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ACTUAL PROBLEMS OF AVIATION AND AEROSPACE SYSTEMS
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ACTUAL PROBLEMS OF AVIATION AND AEROSPACE SYSTEMS
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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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Authors of theoretical works have to show the possible areas of applications in engineering practice.
The languages of publications are RUSSIAN, ENGLISH.

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ACTUAL PROBLEMS OF AVIATION AND AEROSPACE SYSTEMS

Kazan Daytona Beach

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(38), Vol.19, 2014*, is another special issue devoted to the greatest events of the history of Mankind associated with Aviation and Cosmonautics, with the beginning of Space exploration Era.

This Era 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, V.F.Utkin, G.N.Babakin,V.P.Makeev,.…
… – are the subject of special scientific research.

It was the fundamental 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 by 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 was celebrating its 80th Anniversary in 2012 year), 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 fundamental and applied domains 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 Engineering School (**P.L.Chebyshev – A.M.Lyapunov– N.G.Chetaev- …**).

The special issues are devoted to the 120-th Anniversary of General Designer ,Academician *S.V.Iljuschin*; 80-th Anniversary of First Cosmonaut of Earth planet *Yu.A.Gagarin*.

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, scientific meditations about Mankind Evolution, 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.

Our Partners on special issues:
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, Concern "TsNII "Electropribor".

Our authors are well-known 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.

S.K.Krikalev, B.I.Kryuchkov, A.A.Kuritsyn, M.M.Kharlamov ("Gagarin Research&Test Cosmonaut Training Center", Russia), specialists in the field of modeling cosmonaut training process; designing and operation of automatic control systems as applied to cosmonaut training on simulators and stands; – with investigation of models and methods on studying human capabilities and ways to ensure the high performance and effective activity of a man in deep space.

M.V.Levskii (Research Institute of Space systems, Khrunichev State scientific-and-production Space Center), specialist in the domain of control theory, automatic control systems and devices, – with author's results on investigation of spatial turn regime of multimodular space station.

Wang Zhijin, Huang Sheng, Shen LvBing, Zhou HuaZhi, Zhi Jiaoyang, A.S.Kretov (Nanjing university of aeronautics and astronautics, Kazan National Research Technical University named after A.N.Tupolev; China, Russia), specialists in domain of designing of flying vehicles and composite materials, – with discussion of statements and results in conceptual design of multi-purpose aerospace plane.

B.Ya.Lokshin, Yu.M.Okunev, V.A.Samsonov (M.V.Lomonosov Moscow State University, Russia), the specialists in area of problems of motion of bodies in force fields of various nature, – with results on problem, connected with modelling bolides flight in Earth atmosphere. It is considered on example of study of the dynamics of a non-homogeneous solid ball in medium with resistance.

Emilio Spedicato (University of Bergamo, Italy), the specialist in the field of Operations Research, – with analytical survey on methods of modelling in a problem of interaction of large space object with the Earth, including multidisciplinary processes of capture of a body by the Earth, dynamics of a body and the Earth, geodynamics, dynamics of Earth atmosphere, dynamics of oceanic masses, … and the subsequent evolution of a human society on the Earth.

V.D.Denisov ("Salyut" DB M.V.Khrunichev SRPSC, Russia), the specialist in the field of designing the piloted space complexes, – with discussion of problems and prospects of expeditionary space complex of new generation.

Scientific-and-information section

A.Ye.Shakhanov, E.V.Zamkovaya (Lavochkin Association, Russia), specialists in area of general problems of Spacecraft design, communication systems, – with analytical, scientific-information survey on Section 18 of G.N.Babakin name "Automatic spacecraft for planetary and astrophysics researches. Engineering, design, tests and calculation". It was organized in framework of XXXVIII Academic Conference on Cosmonautics.

Before the launch Yu.A.Gagarin wrote in his letter (10.04.1961):
"... I'd like ... to devote this flight to the people of new Society, ..., to our great Motherland, to our Science".

Yuri Gagarin

The first Person of the Planet Earth who performed a Space flight

80-th Anniversary of Yu.Gagarin's birth
(09.03.1934-27.03.1968)

Manned flights to Mars: prospects and results with participating the ISS crews

S.K.Krikalev, B.I.Kryuchkov, A.A.Kuritsyn, M.M.Kharlamov
State organization "Gagarin Research&Test Cosmonaut Training Center"
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Mars is one of the most promising planets which a human dreams of. Gagarin R&T CTC carries out the extraordinary experiments on studying human capabilities and ways to ensure the high performance and effective activity of a man in deep space. The ISS crewmembers participate in those experiments a day after landing.

1. Introduction

From the very beginning of manned spaceflight in 1961, missions of a man to space have become the most impressive kind of human activity. Political background of the first manned flights to space and the "cold war" led in 1960s and 1970s to a large-scale competition in space and to the race for the first place on the Moon between the two superpowers of the time – the Soviet Union and the United States. USA accomplished the landing of its astronauts on the lunar surface as early as 1969 within the framework of the "Apollo" program. However, during the several following years this exploration breakthrough has lost its dynamism and now human activity in space does not go beyond low Earth orbit with programs limited to spaceflight of transport vehicles and space stations. This turn of events was accompanied with an important change: international cooperation instead of competition has become the main political basis when realizing manned programs, what eventually led to the creation of the International Space Station by joint efforts of major partners (Soviet Union/Russia, U.S., Europe, Canada, and Japan.

Now that the ISS already exists and successfully operates the new question arises: what next? Should it be a continuation, possibly with a broader international base, of current human activities in LEO, focused on sciences in microgravity? Or would it be possible to resume an exploration activity at a higher level, but to do this on the basis of international cooperation which has proved its successfulness?

Apparently, XXI century will be the century of a manned flight to Mars. For the present such mission seems very problematic both in terms of technological potentials and of human capabilities [1-4]. The other problem is financing such a costly project. An estimated cost of the Martian project provided in various sources is astronomical. Therefore, a manned mission to Mars will most likely be implemented on the basis of international collaboration. Surely, the international project could ensure much more effective integration of scientific and technological potentials of the partner countries. To date, significant achievements in exploration of Mars have been made with the help of unmanned facilities. Scientific results obtained by automatic space probes and rovers on the planet surface have confirmed the great prospects of colonization of Mars.

