launched for the 28th time on 16 January 2003. This mission phase is always tense for everybody. This 107th half-month mission seemed to have been launched in nominal mode. Initial survey of launch records in Control Center discovered nothing abnormal. However, more detailed analysis of the records of higher resolution demonstrated that large debris separated and approached the Shuttle wing on the 82nd second of flight. This made the specialists feel uneasy. Comprehensive examination showed that 57 seconds after the launch Columbia sustained a side gust of 11.5 m/s being at the altitude of 10 km. The control system compensated for the deviation leading to low-frequency oscillations of liquid oxygen in the external tank, which were further transmitted to the tank structure. The load level suffered by the Shuttle was at that moment about 70% of the design load. This was obviously the reason why one large and at least two small pieces of fuel tank insulation seen in the images broke off the left bipod foam ramp 25 seconds later.
Similar accidents had been observed on previous flights. Later the Investigation Board established that the foam was shed during 65 out of 79 flights, for which the video of external tank was available. Such foam shedding from the left ramp was observed in 7 out of 72 flights, for which there were exhaustive data available: 1 – Challenger, 1 – Atlantis, 5 – Columbia. These accidents were initially considered as serious flight safety hazards, but later were classified as inevitable and allowable risk.
But this time the size of debris scared the specialists. Analysis performed using a simplified mathematical model showed that some problems could occur in the insulation, which suffered the impact of such a piece of foam. However, these results were left behind. Meanwhile, the rumours leaked out of NASA, inviting some questions from those, who were keen on astronautics. NASA had to soothe public fears and get the astronauts prepared for possible questions from journalists. But it turned out later that it was necessary to get them prepared for an emergency, not for an interview. Flight director informed of the events that had happened during the launch and assured the astronauts that there had been no danger at all. The version that the piece of foam had not damaged the wing thermal protection system became an official one.

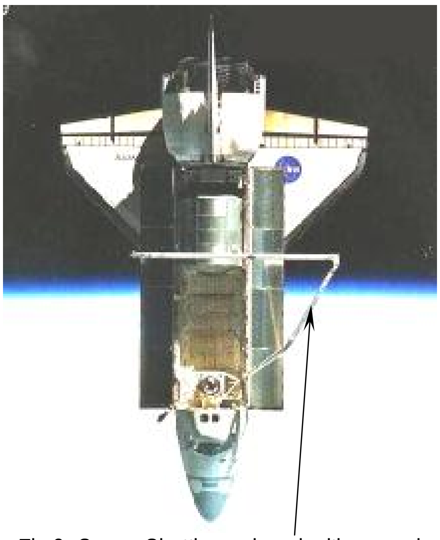

Fig.2. Space Shuttle equipped with a manipulator that 107th mission missed so much…

What could the astronauts do in such a situation? Much was said and written about it, and we are all wise after the event. The part of the wing that had been hit is invisible from the crew cabin. And as there had been no problems with thermal protection system for years, the flight directors considered it inexpedient to equip each mission with a 15-meter long manipulator with the mass of ~0.5 together with the personal means for autonomous spacewalk and a service kit. If that very spacecraft had been equipped with a manipulator, it would have helped to perform an impartial analysis (fig.2).
Thus, the crew had no chance to estimate the state of their spacecraft; therefore each astronaut was busy carrying out his/her task: 86 experiments had been scheduled including the research of minigravity and survival of worms in space.

And what the flight directors could do, if they were aware of the real technical condition of the spacecraft and if it was decided to evacuate the crew? Space Shuttle system has simply no means provided for such case. The only possible alternative was to try and prepare another Shuttle – Atlantis – which was at the stage of processing and more than one month was left before its launch. Specialists believe it could be launched not until 10 February. Columbia crew could hardly survive till 15 February. The weakest link in life support system was removal of carbon dioxide from the expired air (here the story suggest itself of Apollo-13 crew survival, when the astronauts had to stay inside the lunar spacecraft cabin after the fire and managed to make use of capsules with carbon-dioxide absorbent from the Command Module which were unfit for use).

According to the considered theoretical version, Atlantis with two pilots and two specialists on board was to approach Columbia as close as possible. The specialists were to put the extra-vehicular suits for Columbia crew into the cargo bay and then evacuate the crew. After that Atlantis carrying 11 astronauts was to return to the Earth, and Columbia was doomed to wreck (it has been already mentioned that Space Shuttle system was unable to perform unmanned landing).

It is absolutely clear that nobody from the management could take a risk of such a mission, which would result in Columbia loss, one extra launch (the official cost of which was $500 million) and definitive failure of the whole Space Shuttle Program. And nobody believed that a brief-size piece of foam with the mass of 0.8 kg (according to the official version) having hit 100-tonne Columbia would put an end to it in the literal sense of the word.

Let us once again return to 16 January 2003, when at 20-km altitude a piece of insulation with the size of ~0.5×0.375×0.125 m was shed from the external fuel tank of the Shuttle, which was moving at 785 m/s. The piece was entrained by the streamlining flow and reached the acceleration of 10g relative to the Shuttle. Having passed almost a half of the spacecraft length and having attained the speed of about 220 m/s, the foam hit the left wing's leading edge and crumbled to pieces (fig.3).

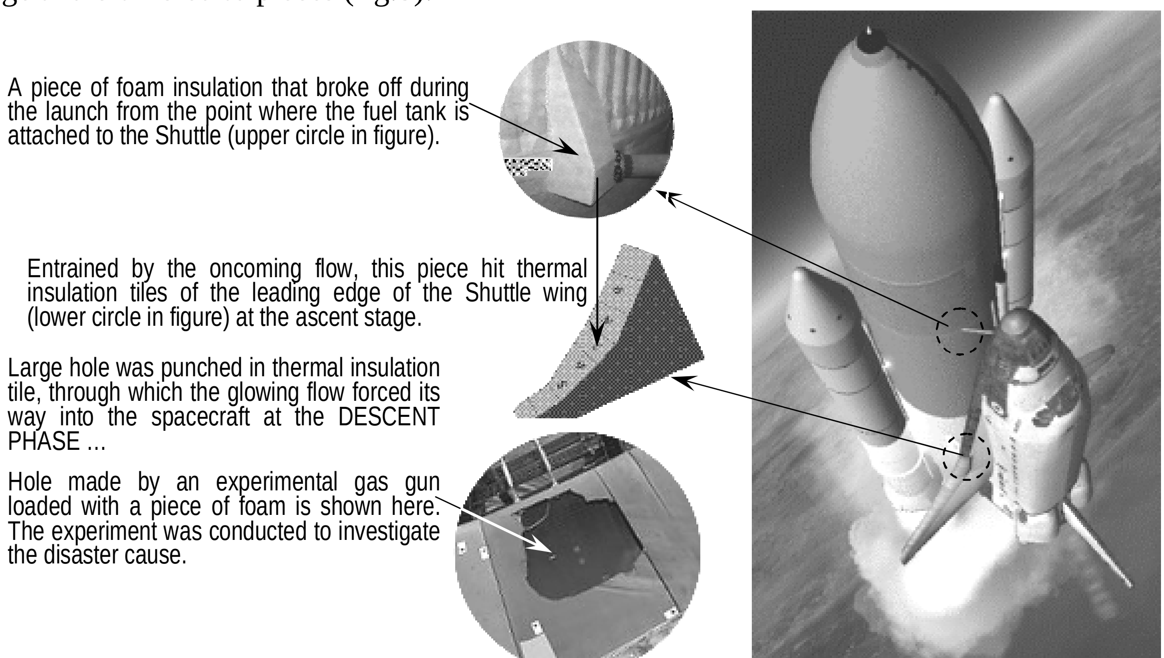

Fig.3. Official version of the catastrophe cause

This process was simulated in the laboratory afterwards using a gas gun, and the results shocked everybody. A large hole was punched in the carbon thermal insulation of the horseshoe-shaped leading edge of the wing (fig.3). It is impossible to reproduce a real flight in laboratory environment, but all the same one can not get rid of the feeling that experimenters have overdone it.

Before Columbia's deorbit, its photographs were shot by the US Air Force satellite. The pictures not only appeared unable to clear the situation up, but also triggered new questions. Some strange defects were noticed in the region of wing-fuselage mating – it was not clear whether the picture was of poor quality, or some problems had really emerged. No answer was given to this question either before the catastrophe, or after it.

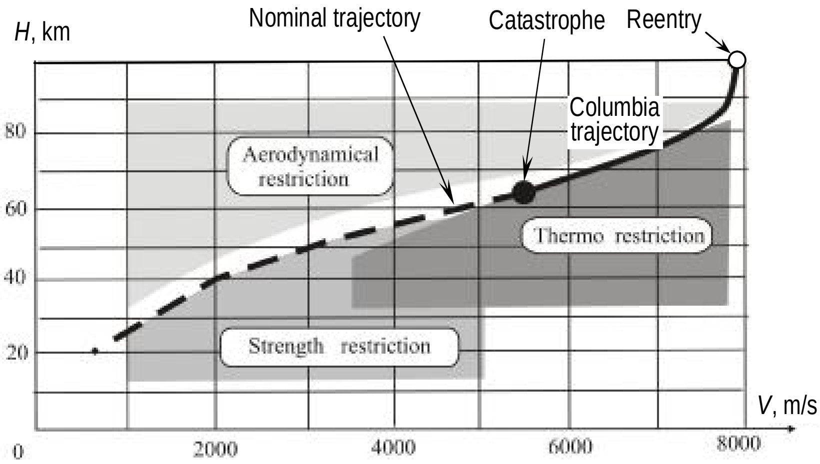

Fig.4. Corridor of the spacecraft moving under aerodynamic, strength and thermal restrictions

Without giving specifics, let us draw a corridor of the spacecraft descending in the atmosphere (fig.4). Its upper boundary is defined by the aerodynamic bearing capacity of the vehicle and is determined given the conditions of equilibrium glide ability under aerodynamic gravitational forces and the given initial velocity.

The lower boundary of this corridor is associated with two restrictions: strength restriction defined by the maximum normal acceleration ($n_y \leq 2.5$) and thermal restriction connected with the maximal temperature of the vehicle surface (T≤1650°C).

Let us also plot the nominal trajectory (dashed line) and Columbia's trajectory (solid line). At 13:43 GMT Columbia entered the atmosphere, and at 14:16 it was to land on the runway strip of Kennedy Space Center in Florida. Having performed S-type maneuvers to stay within the corridor, Columbia reached California coastline at 13:51. It should be noted that many probes and sensors used in test flights of 1981 were left mounted on Columbia allowing detailed reconstruction of further events described later both in scientific and popular editions.

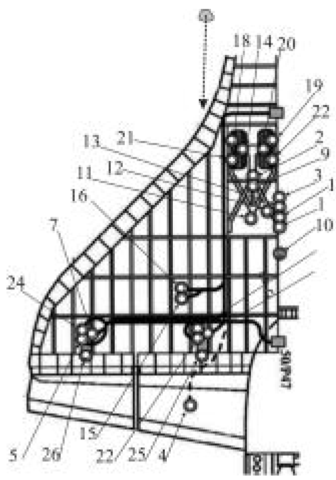

Fig.5. Figures show the sequence of tripping of the left wing's sensors.

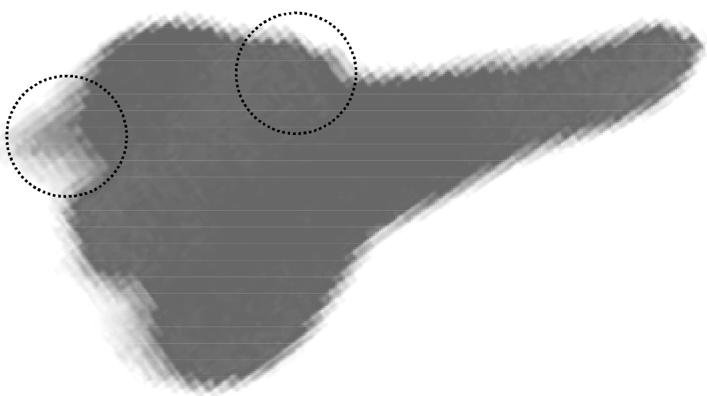

Fig.6. The last picture of Columbia taken from Kirtland Air Force Base: left wing's contours look defective.