In fact, various countries have already begun preparations for a manned mission to Mars by laying the necessary scientific and technological groundwork. Much of the research is aimed at ensuring the technical feasibility of the project.

Different concepts of manned mission to Mars are being developed. Mainly they differ by the structure and layout of the habitat complex, by the choice of the flight route, by rationale of the reliability of a launch vehicle, an expeditionary complex and launch/descent vehicles as well as by the kind of the propulsion system, schemes of deployment, ballistic rationale, etc. One of the distinctive characteristics of the expeditionary complex is its weight which can reach 1500 tons when starting from Earth orbit. About 850 tons of propellant is needed to accelerate the complex. Various options of launch vehicles for those purposes and also the feasibility to reduce the launching weight of the complex by means of double aerodynamic braking in the Martian atmosphere to go into the Martian orbit (ESA project), etc. are being studied [1]

Far less attention is paid to the study of human capabilities in such ultra-long-range and super long spaceflight. Some biomedical and psychological problems have been investigated in the course of missions aboard the orbital stations Salyut, Mir, ISS and in experiments under Mars-500 project. However, many issues remain unsolved.

One of the major concerns relates to the assessment of crew performance and ability to perform complex operator activity both during long-duration transit flight to Mars and on the planet. The problem becomes particularly acute because of the high autonomy level of the Martian mission, which is characterized by the absence of operative communication with the Earth and inability to return quickly on the ground as distinct from space missions in low-Earth orbit. The distance between the Earth and Mars varies from 50 to 400 million km, communication delay – from 8 to 40 minutes, and flight time to Mars and back is estimated at 2.5-3 years.

Russia has accumulated wide experience in accomplishing long-term missions aboard the orbital stations.

Salyut – 7 211 days	Berezovoy A.N., Lebedev V.V. May 14 – February 12, 1982
Salyut – 7 237 days	Kizim L.D., Solovyov V.A., At'kov O.Yu. February 7 – October 2, 1984
Mir 326 days	Romanenko Yu.V. February 5 – December 29, 1987
Mir 365 days	Titov V.G., Manarov M.Kh. December 21, 1987 – December 21, 1988
Mir 311 days	Krikalev S.K. May 11, 1991 – March 25, 1992
Mir 437 days	Polyakov V.V. January 8, 1994 – March 22, 1995
Mir 379 days	Avdeev S.V. August 13, 1998 – August 28, 1999

211-day and 237-day manned missions were performed on the orbital station Salyut-7. Five manned missions of about a year each were performed on the orbital station Mir. We have obtained a considerable amount of data which may be used to prepare long-term expeditions into deep space.

2. Providing human performance ability during spaceflight to Mars

According to the Study Group (SG 3.16), which has been set up by the International Academy of Astronautics (IAA) for researches connected with implementation of a manned mission to Mars, the main stressors, which affect human activity during spaceflight to Mars and back are: low gravity, radiation, psychological and sociocultural factors. These stressors, in turn, affect human physiology, cognition, and individual and crew psychosocial status. [2].

<u>Physiological issues due to low gravitation</u>

Many, but not all, of the human physiological responses to spaceflight are functions of "g-transitions" and occur during and after dynamic phases of flight in which acceleration loads are presented acutely and static gravity levels are changed chronically. Thus, we expect sensorimotor function to change most quickly during these dynamic flight phases and to reach homeostasis within a few days or a week. Muscle mass and bone integrity respond to changes in the physical workload associated with gravity levels but very slowly, over periods up to months (decrements in weightlessness may be obviated by rigorous physical exercise, as is being currently demonstrated on the ISS). The relatively low Martian surface gravity should not pose the same threat of orthostatic intolerance or bone fracture as ISS astronauts experience on returning to Earth. Unfortunately, it cannot be assumed that this low gravity will be useful in reversing the losses of sensorimotor, cardiovascular and musculoskeletal capacity that occurred in transit.

Physiological issues due to radiation.

The radiation can cause acute and chronic health effects in biological systems depending on: the magnitude of the radiation absorbed the species of the radiation, the dose rate, the tissues affected, and the individual irradiated. These potentially occur at any cycle phase and cannot presently be predicted.

The effects of microgravity.

It is presently considered that biological results obtained under terrestrial conditions cannot be truly representative of what occurs in the space environment. In this regard, a variety of fluid redistribution effects and hormonal responses occur in microgravity which may influence cellular damage induction and repair systems.

The effects of space travel on cognition.

To the dangerous physical factors of spaceflight we have to add the special environmental characteristics of a spaceship for a mission of this kind including: isolation, noise, air, space limitation, etc. Experience of flying aboard the ISS and “Mir” orbital complex has shown that various psychomotor and neurocognitive functions are degraded during spaceflight, among them central postural functions, the speed and accuracy of aimed movements, internal timekeeping, attentional processes, limb position sense and the central management of concurrent tasks.

Physiological and sociocultural issues.

There have been several research studies involving astronauts and cosmonauts that have given us information about important psychological, interpersonal, and sociocultural issues that affect space crewmembers. There was significant evidence for the displacement of tension and negative emotions from the crewmembers to mission control personnel. The support role of the leader was significantly and positively related to group cohesion among crewmembers. A number of psycho-physiological problems have been reported during on-orbit space missions. Most common are adjustment reactions to the novelty of space. These largely consist of transient anxiety or depression. Psychosomatic reactions also have been reported. Asthenization, a syndrome consisting of fatigue, irritability, emotional susceptibility, and attention and concentration difficulties, have been reported to occur commonly in cosmonauts by Russian flight surgeons.