The main question here is why the temperature rise began at 13:52 at first in the region where the left wing was connected with the fuselage and in its leading part around its elevons, and later in its trailing part, where thermal insulation had been damaged according to the official version (fig.5). This is usually caused by a number of reasons, when series of events coincide.
The Commander’s last words sounded calm and confident. And after they have been interrupted, telemetry from the spacecraft, which fixed the sequence of tripping sensors, was received for 32 seconds more.
Some problems with the left wing are already evident in the picture (fig.6) taken from Kirtland Air Force Base. At 14:00 Columbia and its crew consisting of Rick Husband, Laurel Clark, Kalpana Chawla, David Brown, Michael Anderson, William McCool, and Ilan Ramon (the first astronaut of Israel) were gone…

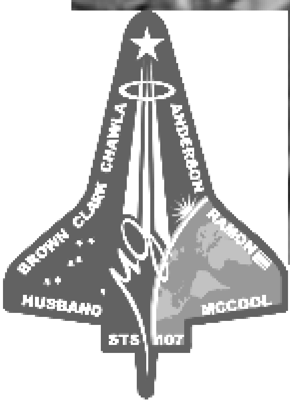

Fig.7. STS-107 insignia; crew of Columbia – Rick Husband, Laurel Clark, Kalpana Chawla, David Brown, Michael Anderson, William McCool, and Ilan Ramon (one of the last pictures taken in space and reconstructed after the catastrophe by NASA)

The eyewitnesses tell that further descent of Columbia resembled the deorbiting of Mir Space Station in 2001, when it was falling to the Pacific Ocean in the course of its scheduled destruction.

After the catastrophe

We will not once again give the conclusions made by the Columbia Accident Investigation Board headed by US Navy Admiral Harold W.Gehman. We will only cite one of the Admiral's wise phrases that the more complex an engineering system is, the more it needs human care and help.

When searching for debris, the sealed canisters with worms were found. Four of the five worms appeared to survive re-entry and impact with the ground. This was an absolutely unexpected result of biological research performed on Columbia. According to the member of the Russian Academy of Sciences and the leading NASA specialist Roald Sagdeev, "the worms showed an astonishing viability bordering on immortality".

The last launch in the framework of Space Shuttle Program was performed in summer 2011, and orbital planes took pride of place in the US museums. Fig.8 shows the distribution of all the missions over years and a number of missions performed by each Shuttle.

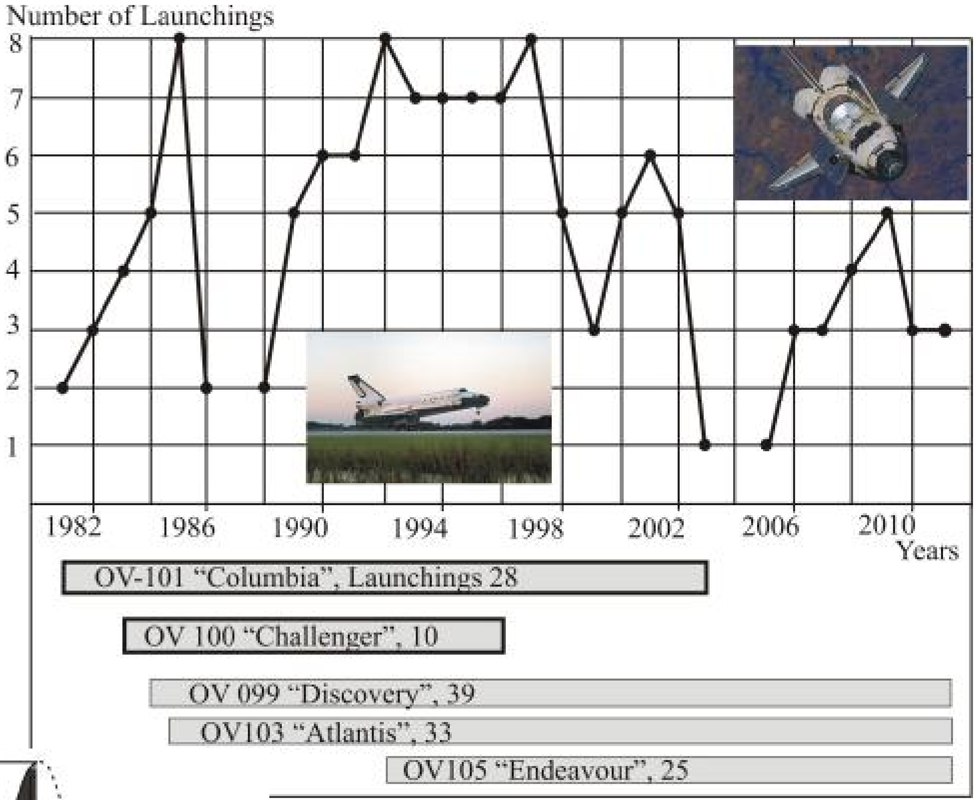

Fig.8. Space Shuttle Missions

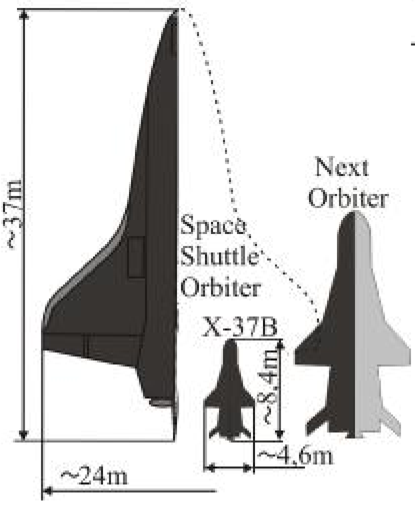

Fig.9. Correlation of Space Shuttles in size.

NASA representatives evaluate the cost of the Program as $113 billion, but one can find far higher estimates. What is left after the 40-year Program? Some spare no efforts in criticism, other admire it. Some try to convert all the achievements into "primitive" money equivalent (e.g. Teflon coating, Velcro, orthopedic mattress, pillows with memory, etc. which turned out to bring billions of dollars). Going into details can lead to the cost of $400 per one gulp of water and $30 per a breath of air on board of Space Shuttle.

Great achievements of the human race, including the engineering ones, are of lasting value, and this means that

some other rating applies to them, as they provide the progress of the Mankind.
As for the Space Shuttle Program, it must be admitted that it was poorly justified. This led to human losses and premature termination of the Program. At present an unmanned Boeing X-37 space plane is performing its third long mission. Mass media claim that the USA use it for testing of some new space plane technology (fig.9). Such a path seems reasonable.

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About influence of non-simultaneity of opening stabilizer consoles on uncontrolled aircraft motion

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This paper examines the effect of various asymmetries during opening stabilizer the precision of movement uncontrolled aircraft.

In relation to the uncontrolled aircrafts, there are two various "passive" methods of stabilization: stabilization by rotation and stabilization by using different stabilizers. In this article the second method is considered.

Stabilization of the uncontrolled aircrafts is that stabilizers which are different in shapes and sizes are revealed on the tail part of the fuselage and they open after launching the aircraft. In real launch of similar aircrafts there is the "non-simultaneity" of opening consoles of stabilizer's. It leads not only to a low mass inertia asymmetries and aerodynamic asymmetries, but also changes the aerodynamic coefficients which impairing stability of aircraft movement and target accuracy (i.e. increase of deviations in the lateral direction Δz_c and of range deviations Δx_c). Mentioned asymmetries of uncontrolled aircraft are considered as perturbations of mass inertia characteristic and geometrical characteristic of rotation body. Other possible disturbances are: lateral shift of the center of mass from the axis of symmetry; misalignment of the principal axes of inertia, which leads to the appearance of product of inertia relative to the axis of geometric symmetry; deviation of the aircraft form from the nominal form of the body of revolution. Small asymmetries and thrust misalignment cause the appearance of the excess torque which action can lead to the increase of the angle-of-attack and of the yaw angle. In this case, statically stable implement can become dynamically-unstable [1].

To calculate the parameters of the perturbed motion of uncontrolled aircraft and for the research of the impact small asymmetries and thrust misalignment on target accuracy, the mathematical model of motion was used. The structure of the equations of such model has to include different asymmetries, thrust misalignment, and also changes in asymmetries on a subphase of the opening stabilizer.

Mathematical model of spatial motion of aircraft which have small asymmetries and thrust misalignment is given below [2].

The dynamic equations of translational motion of the aircraft in the projections on the body-fixed axes which is located in the center of mass axisymmetric aircraft:

$$
\begin{aligned}
\dot{V}_x &= \omega_z V_y - \omega_y V_z - gA_{12} - q\frac{SC_x}{m} + \frac{P_T}{m}\cos\varepsilon_z \cos\varepsilon_y \\
\dot{V}_y &= \omega_x V_z - \omega_z V_x - gA_{22} - q\frac{SC_y}{m} + \frac{P_T}{m}\cos\varepsilon_z \\
\dot{V}_z &= \omega_y V_x - \omega_x V_y - gA_{32} - q\frac{SC_z}{m} + \frac{P_T}{m}\cos\varepsilon_z \cos\varepsilon_y
\end{aligned}
\tag{1}
$$

The dynamic equations of rotational motion of aircraft in projections on the body-fixed axes:

$$\dot{w}_x = \frac{1}{J_x}\left[J_{xy}(\dot{w}_y - w_x w_z) + J_{xz}(\dot{w}_z + w_x w_y) + J_{yz}(w_y^2 - w_z^2) \right] + (J_y - J_z) w_y w_z + \tag{2}$$

$$+qSl(m_{x0} + m_x^{\bar{w}_x} \frac{w_x l}{V} + C_y \frac{\Delta z}{l} - C_z \frac{\Delta y}{l}) -$$

$$-P_T(d_y \cos e_z \sin e_y + d_z \sin e_z);$$

$$\dot{w}_y = \frac{1}{J_y}(J_{xy}(\dot{w}_x + w_y w_z) + J_{xz}(w_z^2 - w_x^2) + J_{yz}(\dot{w}_z - w_x w_y) + (J_z - J_x) w_x w_z +$$

$$+qSl(m_{y0} + m_{yC} + m_y^{\bar{w}_y} \frac{w_y l}{V} + C_x \frac{\Delta z}{l}) + qSlm_M^a \frac{a\, l}{V} +$$

$$+P_T(d_z \cos e_z \sin e_y + x_T \cos e_z \sin e_y);$$

$$\dot{w}_z = \frac{1}{J_z}(J_{xy}(w_x^2 - w_y^2) + J_{xz}(\dot{w}_x - w_y w_z) + J_{yz}(\dot{w}_y + w_x w_z) + (J_x - J_y) w_x w_y +$$

$$+qSl(m_{z0} + m_{zC} + m_z^{\bar{w}_z} \frac{w_z l}{V} - C_x \frac{\Delta y}{l})$$

$$+P_T(x_T \sin e_z - d_y \cos e_z \sin e_y)$$

Kinematic equations of translational motion represented in coordinate form - the projections of the velocity vector on the earth axis system

$$\dot{X}_g = \frac{dX_g}{dt} = V_x A_{11} + V_y A_{21} + V_z A_{31} \tag{3}$$

$$\dot{Y}_g = \frac{dY_g}{dt} = V_x A_{12} + V_y A_{22} + V_z A_{32}$$

$$\dot{Z}_g = \frac{dZ_g}{dt} = V_x A_{13} + V_y A_{23} + V_z A_{33}$$

Kinematic equations of rotational motion are in the form of the Poisson equations:

$$\dot{A}_{11} = \frac{dA_{11}}{dt} = w_z A_{21} - w_y A_{31},\ \dot{A}_{12} = \frac{dA_{12}}{dt} = w_z A_{22} - w_y A_{32},\ \dot{A}_{13} = \frac{dA_{13}}{dt} = w_z A_{23} - w_y A_{33} \tag{4}$$

$$\dot{A}_{21} = \frac{dA_{21}}{dt} = w_x A_{31} - w_z A_{11},\ \dot{A}_{22} = \frac{dA_{22}}{dt} = w_x A_{32} - w_z A_{12},\ \dot{A}_{23} = \frac{dA_{23}}{dt} = w_x A_{33} - w_z A_{13}$$

$$\dot{A}_{31} = \frac{dA_{31}}{dt} = w_y A_{11} - w_x A_{21},\ \dot{A}_{32} = \frac{dA_{32}}{dt} = w_y A_{12} - w_x A_{22},\ \dot{A}_{33} = \frac{dA_{33}}{dt} = w_y A_{13} - w_x A_{23}$$

Constraint equations:

$\sin j_П = V_z/(V \cdot \sin a_П)$; $a_П = \arccos(V_x/(V)$; $M = V/a$; $m(t) = m_0 - \int_0^{t_k} \dot{m} \cdot dt$; $P = P(t)$; $J_z = J_z(t)$; (5)

$J_x = J_x(t)$; $\cos j_П = V_y/(V \cdot \sin a_П)$.

where: V_x, V_y, V_z, projection of the velocity vector of the aircraft's center mass on the body-fixed axes; w_x, w_y, w_z, the projections of the attitude rate of the aircraft on the body-fixed axes; C_x, C_y, C_z, the aerodynamic coefficients ADC – aerodynamic axial force, aerodynamic normal force and aerodynamic side force (forces projected on the body-fixed axes *OXYZ*); *S* – fuselage maximum cross-sectional area; *q* – ram-air flow; *l* – the length of the aircraft; the P_T

– projection of nominal thrust vector on the X – axis on the body-fixed axes; m_{yC}, m_{zC} aerodynamic coefficients of stabilizing yaw moment and of stabilizing yaw moment pitch; J_{xy}, J_{xz}, J_{yx}, J_{yz}, J_{zx}, J_{zy} - moments of inertia; $m_x^{\bar{w}_x}, m_y^{\bar{w}_y}, m_z^{\bar{w}_z}$ – the derivatives of aerodynamic coefficients of stabilizing yaw moment and of stabilizing yaw moment pitch on attitude rate; $\bar{w}_x, \bar{w}_y, \bar{w}_z$ – the dimensionless attitude rate; m_y^b – yaw moment due to sideslip; m_z^a – pitch moment due to angle-of-attack; A_{ij} – the matrix coefficients of the transition from the earth axis system to the body-fixed axes; $a_П$ – spatial angle of attack; $j_П$ – aerodynamic bank angle.

To research the influence of non-simultaneity opening stabilizer on the motion of the uncontrolled aircraft we will use mathematical model of (1) – (5). For example we are going to use hypothetical aircraft with constant mass and the inertia tensor and with the following parameters [2]:

size and mass-inertia parameter of the aircraft [2]:

$$l = 0{,}9\text{m};\ S=0{,}01131\text{m}^2;\ m=20\text{kg};\ J_x=0{,}041\text{kg}\cdot\text{m}^2;\ J_y= J_z=0{,}753\ \text{kg}\cdot\text{m}^2.$$

The initial condition of aircraft movement:

$$V_0=440\text{m/s};\ q_0=50°;\ Y_0=0°;\ x_{g0} = y_{g0} = z_{g0} = 0\ \text{m}$$
$$w_{x0} = w_{y0} = w_{z0} = 0\ \text{rad/s};\ q_0 =50°;\ y_0 = g_0 = 0°$$

For definition of a nominal trajectory mathematical model (1) – (5) was simulated without various asymmetries which arise at the launch of the uncontrolled aircraft.

According to the results of the calculation of the nominal trajectory, the following coordinates values of the nominal impact point $c_н$ ($x_{с.н.}$ $z_{с.н.}$):

– range deviations $x_{с.н.}$=7219 m;
– deviations in the lateral direction $z_{с.н.}$=17 m.

During the process of opening stabilizer three versions of changes in aerodynamic coefficients are considered (fig.1).

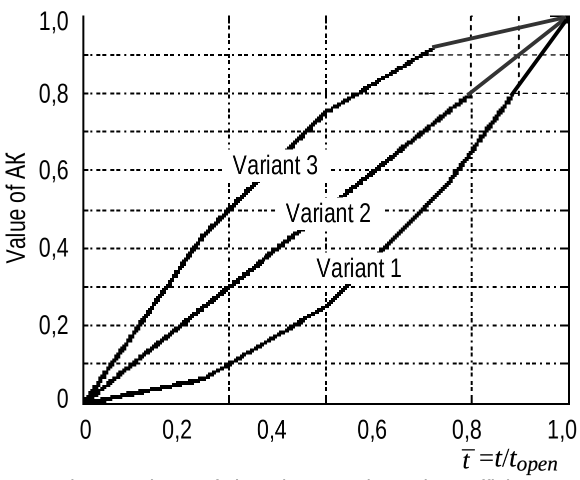

Fig.1. Variants of changing aerodynamic coefficients.

Use the below form:

$$A_K = A_{K_0} + (A_{K_p} - A_{K_0})C_{AK}$$

$C_{AK} = \bar{t}$ for variant 1;
$C_{AK} = \bar{t}^{\,2}$ for variant 2;
$C_{AK} = (2-\bar{t})\,\bar{t}$ for variant 3.

where: A_K – current value of aerodynamic coefficient; A_{K0} – value of aerodynamic coefficient after opening the stabilizer;
$\bar{t}$ – the dimensionless (relative) time during opening stabilizer of aircraft;
$\bar{t} = t/t_{open}$, $0 \le \bar{t} \le 1$, where t – time.

The decision of the general problem is divided into four particular solutions.

<u>The influence aerodynamic coefficient during the process of opening stabilizer (t_{open}=0.1s) on the deviation coordinates of impact point</u> are shown on the fig.2.

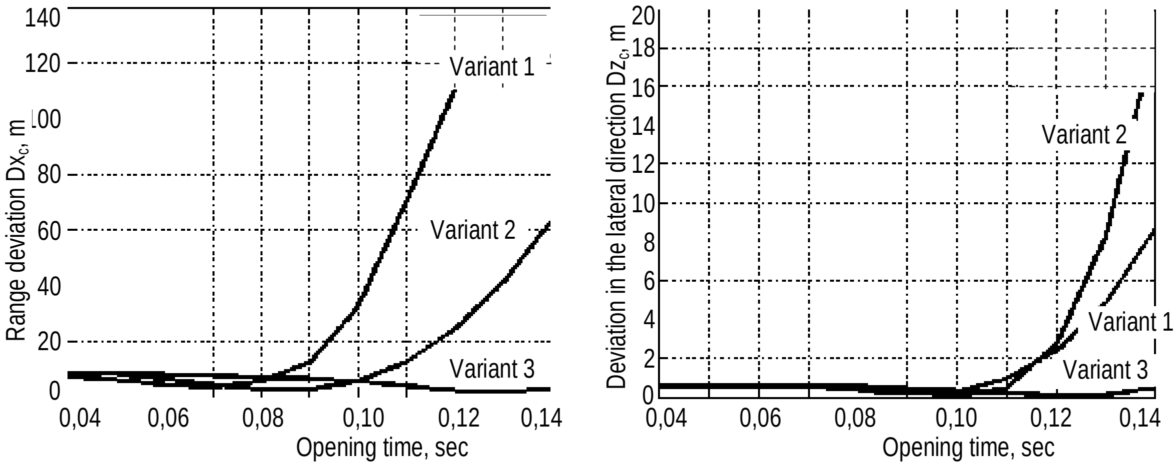

Fig. 2. The effect of changes in aerodynamic coefficients on the deviation coordinates of impact point

Examine the effect of small asymmetries during the process of opening stabilizer on the deviation coordinates of impact point (t_{open} =0.1s).

During the process of opening stabilizer three versions of changes in aerodynamic asymmetry are considered

$$m_y = m_{y0} + (m_{yp} - m_{y0})C_{AA}\,, \quad m_z = m_{z0} + (m_{zp} - m_{z0})C_{AA}$$

where:

m_y and m_z value of aerodynamic asymmetry during opening stabilizer;
m_{y0} and m_{z0} - value of aerodynamic asymmetry before opening stabilizer;
m_{yp} and m_{zp} - value of aerodynamic asymmetry after opening stabilizer

$C_{AA} = \overline{t}$ for variant 1; $C_{AA} = \overline{t}^{\,2}$ for variant 2; $C_{AA} = (2-\overline{t}\,)\,\overline{t}$ for variant 3.

Results of influence small asymmetries at the time of opening stabilizer (t_{open} =0.1s) on the deviation coordinates of impact point are shown on the fig.3.

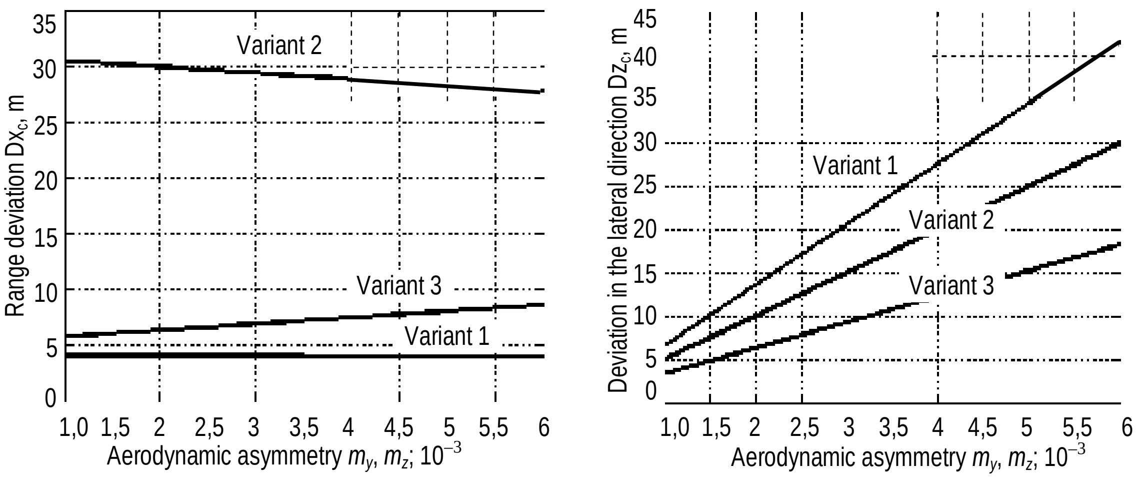

Fig. 3. The effect of changes in small asymmetries on the deviations in the lateral direction and of range deviations during the process of opening stabilizer

Examine the product of inertia during the process of opening stabilizer on the deviation coordinates of impact point.

Results of influence product of inertia at the time of opening stabilizer (t_{open} =0.1s) on the deviation coordinates of impact point are shown on the fig.4.