3. Post-flight investigation with the participation of the ISS crews

Currently the flight duration of the ISS primary expeditions is about six months, so it is comparable with the duration of the flight to Mars. During the flight aboard the ISS the crew implements the timeline and performs operations similar to the operations on the Mars expeditionary complex. Thus, after six-month stay on the ISS, the cosmonauts’ physical, functional and psycho-physiological status is similar to the status of the cosmonauts who has arrived to Mars. All this gives grounds to study the ISS crew members’ ability to implement complex operator activity after a long-term flight, to make forecasts and to generate instructions for the similar activity on Mars on the basis of the obtained results. *Such technologies for the study of human performance and abilities after a long-term flight are new and have not been yet applied.*

In order to implement proposed studies, the State Organization "Gagarin Research&Test Cosmonaut Training Centre" has developed the concept and the model of post-flight investigation with the participation of the ISS crew members immediately after their spaceflight.

The aims of these experimental researches are the assessment of cosmonauts' ability to perform complex operator activity immediately after a long-term spaceflight under the conditions of low gravity and G-loads and obtaining information of quality of this activity.

The important tasks of operator activity, which will be specific for the missions to Mars, are control of spacecraft dynamic modes and control of cosmonauts' activity on the surface of the planet. These tasks, in particular, include: manually controlled descent, extra vehicular activity (EVA), operations with complex engineering systems on the planet's surface.

Exactly these tasks were included in the primary post-flight experiments with the ISS cosmonauts' participation.

The aims of the experiments were:

1. Assessment of cosmonaut capabilities to perform manually controlled descent under the effect of simulated g-loads after a six-month transit flight.

2. Assessment of cosmonaut capabilities to move and to carry out routine EVA operations in spacesuits (in a vertical position in a gravity offload system) under simulated Martian conditions.

The experiments are carried out concurrently with the ISS crews' post-flight rehabilitation process.

The basic structural elements of the model include (fig. 1):

– preflight baseline experiments;
– long-term mission and returning to earth;
– crew arrival to the rehabilitation and experimental base (the CTC);
– experiments on manually controlled descent of a manned transport spacecraft on the dedicated stand under simulated overloads;
– experiments with cosmonauts in EVA spacesuits under simulated Martian conditions.

Fig.1. Structure and sequence of post-flight experiments

The sequence and time of the experiments accord with the potential schedule of flight to Mars and EVAs on its surface. These structural elements characterize only the first step of investigation. Subsequently they will be amended and supplemented depending on given tasks.

4. Experiments on manual descent control of a manned transport vehicle

Commonly, the sequence of lunar exploration under the Apollo program is accepted as an analogy for exploration of Mars. Initially, Apollo 8 and Apollo 10 performed a flyby and an orbital flight of the Moon, respectively. Only after successful implementation of those two missions Apollo 11 took off from the Earth to perform its historical flight to the Moon. A man stepped on the lunar surface.

However, such scheme of missions to Mars is irrational because of the large remoteness from the Earth and the huge cost of the project. It would be more effective if cosmonauts perform landing and exit on the Martian surface already in the first mission.

Any manned spacecraft is designed with two loops of landing system. A cosmonaut should be able to perform manual descent and landing if an automatic mode fails. However, in this case a reasonable question arises: can a cosmonaut ensure the required accuracy and safety when controlling manually the descent operations after long-duration transit flight? Various theoretical models of the manually controlled descent give quite remote idea of reality as they do not allow to take into account many factors affecting a crew in long-duration spaceflight.

Gagarin R&T CTC has developed and carried out a full-scale experiment on the assessment of capabilities of a cosmonaut to control landing on Mars manually using the centrifuge TsF-18 (figure 2). Computer-assisted simulation of MCD (manually controlled descent) using a model of the descent control handle is provided in a cabin of the centrifuge. The workplace of a cosmonaut (a couch and MCD equipment) is located inside a cabin of the TsF-18, having a radius of rotation of 18 meters. Electric motors allow positioning the cabin in any given direction of the sum vector of *g*-loads. The centrifuge is equipped with controlling and measuring instrumentations and recording equipment to measure and record technical and physiological parameters (figure 3).

Fig. 2. Centrifuge TsF-18

Fig. 3. Control console of the centrifuge TsF-18

MCD loop of the Soyuz-type spacecraft was used as a manual control loop. The Martian working conditions were simulated by the following:

a) Crews of ISS-33/34, ISS-34/35, ISS-35/36, ISS-36/37 worked as the Martian crews after the end of their orbital flights of 143, 145, 166, and 166 days, respectively, what is comparable with the duration of transit flight from Earth to Mars;

b) The experiment was carried out in 32-34 hours after landing – the time which is comparable with the time of staying in Martian orbit before the descent and landing on the planet;

c) The structure and content of MCD operations performed by cosmonauts were analogous to the control operations during the descent phase (handling the controls, monitoring the passage of commands, forecasting the descent trajectory, etc.);

d) Cosmonauts worked autonomously, i.e. without the support from the MCC;

e) G-loads did not exceed 3 g what corresponds to conditions of descent and landing of manned spacecraft on Mars.

Three MCD modes were used for the first two crews (ISS-33/34, ISS-34/35), namely: mode 1 (static, without the centrifuge rotation), mode 2 (dynamic, with the centrifuge rotation), and mode 3 (static). Two modes (2 and 3, dynamic and static, respectively) were used for the ISS-35/36 and 36/37 crews.

The objective of the experiment was to estimate the overload values n_x and the distance L_x of landing of a crewed module that depend on the correctness and accuracy of commands issued by a cosmonaut (fig.4). The different initial conditions of entering the atmosphere of the planet were set in modes 1, 2, 3 for each cosmonaut what exactly corresponds to conditions of the preflight experiments.