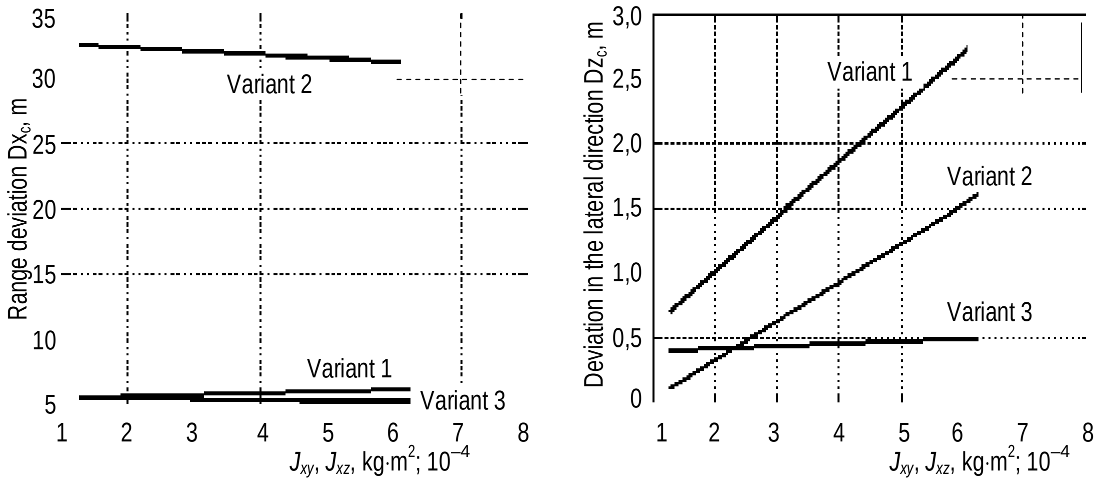

Fig.4. The effect of changes in product of inertia on the deviations in the lateral direction and of range deviations during the process of opening stabilizer

<u>Examine the position center of gravity</u> during the process of opening stabilizer on the deviation coordinates of impact point.

Results of influence position center of gravity at the time of opening stabilizer (t_{open} =0.1s) on the deviation coordinates of impact point are shown on the fig. 5

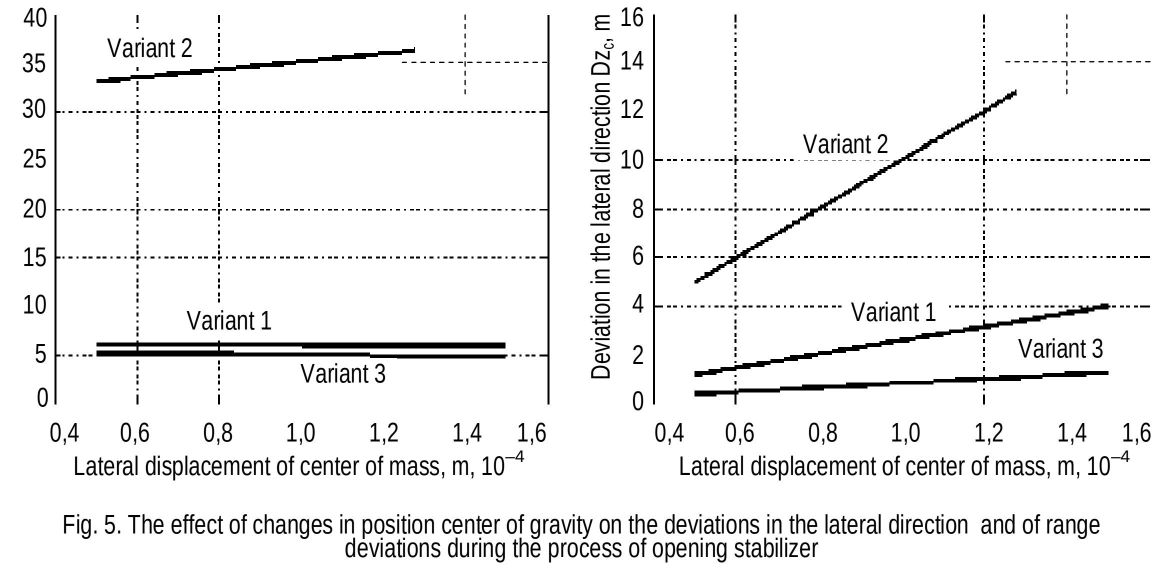

Fig. 5. The effect of changes in position center of gravity on the deviations in the lateral direction and of range deviations during the process of opening stabilizer

Conclusion

– At a variation of value of a total opening stabilizer t_{open} the deviation coordinates of impact point are changed. Also there is a limit time value of opening stabilizer $t_{open,\ lim}$ after which the influence of aerodynamic coefficient on the deviation coordinates of impact point increase sharp , in this example ($t_{open,\ lim}$ =0.1s), so in practice the time of opening stabilizer must not exceed $t_{open,\ lim}$, $t_{open} \leq t_{open,\ lim}$. The greatest change in the deviation coordinates of impact point are in the second variant of changing the aerodynamic coefficient.

- Considering the influence of the change in the aerodynamic asymmetries during opening stabilizer in relative value, it can be noted that the maximum value of the relative deviation in the lateral direction $\overline{\Delta}$ =3,2 and the relative value of the deviation in range $\overline{\Delta}$ =0,0045.
- The deviations of coordinates at change of position of the mass center and at change of the centrifugal moments are insignificant.

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For discussion

The Cosmology and our Universe
(premises and hypotheses)

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Our Universe is a local bubble in the timeless and boundless Universe of dark matter, a special Universe caused by a big bang, i.e., explosion of a black hole, destiny of the core of previous Universe. An ordinary Universe arises from the steady shrinking of superstrings that evolves into nested fractal sequences of depression that becomes nested fractal sequences of cosmological vortices. A special Universe starts as super…super depression due to a big bang. Once visible matter forms in it, it gets entangled in usual cosmological vortices around it that it draws in by gravity as it expands. From then on they share common evolutionary development differing only in scale and circumstances of birth. This paper highlights the birth of our Universe, the Cosmic Burst, and the dynamics of its evolution in common with a usual Universe down to its destiny, black holes [1-31].

1. The Cosmological landscape

Cosmology is an account of the origin, evolution and destiny of a Universe. Our analysis is based on the grand unified theory (GUT) [9]. The Universe of dark matter is boundless, by flux-low-pressure complementarity [6]. Since there is no evidence of its beginning or end it is also timeless and our Universe is a local "bubble" in it, a super…super galaxy, its dark halo 10^{10} light years across [13], its core (collected mass around the eye) a tightly packed cocoon shaped galaxy cluster 650 million light years across discovered by French astronomers in 1994 [12].Therefore, the nested fractal sequences of superstrings [9] that make up dark matter have no last terms that make them indestructible.

There are two kinds of Universes. An ordinary or usual Universe is due to the steady shrinking of superstrings, by energy conservation, that forms nested fractal sequences of depression, by uneven development [6, 9], and evolves to nested fractal sequences of cosmological vortices, by flux-low-pressure complementarity [6, 7]; its common first term is the Universe itself. From then on the nested fractal sequences go through galaxy clusters, galaxies, stars, planets and planetoids, moons and cosmic dust. Our Universe is special started by a rare colossal event, explosion of black hole called Big Bang; that black hole being the destiny of the core of a previous Universe. A big bang is an explosion caused by suitable sequence of hits on a black hole by cosmic waves that triggers the explosion. It creates a super…super depression that evolves to a super…super galaxy, a Universe, by flux-low-pressure complementarity.

There is optimal spread of nested fractal sequences of depression that forms an ordinary Universe. For our purposes the basic unit of a Universe is galaxy. Some galaxies have galaxies among their minor cosmological vortices. For example, the Milky Way has 11 among which is a dead one now the Sagittarius cloud of stars [13]. Another is Andromeda with 22 minor galaxies, all young.

Only a Universe launched by a big bang evolves to a super…super galaxy due to infusion of great energy by the explosion and a secondary but more powerful cosmic burst [10].

There is strong evidence that the Milky Way formed the usual way far from the Big Bang and was drawn into our Universe as the latter expanded to a super…super galaxy. Part of it is its being the oldest galaxy in its neighborhood. A young galaxy, e.g., spiral nebula, is bright with prominent spiral streamlines of minor vortices falling into its core due to gravity (suction by its eye) while the Milky Way is dim having faint spirals of falling minor vortices most of which already sucked by the main eye [13]. Another part of the evidence is our being able to see our young Universe (through Hubble) when it was only 3% of its present age. Still another is the discovery of stars in the Milky Way older than the Big Bang [21].

2. The birth of our Universe

The Big Bang started our Universe. In traditional cosmology the Big Bang is assumed to have occurred spontaneously with neither rhyme nor reason as if our Universe started with

spectacular violation of energy conservation. In fact, it was a natural phenomenon subject to the laws of nature.
The Big Bang created two physical systems: a super…super depression in dark matter and expanding spherical wave front at accelerated rate called Cosmic Sphere. During this period, $0 < t < 1.5$, the Cosmic Sphere was a compressed layer of dark matter trapped and pressed between the force of explosion and suction by the super…super depression, by flux-low-pressure complementarity, and pounded and agitated by less energetic shock waves (concentrated cosmic wave with enhanced latent energy) bouncing between its inner and outer boundaries. This agitation endowed the Cosmic Sphere and the superstrings in it with enormous latent energy. Compression kept them from conversion to prima; they remain semi-agitated superstrings. The more energetic shock waves pierced the Cosmic Sphere and converted dark to visible matter outside. The expanding Cosmic Sphere weakened and, combined with outward pressure from the compressed semi-agitated superstrings and pounding by the shock waves, burst at $t = 1.5$ billion years from the start of the Big Bang. We refer to it as Cosmic Burst or second big bang [19], more powerful than the Big Bang because of infusion of huge latent energy on the semi-agitated trapped superstrings.
The Cosmic Burst released the semi-agitated superstrings that initially converted to simple prima at very high temperature forming the first visible matter of our Universe. They formed the bright radioactive clusters called quasars that peaked at $t = 2.5$ billion years [28]. Dark viscosity reduced their kinetic energy and allowed formation of coupled prima such as proton, neutron and neutrino and light nucleons like hydrogen's that got entangled into usual cosmological vortices in the vicinity of the once Cosmic Sphere. This marks the birth of our Universe and its early galaxies. To use a biological analogy, the Big Bang was only the mitosis of the fertilized egg and the Cosmic Burst gave birth to our Universe. An ordinary Universe has no birth; it simply claims its place in the Cosmos gracefully.
The energy imparted by the Big Bang plus the accumulated latent energy on the trapped semi-agitated superstrings due to 1.5 billion years of agitation enhanced the power of the Cosmic Burst that added to the breadth and depth of this super…super depression. It sucked the cosmological vortices around it and formed the transitory phase of chaos [5]. By energy conservation, chaos gave way to its expansion and evolution into a super…super galaxy pulling cosmological vortices along the way by gravity. The super…super depression started as a local vortex but the micro component of turbulence at its core generated seismic waves that converted dark matter in and around it. It added instant momentum to its spin which was further enhanced by falling visible matter around it that also imparted more momentum raising the power of its spin even more and, enhanced by dark viscosity, extending its influence outward. As our Universe increased its spin it imparted greater centrifugal force on the galaxies, but suction by the eye balanced it and induced some galaxies to form elliptical orbits around the main eye. As its power rose further, centrifugal force surpassed gravitational suction and propelled or catapulted the galaxies outward. This explains its present accelerated radial expansion.
The galaxy clusters traversing our Universe [27] reveal the existence of more powerful Universe that catapulted them. Such a Universe could not have been formed the usual way. There are other evidences of the existence of another Universe such as the collision of galaxies coming from different directions [29]. Galaxies in our Universe travel along outward radial trajectories and cannot collide among themselves.
In any galaxy including a super…super galaxy there is another dynamics: as visible matter falls into its core, resonance with its dark component and flux-low-pressure complementarity pull dark matter with it and thins out the gravitational flux reducing dark viscosity and hence

suction by the eye on the minor vortices. Suction reaches its peak and declines resulting in an isolated vortex once again as it treks to its destiny leaving also the minor vortices on their own.

3. Internal motion of our Universe

A great surprise of the last century that haunts relativists was the discovery of the staggering rapid expansion of our Universe at accelerated rate [23]. Based on extensive direct measurement of the separation of galaxies from our vantage point Edwin Hubble formulated his law that expresses the rate of separation of a galaxy from us at distance s from the Earth:

$$ds/dt = rs \tag{1}$$

where $r = 7\times10^{-2}$/km distance of the receding galaxy from the Earth. For convenience, we measure distance S along a great circle in the spherical dark halo of our Universe. Then,

$$dS/dt = rS \tag{2}$$

Since the discovery of the rapid expansion of our Universe the estimate of its age has increased from the original 8 billion to the present 14.7 billion and there is talk of raising it to 20 billion. Each time an older star is discovered the estimate is adjusted to accommodate it. This star-chasing game is based on the wrong premise that only our Universe exists. In fact, there are others and the evidence is quite strong as we have just seen. Still another is the discovery of stars older than the Big Bang [21].

Therefore, we stick to the original estimate of 8 billion to solve (2) and find the radius r as a function of t. Since $dS/dt = 2pdr/dt$ and (2) is independent of the distance between us and the other galaxy it holds when $S = r$ (i.e., when the distance from the Earth is r). Then,

$$2pdr/dt = rr \quad \text{or} \quad dr/r = (r/2p)dt \tag{3}$$

Solving r, reckoning time from the Big Bang and taking light year and 1 billion years as units, we have,

$$r(t) = 10^{10}e^{(r/2p)(t-8)} \text{ light years,} \tag{4}$$

$$r'(t) = (\rho/2p)10^{10}e^{(r/2p)(t-8)} \text{ light years/billion years,}$$

$$r''(t) = (\rho/2p)^2 10^{10}e^{(r/2p)(t-8)} \text{ light years/(billion years)}^2$$

Using standard units we have, at $t = 8$,

$$r(8) = 3.2\times10^{22} \text{ km}, \quad r'(8) = 840 \text{ km/sec}, \quad r''(8) = 7\times10^{-2} \text{ km/sec}^2 \tag{7}$$

Since $r'' > 0$, our Universe is on the young phase of its cycle, its power of spin still rising. This acceleration is quite considerable and it will not take long for the outward flight of the galaxies to surpass the speed of light.

The value of r is based on direct observation and analysis of Doppler effect on the spectrum of light coming from a receding source. Now Encarta Premium has this: r = 260,000 km/hr/3.3 million light years, i.e., the receding galaxy is moving away from the Earth faster by 260,000 km/hr for every 3.3 million light years distance away from us, calculated based on the assumed age of our Universe of 14.7 billion years [3]. Does it make sense?

Using standard units and simplifying we get $r = 3\times10^{-19}$/km; inserting this in (3) we obtain, $r'(t) = 5\times10^{-14}$ km/sec, the supposed rate of radial expansion of our Universe and acceleration of 3×10^{-32} km/sec^2. They point to a static Universe that does not match present observation and measurement. Moreover, if these values are correct we would have been roasted by intense heat due to the steady formation of stars in the Cosmos, one per minute [1, 20, 26], and emergence of two baby galaxies discovered since 2004. On the contrary, the average temperature of the Cosmos remains steady.

4. Genesis, evolution and destiny of a galaxy

All galaxies are ordinary, i.e., they are the result of the natural shrinking of superstrings. However, we consider special galaxies that got their initial visible matter from Cosmic Burst. All galaxies including our Universe as super…super galaxy share common evolution and destiny. They only differ in the circumstances of birth. Thus, the predecessor of any galaxy is nested fractal regions of depression that evolve to nested fractal sequences of cosmological vortices. Its visible matter is mainly generated internally but augmented by visible matter formed from the cosmic burst of some Universe that got entangled with it as well as cosmic dust that routinely form in the Cosmos [1, 10]. As soon as nested fractal sequences of cosmological vortices form, dark to visible matter conversion begins due to agitation by its hot spinning core. Visible matter formed this way acquires instant mass and momentum that augment the core spin, mass and angular momentum. The high temperature of the core forms only prima and light nucleons like hydrogen's. Outward pressure from the hot core shoots them off through the cylindrical eye as jet outflow traveling as much as 75 times the speed of light [3].

Most galaxies have single core, by uneven development, with minor vortices around it that line up along spiral flux streamlines and fall into it due to gravity. They are prominent among young galaxies called spiral nebulae (in contrast to the old Milky Way). Andromeda has close double core [4].

Every vortex has an eye due to energy conservation; there would be much friction, collision and dissipation of energy without it. A cosmological vortex is a vortex flux of superstrings. A superstring has mass (but no weight, more precisely, has dark weight; mass defined by $F=ma$, acceleration a measured when known force is pushing it, e.g., cosmic wave). In quantum gravity the energy of the primal induced vortex flux of superstrings is a charge; in macro gravity it is gravity, suction by the eye of the gravitational flux or magnetic field of a cosmological vortex, a feature of quantum- macro gravity duality. Vortex spin is most powerful near the eye. Not only do the staggering spin and micro component of turbulence of the core agitate and convert the superstrings to prima, core spin also pulls visible matter in its vicinity into rotation around it due to dark viscosity and imparts centrifugal force on it. The more vigorous the spin the bigger the eye, since centrifugal force pushes its boundary outward, and the stronger its suction. Thus, any vortex in the Cosmos has an eye, a rarefied region of calm and de-agitation. Therefore, by flux-low-pressure complementarity, it sucks and accumulates visible matter around it. Thus, two opposite forces are at work on any mass around the eye from its immediate vicinity to the rim of the cosmological vortex: suction by the eye and centrifugal force on it directed outward. Calculation of inward flux pressure is provided by Newton's gravitation law. Around the eye is balance of vigorous spin, hence, strong centrifugal force against strong inward flux pressure so that minor vortices caught at this balance take elliptical orbits (elliptical due to radial oscillation). As spin increases, this balance extends outward and the vortex expands. At the height of its power peripheral stars may be catapulted out of its influence. There are such stars in the cosmos [3]. However, the countervailing dynamics that we have noted, i.e., the thinning out of the dark and visible halo, reduces dark viscosity and the impact of the core spin as well. Their limit of balance marks the summit or maximum power of the vortex. Then it declines, leaving minor vortices free and the core isolated. The same dynamics governs the genesis and evolution of galactic minor vortices. In other words, all the dynamics in the main cosmological vortices is replicated in the minor vortices.

Apparently, some stellar systems are so powerful that one has been found with a star at its core with stars as its minor vortices [3]. Our solar system is not quite as massive as that one since its minor vortices collect only planets and planetoids. At any rate, the solar system consists of nested fractal sequences of cosmological vortices with the Sun (as a cosmological vortex) as its common first term followed by the planets as minor vortices and, further on, the moons and cosmic dust. At the opposite tendency of fractal clustering is the formation of galaxy clusters behaving like ordinary galaxies but with galaxies as minor vortices, e.g., Milky Way and Andromeda [13].

In the ascendancy of any cosmological vortex towards its summit the more massive it is (i.e., having powerful core spin generating great kinetic energy and high temperature) the more gaseous (e.g., Jupiter, Uranus, Saturn, Neptune). It has a solid compact deep core, however, e.g., the Sun's, with specific gravity 150, due to its deep core's composition of compactly clustered pure prima and light nucleons, it is also compressed by gravity but a secondary factor. The Earth's inner core's specific gravity is also 150 verified during the earthquake by seismic waves that travel faster through denser material. Due to its high temperature – 6,000ºC – it cannot have complex atoms there, only pure prima and possibly light nucleons, like hydrogen's.

5. Populating a cosmological vortex

The core of a cosmological vortex is initially dark and isolated but the kinetic energy of its spin raises its temperature that agitates and converts the superstrings mainly to prima. Thus, its expansion and enhancement of visible matter come mainly from within. As turbulence, the core's micro component [5] generates seismic waves that augment conversion of dark to visible matter in it and its vicinity; in the former mainly simple prima, in the latter also simple prima that form atoms and cosmic dust that collect in the cores of micro vortices and get entangled in minor cosmological vortices. Converted visible matter in the core instantly gains momentum that augments core spin and angular momentum and, combined with momentum imparted by falling visible matter raises the power of spin, expands its influence outward by dark viscosity and pulls and catapults outlying cosmological vortices into rotating spiral streamlines of falling minor vortices. The same dynamics is replicated in the minor vortices at smaller scales. Cosmic dust in a cosmological vortex also emerges from what are called cosmic ripples which are energetic cosmic waves some of which gamma-ray bursts [26]. Then it gets entangled with cosmological vortices that collect at their cores as stars, planets, moons, etc. There are regions in the Cosmos called star nests that generate stars rapidly [20, 26]. This phenomenon of populating a cosmological vortex is dramatically illustrated by two baby galaxies discovered recently showing the spirals of visible matter just forming and falling into their cores. Once minor vortices form they become self-sustaining, i.e., they do what the main vortex does. The spinning matter around their eyes also generates seismic waves [9, 10] that convert visible matter within and around them.

The Earth's gravity was 67% of its present gravity 65 million years ago [14], which is roughly the same percentage of mass relative to its present mass. The increase in mass comes from agitation by the hot spinning core, the principal factor in the formation of visible matter within it so that the Earth becomes more massive over time. This is augmented by the impact of its micro component of turbulence and falling matter into it. Visible matter formation in and around the Earth's core exerts outward pressure on its mantel and forces magma to ooze out of the surface, fuel volcanic eruption and pile up mountains of lava along constructive tectonic plate boundaries under the oceans. The lava solidifies and becomes a part of the Earth's crust.

6. Vortex interaction

In any cosmological vortex a few lucky minor vortices that lie at the balance between suction by the eye and centrifugal force take their orbits around the eye along rotating spirals. In the solar system they are the planets and planetoids that orbit the Sun. The Sun is a minor vortex of the Milky Way and the Sun that we see is its core. In an average galaxy the minor vortices are the stars and in a planet - its moons, if any, and they are all minor vortices of Milky Way.
Consider any cosmological vortex. Since it rotates at great speed, greatest at the equator and 0 at the poles, centrifugal force throws visible matter outward at the equator. Then it becomes a thin disc of visible matter consisting of minor vortices and their cores and clouds of cosmic dust riding on the gravitational flux. They are thick and concentrated around the eye. The thin rim of a cosmological vortex is confirmed by the thin rings of Saturn as a tracer and the rings of other massive planets with powerful vortices that throw fine debris that forms these rings. The discular shape of a cosmological vortex is also seen in pictures of galaxies. The solar system is also discular with the planetary orbits along the solar equatorial plane. Mercury is the only planet that lies on its thicker portion just off the solar equatorial plane. This explains its perihelion shift of 1.67 seconds of an arc, i.e., the angle that the solar radius to its center forms with the solar equatorial plane. Although the dark halo is spherical, being unaffected by centrifugal force, resonance with the dark components of the visible halo along combined with flux-low-pressure complementarity leads to its greater concentration in the discular visible halo.
Flux compatibility and flux-low-pressure complementarity have direct bearing on vortex interaction. However, energy conservation and energy conservation equivalence are always at work in any interaction. Other natural laws are their consequences but are highlighted also because of the insights they provide in understanding natural phenomena. To this category belong oscillation universality, fractal, uneven development and resonance laws.
Spin determines interaction between cosmological vortices mediated by their gravitational fluxes by virtue of flux compatibility: two vortices of opposite spins are attractive through the common coherent induced flux at their rims along their equatorial planes; they are repulsive otherwise. If they have the same spin and their masses have the same order of magnitude, they evolve into binary vortices each revolving around the other and mutually riding on each other’s spiral flux; centrifugal force prevents them from falling into each other. If they have the same spin, regardless of their relative masses, they have mutual repulsion unless one is a giant compared to the other in which case the more massive one may gobble up the other by gravity. However, if one is large compared to the other and has opposite spin, the latter rides as a minor vortex or an eddy on the gravitational flux towards and merges smoothly with the core of the former unless the centrifugal force on the smaller vortex balances the main gravitational flux pressure, in which case it takes elliptical orbit around the main core. Otherwise, if centrifugal force on a suitably light minor vortex at the rim exceeds gravitational pull, it gets catapulted off the vortex’s influence. Elliptical orbit, being due to radial oscillation, is the most probable orbital configuration since perfect balance that yields circular orbit is unstable, by uneven development. A minor vortex along the main spiral streamline that spins opposite that of the main vortex either forms an elliptical orbit around it as an eddy or gets sucked into and is crushed by the core and becomes a part of it. As an eddy a vortex has relative autonomy. Two contiguous vortices of comparable masses with the same spin do not crash into each other due to mutual repulsion of opposite fluxes. Here, again, we see quantum-macro duality.
As in a game of chance, an even game is unlikely over a period of time. While a pair of vortices may have initially the same mass and vortex power, once one vortex gains advantage,

by uneven development, it builds up over time until it is more massive than the other. Then one becomes a minor vortex of the other. Thus, the most likely configuration of nested fractal sequences of vortices is one with a single large core vortex and many minor vortices of diverse masses along its rotating flux spirals. There are, of course, binary stars and that happens when the balance is attained at the tapering of their increase in mass.