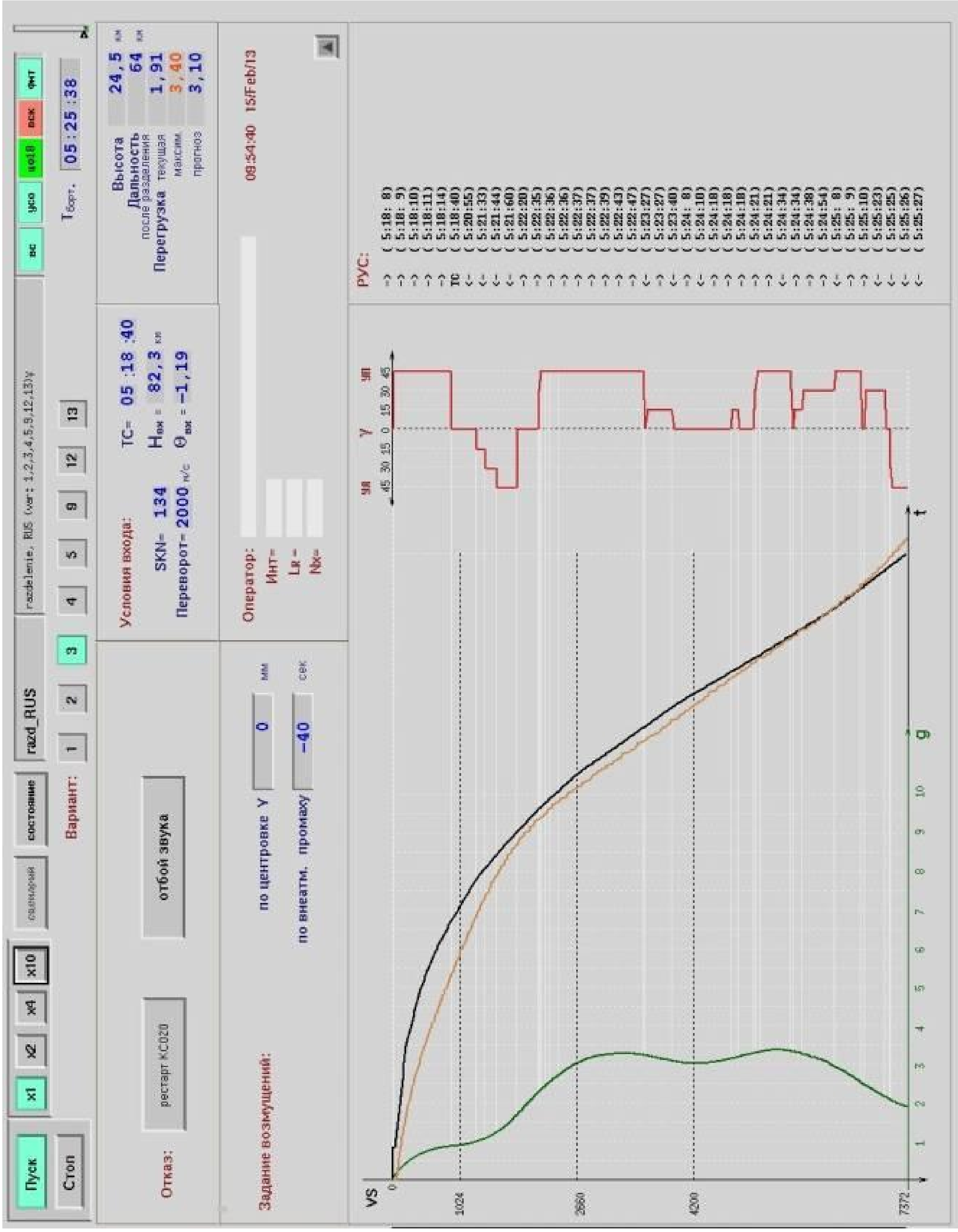

Fig. 4. Format of MCD mode on the TsF-18.

As a rule, cosmonauts successfully kept the maximum overload parameter n_x in accordance with the recommended MCD procedure. At the same time, there were some differences as compared to preflight data on the landing distance for modes 1 and 2. On average five cosmonauts showed the poorer execution of MCD operations by 14% as compared to the pre-flight training.

The following physiological parameters were continuously monitored before, during and after rotation:

- Nehb ECG data;
- ECG heart rate (HR);
- Tachooscillogram data (from a lead on the brachial artery);
- Breathing rate (BR);
- Electromyogram data (from leads on the chest, abdominal wall, and thigh);
- Video recording of a cosmonaut's face.

Additionally, the state of a cosmonaut is monitored by video cameras.

Medical examination before and during exposure to *g*-loads has shown the normal parameters of heart rate, blood pressure, and body temperature. Mean and maximum values of heart rate and breathing rate did not exceed indicators observed in the course of the preflight training for manual descent operations. The experiment did not cause any difficulties in medical aspects.

5. Experiments in EVA spacesuits under simulated Martian conditions

Exit from the landing module and routine operations on the surface of Mars were simulated on the stand Vykhod-2 (fig.5). It is designed to simulate reduced gravity environment, such as Lunar or Martian, in order to practice EVA operations. Simulation of the Martian environmental conditions was reached by the following:

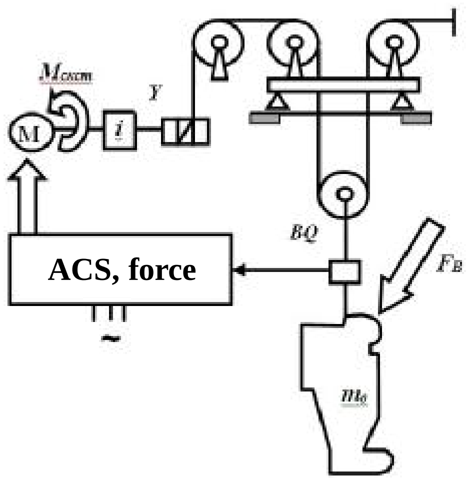

Fig. 5. Kinematic scheme and the general view of the stand Vykhod-2

a) Weight of a subject in the Orlan-type spacesuit was compensated using a special system to 0,38 g what corresponds to the Martian gravity;

b) The required freedom of action of a suited subject was reached by way of decreasing an excess pressure to 0,1 – 0,12 kg/cm^2 inside a pressure suit (an excess pressure of about 0,4 kg/cm^2 is created when simulating EVA operations in Earth orbit);

c) For simulation the routine EVA operations were chosen;

d) The choice of the experiment conduction time was well-grounded – it was carried out on the fourth day after landing what can be compared with the time of exit of a crew from the landing module after adaptation to the Martian gravity of 0,38 g.