Among the intriguing questions arising from this theory is the possibility of tampering natural object to break global flux coherence and quash its capability to exert gravitational pull on other objects. (Local flux coherence cannot be eliminated since every atom has it) Moreover, by flux-low-pressure complementarity, such tampering cannot shield objects from the gravitational pull of another. However, like the stealth bomber that breaks coherence of reflected radar beams to evade detection, a sufficiently tampered body, e.g., debris like asteroids, may lose global coherent fluxes that, while acted upon by gravity, may no longer exert gravitational pull or push on other bodies. They are bodies that have lost cosmological history. To verify, we use some natural laboratory: the asteroid belt along the orbital corridors of Jupiter, Neptune and Uranus [17, 32] (there should be asteroid belts also along the orbital corridors of the other powerful planets). The irregular shape of asteroids and the objects that form the planetary rings reveals lack of cosmological history, meaning, lack of coherent gravitational vortex flux; they are debris rather than matter collected at vortex cores. They do not form gravitational clusters either, that is, they do not exert gravitational pull or push among themselves and yet they have masses. This is a major verification of GUT that also serves as counterexamples to Newton’s law of gravitation.

Remember Galileo’s amazement about his own discovery that the rate of acceleration of a free-falling body above the Earth is constant regardless of mass? This question is enlightened by a simple experiment. In a water vortex, say, a sink full of water with objects of different weights floating on it; release the water through an orifice at the center-bottom of the sink. A vortex will form and the floats will be accelerated at the same rate along spirals towards the center-bottom. In Galileo’s experiments the bodies were falling into the Earth’s core along gravitational flux spirals. The rate of acceleration is specific to the cosmological vortex; thus, the Earth and the Moon have different rates of acceleration.

Recent study reveals that cosmic dust particles are oblong, confirming they have cosmological history, i.e., like a planet, a piece of cosmic dust is accumulated mass at the core of a micro vortex. Its axis of rotation is known to wobble like the Summer and Winter solstices. Like the Earth, it has crust and mantle. It is estimated that interstellar dust constitutes one thousandth of the Milky Way’s mass and hundreds of times more than the mass of the galaxy’s planets [1]. This means that cosmic dust is a significant factor in mass enhancement of a planet. Cosmic dust continues to form and collect into stars at the cores of stellar vortices. While our Universe is the first term of its nested fractal sequences as a super…super of galaxy, the last terms of its cosmological vortices are the cosmic dust. We append to it the molecules, atoms and superstrings to have the full stretch of our fractal Universe [13(b)] all the way from the super…super galaxy through dark matter.

The fractal-reverse-fractal algorithm [11] locates any vortex in our fractal Universe starting from any cosmological body including cosmic dust particle where one can trace a fractal sequence up into the macro scale (reverse-fractal) and end up in the super…super galaxy; or go down the sequence at the micro scale and end up at cosmic dust. Conventional science takes the view that these dust clouds formed during the last 1.5 billion years. GUT provides physical explanation of their existence and origin. Conversion to prima that form cosmic dust occurs anytime due to superstring agitation by cosmic waves, cosmic ripples and γ-ray bursts [26]. However, agitation by the high temperature at cosmological vortex core and micro component of turbulence are the principal generators of prima in and around its immediate neighborhood.

7. "Cannibalistic" activity of giant galaxies

In this neighborhood of our Universe we have two giant galaxies belonging to the Constellation Virgo. Andromeda, the brightest and farthest object that can be seen by the naked eye is 2.2 million light years from Milky Way, the other giant. This is an interesting combination because Andromeda is special but Milky Way is ordinary. Both are average giants and have similar features except that Andromeda is a young galaxy as shown by its numerous bright spiral streamlines of falling minor vortices.

Andromeda's visible discular halo is 200 million light years across, its mass equivalent to 3,500 billion Suns [4]. It has a double nucleus or core at the center. The discular halo of a galaxy is spherical since it is unaffected by centrifugal force. However, the visible halo within it is discular in shape due to centrifugal force, resonance and flux-low-pressure complementarity, thick at the center where visible matter collects due to suction by the eye but thin at the rim along the equatorial plane due to centrifugal force. Its profile (seen from its equatorial plane away from the rim) is sinusoidal of large even power comprised of two full sinusoidal arcs joined and tangent to each other at the ends and round but narrow at their crests. This profile is similar to the primum's [7], another feature of quantum-macro gravity duality. Two of Andromeda's 22 minor galaxies are at opposite sides of and near the rim of its visible discular halo and appear headed for gravitational gobbling [4].

Milky Way contains 400 billion stars including our Sun [4]. Its visible discular halo along its galactic equatorial plane is 100 million light years across, its core or metropolis 10 million light years thick [4]. Like Andromeda its dark halo has greater concentration in the visible discular halo due to centrifugal force, resonance and flux-low-pressure complementarity. Sagittarius, now a cloud of stars has been cannibalized by Milky Way that has gobbled some of its stars through the "saw-tooth" action by the rim of its visible halo that slices the Sagittarius' cloud of stars and throws them into a sector between the tangent and normal to the flux rim [13(a)].

8. The trek back home to dark matter

As soon as a galaxy reaches its peak of power and leaves its minor vortices free, each one treks home to its destiny back in dark matter along the same cosmological path. With the thinning of its dark and visible halo the contribution of visible matter falling into the core in augmenting its kinetic energy (includes all visible energy – heat, angular momentum, etc.) declines but mass, spin and angular momentum continue to rise because of dark-to-visible matter conversion that introduces instant momentum to the spinning core. However, the increase in mass absorbs and puts a break on kinetic energy and agitation and reduces the rate of dark-to-visible matter conversion and energy of spin inducing steady deterioration of the kinetic energy of the primal toroidal and vortex fluxes. This results in weakening of primal bonding leading to their separation as simple prima. By energy conservation, the prima collapse to semi-agitated superstrings over a long period of time. Both the prima and semi-agitated superstrings remain around the eye due to the latter's suction.

In a star, when a significant proportion of prima has collapsed to semi-agitated superstring the core becomes what has been called neutron star, a misnomer since there is no such thing. Rather, the core has lost energy, specially, the primal charge, that it has become neutral. Further de-agitation by the eye at its boundary pushes the semi-agitated superstrings to become non-agitated, layer by layer. The non-agitated superstrings join the black hole in the eye. Then the core of the once cosmological vortex has reached its grave and destiny, a black

hole back in dark matter. The black hole becomes naked and there is no longer suction but absence of visible matter that was sucked by its graveyard, the eye that nurtured it. Many such “voids” in the sky have been mapped and catalogued.
It is clear that in the entire history of any cosmological vortex its black hole being dark never sucks matter around it. It is the eye of the vortex that nurtures it that does. Each superstring completes a cycle: non-agitated → semi-agitated → primum (agitated superstring) → semi-agitated → non-agitated belonging to a black hole back in dark matter. The cycle may be cut short at any point when the first term of the nested fractal superstring breaks and its toroidal flux returns to dark matter.
In a galaxy the core transitions as a huge star. This was verified in 1997 with the discovery of a giant star, observed through the Hubble, 10 million times the mass of our Sun; more massive ones as much as 200 million times the Sun’s mass have been discovered since then. Each star has destiny: black hole in its eye [24, 28]. In a massive galaxy cluster or super…super galaxy the core evolves into galaxy clusters (as noted earlier the galaxy cluster at the core of our Universe is 650 million miles across), each galaxy evolving to its destiny as black holes [12]. This is the scenario of evolution of the core of our Universe.

9. Verification of GUT in the solar system

Explanation of natural phenomena by physical theory is part of its (theoretical) verification. Below is a sweeping verification of GUT in the solar system.
(1). The shielding effect of the Earth’s gravitational flux, by flux compatibility and momentum conservation, accounts for the rare hit by massive asteroids on the Earth (twice known) despite the millions of them that whiz by the Earth annually being close to the asteroid belt in Jupiter’s orbital corridor [17].
An approaching asteroid (along SEP) is pulled and deflected by the Earth’s gravitational flux as it enters the rim, by flux-low-pressure complementarity. If it misses the narrow injection angle of about 2 degrees [10], it will be tossed by its own momentum past the Earth and miss it completely. If it approaches the Earth’s gravitational flux on the other side at normal speed of at least 25,000 mph, it is deflected away, by flux compatibility.
There is a threshold of gravitational flux strength, beyond which the shielding effect fails. This is shown by the high frequency of asteroid hits on such powerful planets as Jupiter. In the 1990s asteroids from the tail of a dying comet landed on it and caused powerful earthquakes detected by seismographs on the Earth.
There is also a threshold in the other direction. When the gravitational flux is too weak, the cosmological vortex loses shielding effect. This is verified by the much poke-marked surface of the Moon. At the same time, light objects have less momentum and greater sensitivity to gravity which explains the meteor showers coming from tails of comets that hit the Earth frequently.
(2). The nested fractal structure of the solar system (Sun, planets, moons, etc.) confirms fractal universality as a natural law; it is conceivable that some large moons may have moons as minor vortices.
(3). Gaseous composition of large planets due to powerful spin (hence kinetic energy), e.g., Jupiter, Saturn, Uranus and Neptune.
(4). The diverse tilts of the planets relative to SEP points to the relative autonomy and independent bearing of minor vortices as eddies; another evidence is the opposite direction of four moons of Jupiter relative to the rest of its 63 moons; they are eddies embedded in Jupiter’s gravitational flux [14]; they belong to two different eddies one inside the other (double-layered vortex also appears in kitchen sink and toilet bowl).

(5). Pluto has the most elongated orbit among the planets that lies partly inside Neptune's and Uranus' orbits [15, 25]). It has all the qualifications of a planet as the core of its vortex or gravitational flux, a cosmological vortex as shown by its spherical shape and spin; it is a minor vortex of the Sun since it revolves around it (once in 88 Earth-years [15]) along with the huge asteroids and planetoids in its vicinity [15, 25, 32]. Where do we place the cut-off point between a planet and a planetoid? It looks like Pluto's disqualification has little scientific basis [25]. The shape of Pluto's orbit is quite significant because it reveals that at some point Pluto was close to the Sun but catapulted back by the latter's gravity into elongated orbit like the comets were. Another conclusion is that Pluto was a falling minor vortex of the Sun that just missed it but did not get close enough to sustain damage. In the evolution of a cosmological vortex the first to be saved from gobbling by the eye's suction are at the periphery of its gravitational flux; they are the latest to have their elliptical orbit around the core of the main vortex. This explains the abundance of planetoids far from the Sun. At the same time, minor vortices including planetoids close to the main core, i.e., the Sun, are the first to be gobbled up. That explains the absence of planetoids in our vicinity being close to the Sun.
(6). The discular shape of the visible solar halo along SEP where the planetary orbits lie and the planetary visible halo traced by the thin rings of Saturn, Uranus, Neptune and Jupiter [15]; it is likely that these rings were formed by collision debris that flew off the large planets by centrifugal force or tails of comets caught by the planets' gravity that formed orbits or a combination of both.
(7). The asteroid belt in Jupiter's orbital corridor and along Neptune's orbital corridor [17,32] and the planetary rings of the massive planets are major verification that bodies without cosmological history do not have gravity; they do not form gravitational cluster.
(8). The two-layered seismic waves generated by the turbulence of the spinning mass at the core of a cosmological vortex that convert dark to visible matter in this vortex are the same seismic waves generated at interface of turbulence on the Earth, e.g., tectonic plate boundary (graphics in [8]). They are known to soften metal and crack or pulverize concrete [10]. This also occurs at compressed layers of volcanic lava. They convert dark to visible matter as balls of fire around them. They hover over and around geological fault and volcanoes. Lightning (explosion) in the lower atmosphere also generates seismic waves that convert dark matter to earthlights, e.g., blue jets and gamma rays in the mesosphere [16].
(9). The tidal cycle reveals an error in both Relativistic and Newtonian physics. Both theories predict that it would be high tide when the Sun and the Moon are overhead presumably due to their combined gravitational pull on the ocean. This is not borne out by observation. In fact, it is low tide at this relative position of the Sun, the Earth and the Moon since they have the same spin and, therefore, the Earth's equatorial gravitational flux has opposite direction to that of the combined fluxes of the Sun's and Moon's fluxes on this side of the Moon. Consequently, they are repulsive and the Sun's and Moon's gravitational fluxes push the ocean down to a low tide. Incidentally rural fishermen can predict the occurrence of low tide during the lunar cycle based on the position of the Moon. They cannot be wrong here because their livelihood is linked to the abundance of fish trapped in ponds and springs on the ocean bed at low tide.
(10). Like water eddy, the hair spin at the cowlick on one's head is determined by the polar gravitational flux lag. Since the hair sticks out of the scalp at the cowlick, it is the tail end that spins around. In the North there is greater counterclockwise spin than clockwise; it is the reverse in the South. An informal survey reveals that in St. Petersburg 75% of the hair's tail end spin counterclockwise around the cowlick; it is about the same percentage of clockwise hair spin in Sydney.

(11). Informal survey also reveals 100% counterclockwise and clockwise spins at kitchen sink and toilet bowl in the two cities, respectively. When there are two kitchen sinks with connected bottom orifices joined into a single outlet pipe, they form vortices of opposite spins in accordance with flux compatibility. It can be expected, however, that the manner by which the outlet pipes are angled with respect to the vertical can affect the direction of vortex spin.

10. Celestial spectacle

Ultra-energetic cosmic waves

Cosmic rays of energy level as much as 10^{21} eV have been reported recently [18, 26]. Traditional theories require them to be heavy elementary particles, possibly protons, coming from outside a 100-million-light-year radius from the Earth. The estimate is based on supposed absence of possible source within that radius from the perspective of traditional theories. Acceleration of material object to great speed e.g., proton, is possible through centrifugal force imparted by the powerful spin of some galaxy. If some stars are catapulted, so are protons. However, charged particle encounters resistance in flight and neutron is too heavy to ride on a cosmic wave and cannot be sustained at great speed and at great distances by the natural vibration of dark matter. These energetic cosmic rays are not necessarily particles but cosmic waves that pack huge amount of latent energy through their fractal configuration. They are known to smash protons in the mesosphere (their debris of agitated superstrings fall on Earth) [18] that, incidentally, confirms our prediction that positive prima are pushed high up by the Earth's gravitational flux [10]. Such cosmic waves could have come from the cores of powerful galaxies. Then there are energetic gamma-ray bursts coming from distant regions of the Cosmos and some scientists theorize they are due to black hole explosion [26].

Jet outflow

Many interesting dynamics are displayed by galaxies and stars. Among the spectacular ones is jet outflow of hot gas or pure prima from the cores of nascent stars and galaxies [2]. Jet outflow was the first known case of matter speeding several times faster than light [3] (primal toroidal flux is another, its speed 7×10^{22} cm/sec [2]). How do we explain it?

The eye of a vortex is cylindrical and normal to the plane of its discular halo along the equatorial plane, much like that of the tornado or primum. The rapid spin of the core (pure prima) around the boundary of the eye (event horizon) builds up tremendous kinetic energy and accumulation of hot gas or prima that must find a soft spot to escape through and that is the eye itself. Thus, jet outflow pops out of both extremities of the eye of a young galaxy or star in opposite directions at great speed as much as 75 times the speed of light [3]. As the accumulated mass at the core cools down, the eye extremities suck the mass inward leaving spherical mass slightly flattened at the poles. This is quite evident on the Earth's flattened polar region (its curved rim seen at Lookout Restaurant near Sydney).

11. Clarification of issues and natural phenomena

Stability of our Universe

Traditional cosmology presents an unstable Universe of ours by assuming the anthropic principle. [12] GUT's qualitative model of our Universe presents a stable Universe that upholds energy conservation from the Big Bang through its destiny in dark matter. Moreover, dark matter is stable and serves as an absolute frame of reference that resolves Einstein's twin paradox.

A paradox no more

Originally referring to our Universe, Olber's paradox [12] says it cannot be infinite, otherwise, accumulated light coming from all directions would have fried us in intense light by now. Now moot since our Universe is finite, we broaden it to this question: can visible matter be infinite? There is no reason to rule this out. There are two possibilities: (a) visible matter is suitably dispersed that light reaching our Universe does not accumulate since it dissipates energy before reaching us or (b) light reaching the vicinity of our Universe is refracted away by its gravitational flux.

Transitory natural laws

Natural laws are revealed by natural phenomena. Before the Big Bang there was none; after the Big Bang, natural phenomena appeared with increasing complexity that revealed new natural laws. Now, new natural phenomena exist, e.g., biological phenomena, that reveal biological laws. They will all vanish as our Universe takes its trek home to its destiny as black holes back in the dark matter.

Point of no return

There are three speculations about our Universe (a) steady state, that it will remain as it is forever, (b) pulsating Universe, that it will eventually reverse its present expansion and head toward a big crunch that can be viewed as another big bang and start a new Universe and (c) forever expanding Universe. Obviously (a) does not describe the present state of our Universe, which is steadily expanding at accelerated rate. Item (b) violates energy conservation; it would require staggering amount of force to reverse the huge momentum created by 8 billion years of acceleration due to its centrifugal force of spin [20] and there is none of it now or over the horizon. The only other force in the direction of reversal is gravitational suction which can only diminish with the thinning of dark halo. Moreover, there is no evidence among the billions of galaxies that such reversal can happen. The most that can happen is weakening of the gravitational flux, in which case the galaxies will be on their own heading back to their destiny as black holes. This is exemplified at a smaller scale by the status of the Sagittarius cloud of stars. Most of them that are not gobbled by the Milky Way will trek back to their respective graveyards, their vortex eyes. With respect to (c) while galactic momentum may sustain the galaxies' outward flight, dark viscosity will catch up with and constrain them to a halt as they trek back to their destiny. At the same time, minor vortices still in orbit and others towards the periphery now freed from gravity will steadily fall and join the collected masses around their eyes, enter the transitional phase of de-agitation at the boundaries of their eyes and ultimately join the black holes in their graveyards, their eyes. This means that (c) is impossible. What will happen then? Our Universe will continue to expand, reach its peak and the core will lose influence on the minor vortices as dark halo thins out so that the minor vortices are left on their own, trek to their graveyards and join the black holes there.

Debris in the Cosmos

Debris includes comets, asteroids and meteors. A comet in the solar system is a vortex falling into the Sun that misses and gets catapulted back into an elongated orbit by the Sun's gravity. As it gets near the Sun, it is damaged by the Sun's intense gravitational flux, the fine debris forming the tail pushed away by solar radiation to the opposite side of the comet's head. Meteors and asteroids come mainly from tails of comets. Some asteroids and meteors may have been the result of planetary collision with wayward planetoids or collision among them. Planetoids may be dislodged from their orbit around the Sun when comets pass by due to flux-low-pressure complementarity. Then they may be pulled by the gravity of massive planets and cluster near or collide with them. Some debris from planetoidal collision gets attracted by massive planets and suspended in a neutral region, e.g., a region in the corridor between orbits of nearby planets where the Sun has dominant influence, e.g., Jupiter and Neptune [17, 32].

Supernova

The current understanding of supernova as explosion of star as part of its evolution is incorrect since cosmological vortices are stable. Moreover, a supernova is a rare phenomenon and does not quite match the fact that there are trillions upon trillions of stars in the Cosmos. Left alone, a star evolves towards higher order, a black hole in its eye. Therefore, the only plausible explanation is collision of two stars oblique to each other or of opposite spins that approach each other along their common equatorial plane. If they have the same spin they avoid each other, by flux compatibility. With opposite spins they attract and, by their momentum, the fluxes between their eyes merge smoothly at first until the rim of one goes past the eye of the other and their fluxes, being opposite, collide resulting in double explosion. Then the flux barrier between their eyes breaks and creates huge depression that violently sucks matter around causing more powerful third explosion. This phenomenon is dual to primum-anti-primum mutual destruction of quantum gravity. The triple explosion creates three expanding wave fronts that convert three rings of visible matter. Photographs of supernova show the three rings of visible matter on expanding shock waves corresponding to the three explosions [32].

Background radiation

It is believed that background radiation verified by the COBE project [30] is relic of the Big Bang. Whatever happened during the Big Bang was obliterated by ensuing events, e.g., Cosmic Burst [9]. Even our Universe’s present accelerated expansion has nothing to do with it, but is due to our Universe’s centrifugal force of spin that evolved over a long period of time as a part of the evolution of our Universe as super…super galaxy that throws the galaxies outward at staggering speed [6]. All cosmic waves including the so-called background radiation [30] are generated by atomic nuclear vibration [9], micro component of turbulence at the cores of cosmological vortices, explosions in the Cosmos such as supernova and possibly explosion of a black hole [18, 26].

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Academician Boris Nikolaevich Petrov

(to the 100th Birthday)

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Boris Nikolaevich Petrov is prominent Scientist in area of automatic control, USSR Academy of Science (1960), post-graduate of MEI (1939); Dept.Head of MAI (from 1950); Vice-President of USSR AS; Chair of Council on International collaboration in area of space research and Space exploration (USSR AS, “Intercosmos”), from 1966.

The basic works are related to the theory of automatic control, the invariance theory of automatic control systems, on self-adjusting control systems, on information problems of control theory, on automatic control systems for moving objects.

The results, obtained by B.N. Petrov in theory of automatic control for complex objects, have broad applications in rocket-space technique.

Boris Nikolaevich Petrov was born on the 11-th of March, 1913 in the town of Smolensk.

On finishing school in February, 1930, Boris Nikolaevich worked for some time as an accountant in a kolkhoz, and in fall he went to Moscow, where he was admitted to the Ordzhonikidze Factory and-Workshop School and became a turner.

In 1933, Boris Nikolaevich entered the Moscow Energy Institute.

Boris Nikolaevich studied at the institute splendidly. He drew up his diploma design under the guidance of his teacher – Academician Viktor Sergeevich Kulebakin. The diploma design was recognized as prominent.

In 1939, after graduating from the MEI with honors, Boris Nikolaevich was assigned to work, at the suggestion of V.S.Kulebakin, in the Committee of Remote Control and Automation of the Academy of Sciences of the USSR, on the basis of which the Institute of Automation and Remote Control was set up, which is now known as Trapeznikov Institute of Control Sciences. In this institute, B.N.Petrov worked his way up from engineer to academician, doing his duty in it until the last days of his life. In the hard years of the establishment of the institute, from 1947 to 1951, he was at the head of it.

The first works of the young scientist were devoted to automation of the process of the continuous casting of metal from an open-hearth furnace. When the Great Patriotic war broke out, Boris Nikolaevich began to tackle the problem of the automatic grading of products.

The scientific bases of the construction of automatic control devices were elucidated in the monograph written after the war by V.A.Trapeznikov, B.N.Petrov, I.E.Gorodetskii, and A.A.Fel'dbaum.

In the world scientific literature, it was the first work that generalized the achievements in the field of automatic control and geometric forms of mass production items.

In 1945, within six years after graduating at the MEI, Boris Nikolaevich maintained the thesis on the theme “Analysis of Automatic Duplicating Systems”, for which he was at once, granted the doctor's degree of engineering sciences.