Vykhod-2 is equipped with a gravity offload system and an automatic control system (ACS). A signal from the force sensor BQ, which is installed on the suspension, is fed to the input of the ACS. The DC motor (M) and the transfer unit (Y), which consists of a drum and a reducer, generate the required force and transmit it to the subject of an experiment.
Active forces, generated on the stand by an electric drive to compensate static and dynamic components of the resistance forces to the motion of a suited cosmonaut in horizontal and vertical directions, provide a full range of natural motion for a realistic simulation. The stand provides the starting force of 25-50 ***H*** and an acceleration error of 5-10%. [3]
The experiment’s objective was to evaluate the execution of the following operations by a cosmonaut (figures 6, 7): airlocking systems control; opening/closing an exit hatch; movement along typical routes (with/without a container); going up and down a ladder; handling the tools; usage of handrails and safety hooks; butt-jointing electrical connections; installation and removal of antennas.

Fig. 6. Simulation of EVA operations on the planet surface (opening the exit hatch, movement on the surface of Mars with a container).

The total time of the experiment, excluding auxiliary operations, was:
O.V.Novitsky – 37 min 49 s; E.I.Tarelkin – 38 min 11 s; R.Yu.Romanenko – 23 min 54 s; A.A.Misurkin – 30 min 25 s; F.N.Yurchikhin – 26 min 41 s.

Physical parameters of a suited subject were continuously monitored and recorded by way of:
– electrocardiography in ***D-S*** lead;
– pneumography;
– measuring parotid temperature.

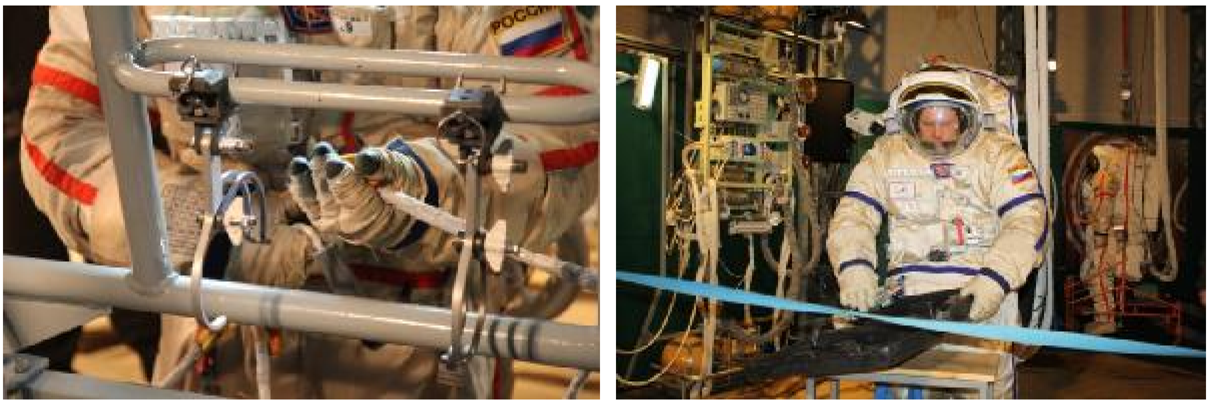

Fig. 7. Simulation of EVA operations on the planet surface
(butt-jointing electrical connections, removing the antenna out of the container)

The experiment provided for the interaction between a cosmonaut and an instructor who issued recommendations on motion activity regime and activity timeline. All movements of a cosmonaut on the site were considered as labor-consuming. Maximal values of HR and BR were observed when walking up the steps and climbing the ladder. The experiment has shown the tendency of increasing HR and BR along with increasing duration of pressure-suited operations as well as increasing the time of recovering physiological parameters. On average five cosmonauts showed the following changes as compared to preflight baseline data:

- Mean value of HR increased of 29 %;
- Maximum value of HR increased of 26 %;
- Mean value of BH increased of 20 %.

Body temperature during the experiments remained in the normal range, however, towards the end of timeline the tendency of a slight increase was observed.

6. Conclusion

The authors of the article have attempted to represent briefly the idea and results of the first experiments with the participation of the ISS crews for future deep space missions. Such approaches are possible when studying crew activity on a lunar base, during landing on an asteroid surface, during operations in Lagrange points, etc. Currently the CTC develops the program of investigations including preflight and post-flight experiments involving the Roscosmos cosmonaut corps. These experiments should help to study the operator skills of cosmonauts, their physiological parameters, psychological features, etc., including their interaction with different technical facilities, e.g. special-purpose robot handlers, robot-androids, rovers, EVA hardware, etc.

Up to date the experimental studies on assessment of cosmonauts’ operator activity (key flight operations) immediately after their long-term flights have been implemented neither in interest of the ISS program nor in interest of deep space missions.

This article represents outcomes, which could be useful for furthering safety of the ISS crews as well as for preparation for the future space missions to Mars.

In the interests of the ISS program for the first time there has been obtained preliminary experimental evidence that after a long-term flight under close to normal conditions, the cosmonauts are able to perform manually controlled descent of “Soyuz”-type spacecraft and to carry out operator activity on the surface of a planet.

Available technical facilities allow to simulate some conditions of crew activity during space missions to the Moon and Mars. However, it is necessary to continue studying issues of the creation and modernization of training facilities in order to train cosmonauts for interplanetary missions.

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An investigation of spatial turn regime of multimodular space station

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Here the problem of identification of attitude controlling of multimodular spacecraft using remote observation of its angular motion is studied. Processing's data of the telemetric information received during controlled turns of a multimodular orbital complex are presented. As an example, the rotation of the long-term orbital stations (and, in particular, of people-piloted space station) is researched. The problem of exact identification of a motion (including a method of control) and determination of numerical values of parameters of control algorithm of station's motion at the regime of a programmed turn has been solved for each concrete maneuver. The method of trained models is used for processing telemetry. As a result of processing, calculated motion around the center of mass during the turns of space station is reconstructed. The main parameters of the algorithm of control system are determined and initial conditions of a motion are specified. Absolute conformity of the measurements data to the motion of the orbital station by a known method of the control of spacecraft turn (Russian Federation patent for the invention No. 2093433, published – 20 October 1997, priority – 22.03.94) is demonstrated.