Boris Nikolaevich developed the method of structural transformation of the designs of automatic systems and worked out an adequate body of mathematics – the algebra of structural diagrams.

Much later, just in the last years of his life, he returned again to these problems in the works written together with his disciples from the Ufa Aviation Institute.

Boris Nikolaevich carried out quite thorough investigations in the field of integration of nonlinear differential equations. The works in this field led to the discovery that outstanding

mathematician N.N.Luzin, who became the second teacher of Boris Nikolaevich, called the “phenomenon of B.N.Petrov”.
B.N.Petrov is one of the founders of invariance theory and also one of the organizers and ideological supervisors of the All-Union conferences on invariance theory. He set forth the necessary conditions of the physical feasibility of the conditions of absolute invariance. These conditions are now well known in the world literature as the Petrov principle of double channeling. The discovery of the double channeling principle had brought an end to the contentions as to the physical unrealizability of invariant systems and predetermined the further development of invariance theory.
Of much importance are the investigations of Boris Nikolaevich on the theory of nonlinear invariant time-lag systems and composite systems. The new types of automatic systems developed on the basis of this theory under his leadership and with his direct participation are implemented in industry.
In the investigations performed together with his disciples, B.N.Petrov opened up a new class of systems, namely, the systems of twofold invariance, derived the solution of the problem of invariance in the systems with varying structures, generalized the conditions of invariance for the case of statistically prescribed disturbances, and elaborated the ideas of double channeling in information and measuring devices.
In the works of Boris Nikolaevich and his disciples the theory of search-free self-adjusting systems was developed. The basic results of these works were generalized in the monograph of B.N.Petrov and his disciples “Principles of Construction and Design of Self-Adjusting Control Systems” (1972).
Under the leadership and with the participation of B.N.Petrov, self-adjusting control systems for the few classes of rockets of Chief Designer I.S.Seleznev were designed and built up in the USSR for the first time.
The further development of the theory of self-adjusting systems led to the theory of coordinate-parametric control. In the works devoted to this theory and in the monograph “Adaptive Coordinate-Parametric Control of Non-stationary Objects”, which B.N.Petrov saw only in proofs (it was published in 1980), studies are made of the principles of construction, the synthesis of algorithms for rearrangement of the parameters of an object, and the possibilities and perspectives of the development of systems of this class.
Boris Nikolaevich also headed the discipline involved with the information approach, which was a new line of investigations in control theory. He, his disciples and coworkers introduced the notion of a “distinguishability threshold” that provided the basis for the concept of a diversity of system states and the method of analysis of the quantum mechanical principle of uncertainty. The monographs “Information-Semantic Problems in the Processes of Control and Organization” (1977) and “Theory of Models in Control Processes” (1978), written by B.N.Petrov together with his coworkers, outline the information aspects and thermodynamic aspects of analysis of complex control systems.
The works of B.N.Petrov are widely known that deal with the non-stationary systems, the synthesis of algorithms for the observation of non-measurable coordinates of a system, and the algorithmic procedure of synthesis of controls of linear objects with arbitrary properties and with an incomplete degree of observability. Of much interest are his investigations on the synthesis of control algorithms as an inverse problem of dynamics.
In the 1950s, B.N.Petrov began to cooperate with S.P.Korolev and V.P.Glushko. Under the leadership of B.N.Petrov, in the Institute of Automation and Remote Control, investigations were undertaken for the first time in the USSR on the dynamics of liquid-propellant rocket engines.

The obtained basic results were considered at the meeting of the special committee of the USSR Academy of Sciences under the chairmanship of Academician M.V.Keldysh. The results received a high appraisal and later on served as a basis for the development of terminal control systems of the consumption of fuel in an effort to synchronize the discharge of tanks of the oxidant and fuel.

In the complete absence of the prototypes of similar systems, under the leadership and with the direct participation of B.N.Petrov, a start was made on the search for the control algorithms and the principles of construction of the given class of systems and also the principles of construction of measuring and actuating elements of a system. This work resulted in the creation of highly effective systems that were set up and are still set up on carrier rockets of Chief Designers S.P.Korolev, V.P.Glushko, M.K.Yangel, and V.N.Chelomei.

The fundamental results obtained in the course of development of the theory of control of fuel consumption were published in the monograph of B.N.Petrov and his learners “Vehicle-Borne Terminal Control Systems” issued in 1983, but after the death of B.N.Petrov.

B.N.Petrov was involved in creating a number of multiman piloted space ships, carrying out their launching, effecting the world's first walk in outer space of a man, developing automatic space stations, placing in a lunar orbit the world's first artificial satellite of the Moon, and actively participating in the formation of the shape of the space ship “Buran”.

B.N.Petrov, First Chairman of the Council “Interkosmos” at the USSR Academy of Sciences, took an active part in the organization of international space programs. One of the large programs was the project “Soyuz-Apollo”, at which the work was carried out by the collectives of scientists, engineers, and designers of the USSR and the USA. B.N.Petrov made a great personal contribution to the solution of numerous organizational, scientific, and engineering problems involved with this project.

B.N.Petrov obtained fundamental results for the progress of the domestic space engineering and he by right is one of the founders of home cosmonautics.

B.N.Petrov wrote about 200 scientific-popular papers on major scientific problems involving the development of automation, computer engineering, experiment automation, and programmed control of space exploration. He supported everything that was new and perspective in science and noted time and again the importance of development of the mathematical or abstract theory of systems, which, as he expressed himself, moves apart horizons of the science of control.

In 1953, B.N.Petrov was elected corresponding member of the USSR Academy of Sciences and in 1960, he was elected Academician.

Boris Nikolaevich was not only a great scientist, but also a prominent organizer of science.

From 1963, he was continuously the academician-secretary of the Department of Mechanics and Control Processes of the USSR Academy of Sciences and in 1979, he was elected Vice-President of the Academy.

Boris Nikolaevich was a gifted teacher. He began to carry out his pedagogical activities in 1944 at the Ordzhonikidze Moscow Aviation Institute at the faculty “Automatic Control and Stabilization of Airplanes”. From 1950 and up to the last days of his life, he headed this faculty, reformed later in to the faculty “Automatic Control Systems of Flying Vehicles”. The lectures of Boris Nikolaevich always found favor on the part of students. Owing to his constant and painstaking work, a highly skilled scientific-pedagogical collective body was made up at the faculty, and its curriculum became a model for many higher educational institutions of the country.

Under the leadership of B.N.Petrov, significant groups of specialists arose. He created a large scientific school that elaborates urgent issues of the modern theory of control. Many of his learners maintained theses, became known scientists and engineers, and are at the head of faculties and various scientific and industrial organizations.

The Soviet Government highly appraised great services of B.N.Petrov. He was given the rank of Hero of Socialist Labor, was reward with five Orders of Lenin, Orders of October Revolution, of the Red Banner of Labor, of the Red Star, and was awarded the Lenin Prize and State Prizes of the USSR.

His activity won wide international recognition. He was a member of the International Academy of Astronautics, a member of the Academies of Sciences of Hungary, Bulgaria, and Poland, was awarded a number of foreign orders, Gold Medal of the International Center of Space Investigations of France.

Concluding the story on the life and activities of B.N.Petrov, it would be desirable to say the following. Boris Nikolaevich was well-liked by his learners, his associates, his elder partners, and his teachers. He was treated with much warmth by Viktor Sergeevich Kulebakin and Nikolai Nikolaevich Luzin, in whose houses Petrov and the members of his family were always, desired guests.

Luzin's letter on the 23-rd of August, 1949 remained, in which he write to Boris Nikolaevich: “Not receiving from you any news for so long a time, I already began to think that the administrative life (B.N.Petrov headed at that time the staff of the Institute of Automation and Remote Control) carried you away from the scientific deepening and sincerely felt pity for you because administration dries up people and makes them old beyond their years, whereas the scientific and the artistic work rejuvenate. But you are young!” N.N.Luzin, the teacher of Boris Nikolaevich, feared that his favorite, gifted learner would with raw from pure science and that 1 worried him. But his misgivings were purposeless. Boris Nikolaevich was both a great organizer of science and a prominent researcher, and so the “administrative life” by no means diverted him from the “scientific deepening”, which was what N.N.Luzin so feared.

All that Boris Nikolaevich achieved, he achieved owing to his large labor. Boris Nikolaevich worked very much, liked to work, and took a pleasure in the work. He was a thoroughly educated person. He excellently knew literature and art. At the rest-time, he liked to paint, and his pictures were splendid for an amateur painter.

Being the excellent family man, Boris Nikolaevich treated with a high tenderness his wife Irina Anatol'evna, who was his faithful friend and companion of the life.

Boris Nikolaevich was the outstanding scientist, the true son of his Motherland, the unusually kind man, the man of a high emotional purity and charm.

Boris Nikolaevich died on the 23-rd of August, 1980.

Vladislav Yu.Rutkovskiy, Dr. Sci.(Eng.), Professor, Head of Laboratory of the V.A.Trapeznikov Institute of Control Sciences of RAS. The main of scientific interest domain: the theory of nonlinear non-stationary objects and its application to aircraft and spacecraft control.

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Congratulations!

75 *Gennadiy Lukich Degtyarev*

(on the occasion of the 75th birthday)

Gennadiy Lukich Degtyarev, Distinguished Professor of KAI, Head of Automatics and Control Department of KNRTU-KAI, Russian Government Prize Laureate in the field of science and engineering, Honored Scientist of the Russian Federation, member of the Academy of Sciences of Tatarstan Republic, turned 75 on 27 January 2013.

G.L.Degtyarev is a well-known scientist specializing in optimal control, mathematical simulation, development of spacecraft control algorithms allowing for elasticity, and development of theory of adaptive optical systems.

Endowed with a talent for organization and being a patriot of Russian basic engineering science, he actively promotes careful attitude towards traditions and augmentation of profound traditions laid by the founder of Kazan Aviation Institute N.G.Chetaev, successor of A.M.Lyapunov – an outstanding developer of the theory of motion stability.

G.L.Degtyarev chaired KAI in 1987 in the capacity of a Rector; since 2007 he has been the University President. He provided intensive development of Kazan Aviation Institute (at present – A.N.Tupolev Kazan National Research Technical University). Under Degtyarev's personal supervision and with his active participation the ideas and concepts of development of KAI as a university have been implemented keeping the spirit and letter of the top-ranking National educational engineering schools, which is of primary importance for a higher school specializing in aviation.

Being an idea hamster with a foresight, scientific and engineering flair, understanding of prospects and important trends of development of Russian science and engineering education on the whole, Gennadiy Lukich has contributed much to the development of new educational technologies with effective cooperation with industrial institutions and plants of the main industrial complexes.

G.L.Degtyarev is an Editor-in-Chief of scientific and engineering journal "Vestnik KGTU im.A.N.Tupoleva" ("KSTU Bulletin"); Honorary Editor of the International editorial committee of the Russian-American scientific bilingual journal "Actual problems of aviation and aerospace systems"; Editor-in-Chief of the international scientific bilingual journal "Problems of nonlinear analysis in engineering systems".

Best wishes to our dear Gennadiy Lukich!
Editorial Committee wishes every happiness, health, success and vigorous activity!

"Stability in all things big and small according to A.M.Lyapunov under all permanent perturbations"!

From all the members of Editorial Committee
of the International scientific edition
January 2013

About corrections in article

In editorial committee the letter from authors of article is received with the request to make corrections in published article (V.G.Degtyar, V.V.Chekanin. Analysis of design methods accuracy of stability for stiffened conical shells. RAJ «Actual problems of aviation and aerospace systems: processes, models, experiment», No.2 (35), v.17, 2012):

«Please, … to assist in elimination of mistakes in the text of article …:

In Russian variant on p. 40, 41, 42, in an English variant on p. 51, 52
«with parameter Y that is less 0,8» or «with parameter Y more than 0,8»
it is necessary to change on -
«with parameter Y less than 8» or «with parameter Y more than 8».

Authors V.G.Degtyar, V.V.Chekanin … »

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