Introduction

Doubtlessly, one of major problems arising during flight tests and nominal exploitation of modern spacecraft still has comprehensive improvement of onboard systems with the purpose of their further modification, including perfecting of motion control algorithms [1-12]. In the present paper, the problem of recovery and identification under the data of telemetry measurements of a true angular motion of multimodular spacecraft (for example, international space station (ISS) and others) is decided at fulfilment by it of spatial turns and definition of principal numerical characteristics of this motion.

For achievement of the purpose, first of all it is necessary to select model depicting computational (or nominal) behavior of parameters describing motion of spacecraft with respect to center of the mass. For solution of a problem, the method of teaching models was used, as one of the most simple and at the same time most floppy and general methods of identification [1]. The projections of the vector of absolute angular velocity on an axes of spacecraft-bound coordinate system were adopted as an instrumental parameters of an attitude.

The main results of mathematical processing and analysis of telemetry measurements about motion of a space complex at a regime of spatial turn are below briefly described. After that, the in-depth enough data of post-flight processing of the telemetric information obtained from an onboard of orbital station are adduced, which has allowed not only to reconstruct actual motion of space station in a turn regime, but also precisely enough to identify a method of turn control, which one the manoeuvres implemented. The data processing of measurements is done using a technique grounded on identification with a pattern model. Within the framework of this technique, the measurements executed during some time interval are processed jointly by least squares process and integration of equations of motion of orbital complex around a center of the spacecraft mass. The equations of angular motion of orbital complex is written according to the logic of a operating of control system which is carried out pursuant to a selected mode of turn. At processing, the parameters of a mathematical model are updated and the adjustment values of parameters of a control algorithm are determined.

The presented results of processing of the measuring information about angular motion of orbital station allow concluding that the turn of multimodular spacecraft has been realised in the form of regular precession.

1. Data of measurements and methods of their processing

The spacecraft is considered absolutely solid body which centre of mass makes uncontrollable elliptic motion. For a study, analysis and identification, three-dimensional turn of spacecraft is very interesting. Indications of all orientation devices are interpreted in so-called building coordinate system *Oxyz* (or body-fixed coordinate system). It is a related rigidly with station a right-hand Cartesian system of the co-ordinates where the axes are directed as follows: the axis *Ox* is directed in parallel to longitudinal axis of the central (main) block; axis *Oz* is parallel to rotary axis of solar batteries of this block; and the axis *Oy* is supplementing the system *Oxyz* to right coordinate system.

For definition of nominal motion of bulky multimodular spacecrafts, the vector of absolute angular velocity w were used only. The information about w is telemetryed by an onboard instrumentation system as its projections w_x, w_y, w_z onto an axis of body-fixed coordinate system *Oxyz*, a center by which one coincides a center of the spacecraft mass. The measured values of different component of absolute angular velocity w are registered independently from each other and consequently can fall to the different moments of time.

At the turn, spacecraft executes a controlled motion, and it is provided with a control system by means of jet micro-engines. A variation of angular velocities w_x, w_y, w_z during turn of space complex is shown on fig.1. They are the actually measured values of parameters of angular motion. As well as at any turn here there are temporary stages, at which one a size of all components of angular-velocity vector (so also a quantity of angular rate $|\mathrm{w}|$) simultaneously increases (decreases). The concern introduces time interval between gaining and damping of angular velocity. The character of variation of angular velocity w_i $(i = x, y, z)$ at this time interval also determines the type of a kinematical trajectory of turn and control method, applicable to it. Further, research of spacecraft rotation we shall conduct only at time period between acceleration and braking of spacecraft (at a phase of nominal motion).

The set of the measurements included in a processing we will designate $t_i^{(k)}$, $w_i^{(k)}$ $(i = x, y, z;$ $k = 1, 2, ...N_i$, $t_i^{(k)} < t_i^{(k+1)}$). Here $w_i^{(k)}$ is the result of measurement of component w_i of vector w at time moment $t_i^{(k)}$. The beginning and the finish of processing interval should not get at acceleration and braking phases. We believe $\min t_i^{(1)} \geq t_{\mathrm{ac}}$, $\max t_i^{N_i} \leq t_{\mathrm{br}}$ $(i = x, y, z)$, where t_{ac} is the time of the ending of acceleration phase, t_{br} is the time of the beginning of braking phase.

Optimized functional which we should minimise has the form

$$G = \sum_{i=x}^{Z} \sum_{k=1}^{N_i} \left(w_i^{(k)} - w_i(t) \right)^2$$

We use a method of the least squares on the basis of the following assumption: regular errors in measurements of component w_i are identical and equal Δ_i $(i = x, y, z)$, and random errors in measurements of all components are independent and have identical normal distribution with zero average value and a standard deviation s.

Identification problem is formulated as follows: it is necessary to find such calculated approximating functions $w_i(t)$ (not only their mathematical form but also coefficients of the functions) which give a minimum for the functional:

$$F = \sum_{i=x}^{Z} \sum_{k=1}^{N_i} \left\{ w_i^{(k)} - w_i^0 \left[t_i^{(k)} \right] \right\}^2 \tag{1}$$

where $w_i^0(t) = w_{i\,\mathrm{cal}}(t) + \Delta_i$; $w_{i\,\mathrm{cal}}$ is the calculated values of component w_i of absolute angular velocity vector w according to functions $w_i(t)$; Δ_i is unknown constants (so-called «displacement of zero»).

For detection of features of spacecraft motion during turn and obtaining of its interesting characteristics, we shall take advantage of experience and consequences of analytical researches [2-4]. Now three ways of programmed turns of spacecraft can be used most frequently:

a). Consecutive turns around of the axes connected with a space vehicle;

b). Turn of spacecraft around of the final turn axis;

c). Turn on type of a precession of solid body (as example, - regular precession).

At last case, some persistence of axial component angular velocity w_1 on the one hand, and form of transverse angular velocities w_2 and w_3 are close to harmonious functions of time on the other hand, will give a basis to draw conclusion about presence of regular properties which have the characteristics as motion of spacecraft in relation to a center of the spacecraft mass as precessions of solid body around of some direction motionless in all-inertial space. The spacecraft carries out the complex movement: “simultaneously” around of some motionless axis h componented with longitudinal axis *Ox* definite angle J and around of a centerline *Ox* with angular velocities of precession $\dot{y}$ and of own rotation $\dot{j}$, accordingly. The indicated type of motion is described by following kinematic equations:

$$w_x = \dot{j} + \dot{y}\cos J, \;\; w_y = \dot{y}\sin J \sin j\,(t), \;\; w_3 = \dot{y}\sin J \cos j\,(t)$$

where j is turn angle of own rotation.

By virtue of the universality last type of programmed turn of spacecraft introduces the greatest concern, though the turn of spacecraft along a trajectories of free motion is generally possible way [4, 5].

For determination of motion type and control method of spacecraft reorientation, it is necessary to select model depicting a dynamics of rotation and programmed (or nominal) variation of angular velocities describing motion of multimodular complex.

2. A choice of pattern model

Let's consider one of turns of the orbital complex representing a large heavy multimodular construction. Data of onboard measurements of angular velocities w_x, w_y, w_z are visually presented by fig.1. The configuration of space complex is asymmetrical, therefore it is impossible to neglect discrepancy of the principal central axes of the ellipsoid of inertia with building axes of a complex. At performance of the given regime of orientation, the orbital coordinate system (OCS) was basic (as reference basis), and a complex was stabilised with respect to it before and after a turn. Therefore, before a turn and on its termination the magnitude of absolute angular rate is distinct from zero.

A feature is the unregularity of rotary motion of space complex which is expressed in dissimilarity of behaviour of angular velocities w_x, w_y, w_z on their typical change at any of known ways of a turn of a solid body. Rotation occurs about all three axes *Ox*, *Oy*, *Oz*. However, rotary velocities in relation to axes of the body-fixed coordinate system *Oxyz* are not constant, and proportions between them are not constants. Hence, the spacecraft turn is not planar [2], and it is not executed in the form of planar rotation around a motionless axis (Euler's axis) [3]. Thus all three angular velocities w_x, w_y, w_z change dynamically enough. Any of components of absolute angular velocity vector w have not constant character (or at least close to it). Also, rotation of a complex is impossible to consider as free motion [4, 5]. Nevertheless, at enough long interval of time, a quantity of angular velocity w changes slightly. Quite probably, that motion of vector w possesses some regular properties, but concerning any other rectangular coordinate system $Om_1m_2m_3$, motionless in relation to the body-fixed coordinate system *Oxyz* (or in inertial space). If such coordinate system $Om_1m_2m_3$ exists, spacecraft motion around the centre of mass has regular character during an investigated time interval between acceleration and braking.

Let there will be such plane m_2Om_3, the vector projection w on which monotonously turns with some angular velocity distinct from zero. If even thus specified angular velocity has almost constant value, it is possible to speak about a precession of the vector w and, accordingly, of a complex. Direction Om_1 which is orthogonal to plane m_2Om_3 and supplementing the system $Om_1m_2m_3$ to right coordinate system, is an axis of own rotation. In this case, the problem of determination of characteristics of spacecraft's true motion around the centre of mass is reduced to definition of mutual position of rectangular coordinate systems *Oxyz* and $Om_1m_2m_3$ (for example, matrix of the directing cosines $B = \left\| b_{ij} \right\|_{3\times 3}$ for axes Om_1 , Om_2 , Om_3 with respect to the axes *Ox*, *Oy*, *Oz*), to a transfer of vector w absolute angular velocity from the body-fixed coordinate system *Oxyz* into coordinate system $Om_1m_2m_3$ related with a direction of an axis of own rotation Om_1 (to vector display w on axis Om_1, Om_2, Om_3), and to a construction of the valid motion w(t) and the main characteristics $\dot{j}(t)$, $\dot{y}(t)$, $J(t)$, $w(t) \equiv |\mathrm{w}(t)|$ of spacecraft's angular motion using known methods [1, 7, 8].

A finding of matrix of the directing cosines is a separate independent problem. Let the matrix of transition from the coordinate system *Oxyz* to the coordinate system $Om_1m_2m_3$ is known: $B = \left\| b_{ij} \right\|_{3\times 3}$, where b_{ij} is cosine of a angle between positive directions of axes Oi and Om_j ($i = x, y, z$; $j = 1, 2, 3$). Then, a display to axes Om_1, Om_2, Om_3 motion of absolute angular velocity vector w in the course of complex's turn can be received using the expressions:

$$w_j = \sum_{i=x}^{z} b_{ij} w_i \quad (j = \overline{1,3})$$

In our concrete case, the transition matrix B (the directing cosines) has the form:

$$B = \begin{vmatrix} 0.6988475330 & -0.2198905795 & 0.6806322492 \\ 0.3087457564 & 0.9510947314 & 0.0000000000 \\ -0.6473457462 & 0.2101423186 & 0.7325604900 \end{vmatrix}$$

Results of the projections recalculation of the vector w from the related coordinate system *Oxyz* onto axis of system $Om_1m_2m_3$ are shown in fig.2. The analysis of the received information allows assuming that in this case, at a phase between acceleration and a braking of angular velocity, rotation of complex is in the form of a precession of solid body. In it specifies an approximate constancy of longitudinal angular velocity w_1 and minor alteration of size of the transverse angular velocity $w_{\mathrm{tr}} = \sqrt{w_2^2 + w_3^2}$. As pattern model, we can accept following equations:

$$w_1 = \dot{j} + \dot{y}\cos J, \quad w_2 = \dot{y}\sin J \sin\left(\dot{j}t + j_0\right), \quad w_3 = \dot{y}\sin J \cos\left(\dot{j}t + j_0\right) \qquad (2)$$

where $\dot{\psi}$ is angular velocity of a precession (around some motionless axis η in inertial space), $\dot{\varphi}$ is angular velocity of own rotation (about axis Om_1, motionless in the body-fixed coordinate system $Oxyz$), ϑ is the angle of deviation of axis Om_1 from precession axis η. The values $\dot{\varphi}$, $\dot{\psi}$, and ϑ are slowly-varying parameters (as functions of time).

Character of complex's motion around the centre of a mass is defined by behaviour of elements $\dot{\varphi}$, $\dot{\psi}$ and ϑ as time functions. Therefore, essentially important authentically and precisely to estimate a varying during time of parameters $\dot{\varphi}$, $\dot{\psi}$, ϑ in the course of turn. Approximation of the measured values of angular velocities by expressions (2) is made by splitting of the given time-interval of processing into final number of subintervals and by a replacement of variable parametres $\dot{\varphi}$, $\dot{\psi}$, ϑ inside everyone subinterval by the constants equal to any values of the same parametres inside or at boundary of considered subintervals. And, initial process with variable parametres $\dot{\varphi}$, $\dot{\psi}$, ϑ at given final interval of time can be approximated by a process with piecewise-constant parameters, with any degree of accuracy [6].

The recovery problem of programmed motion of multimodular spacecraft at the site $[t_{ac}, t_{br}]$ consists in a numerical determination of parameters of control algorithm $\dot{\varphi}$, $\dot{\psi}$, ϑ (and of constant parameters Δ_i also), and decision of the system (2), which give a minimum for the functional F (as the form (1)), when in the formula (1) $\omega_i^{(k)}$ is the measured values of the projections of a vector ω onto body-fixed axes at time moments $t^{(k)}$ ($t^{(k)} < t^{(k+1)}$); $\omega_j(t^{(k)})$ is the values of component ω_j in the projections of axes of coordinate system $Om_1m_2m_3$ which are computed along the decision of model system (2); $\omega_i(t^{(k)})$ is the calculation values of angular velocities $\omega_x, \omega_y, \omega_z$ received from the solution $\omega_j(t^{(k)})$ of system (2).

The set of the measurements $\omega_i^{(k)}$, $t^{(k)}$ selected for processing and reconstruction of spacecraft motion correspond to for time moments which are not overstepping the bounds of time interval $[t_{ac}, t_{br}]$. The components ω_i ($i = x, y, z$) are computed using the matrix of the directing cosines "B" and the solution of the equations (2) $\omega_j(t)$ as time functions ($j = \overline{1,3}$). Obviously, $\omega_i(t) = \sum_{j=1}^{3} b_{ij}\omega_j(t)$

where b_{ij} is the elements for matrix $B = \|b_{ij}\|_{3\times 3}$ of transition from the body-fixed coordinate system $Oxyz$ to coordinate system $Om_1m_2m_3$.

Use the functional F means the hypothesis acceptance, that the measurement errors of component ω_i of all vectors $\omega(t^{(k)})$ in related coordinate system $Oxyz$ are independent random variables with identical standard deviation.

If the tensor of spacecraft inertia is known, the identification problem of angular motion can be facilitated. In this case, most likely, it is necessary to study motion with respect to the coordinate system related with the the principal central axes of inertia of multimodular space complex. For this, we shall enter the right Cartesian system of coordinates $On_1n_2n_3$ formed by the principal central axes of inertia. Thus, axis On_1 is a longitudinal axis of a spacecraft, and axis On_2 and On_3 are directed so that mismatch angles between them and axises of the related coordinate system were minimal. For a correct choice of reference model of motion, it is necessary to compute preliminary angular velocity vector ω in projections to the principal central axes of the ellipsoid of inertia On_1, On_2, On_3. For vector representation ω in projections to the principal central axes of inertia, we should have all three components ω_i ($i=x, y, z$) a vector ω for the same moments of time. The missing values ω_i of component of vector w for time interval $t_i^{(k)}$, we receive by interpolation of a corresponding set of values. A matrix of transition from the body-fixed coordinate system *Oxyz* to the system $On_1n_2n_3$ we will designate $A = \|a_{ij}\|_{3\times3}$, where a_{ij} is cosine of a angle between axises *Oi* and On_j ($i = x, y, z$; $j = 1, 2, 3$).

If results of recalculation of a vector w from body-fixed coordinate system *Oxyz* in a projection to axises of system $On_1n_2n_3$ will show a picture (as variation form) similar to those that is studied from fig.2, then character of change of angular rates w_1, w_2, w_3 in projections to the principal central axes of the ellipsoid of inertia $On_1n_2n_3$ that motion of a multimodular spacecraft around the centre of mass occurred as the precession of solid body; and we can apply the way considered above where instead of system $Om_1m_2m_3$ it is necessary to take $On_1n_2n_3$, and matrix $B = A$ ($b_{ij} = a_{ij}$). Some constancy of longitudinal making angular velocity w_1 on the one hand and variation of transverse angular velocities w_2 and w_3 on close by the form to harmonious functions of a time, on the other hand, specify in presence of regular properties, characteristic for motion in a form precession of solid body around some direction, motionless with respect to inertial space. Space complex rotates simultaneously around some motionless axis h is inclined to longitudinal axis On_1 by the rated angle J and around longitudinal axis On_1 with angular velocities of precession $\dot{y}$ and own rotation $\dot{j}$ accordingly. For such type of motion, equations (2) in which parameters $\dot{j}$, $\dot{y}$, and J are slowly-varying functions of time are fair.

Rotation of multimodular spacecraft can be described by mathematical model in the form of dependences (2), in which variables w_j ($j = 1, 2, 3$) are projections of angular-velocity vector w onto axises of system $On_1n_2n_3$ ($On_1n_2n_3$ is coordinate system related with principal central axes of spacecraft inertia). The description of spacecraft motion is probably and in angular velocities w_i ($i = x, y, z$), being projections of a vector w_{pr} of programmed absolute angular velocity onto axises of the body-fixed coordinate system *Oxyz* (we have this possibility). For this purpose, it is necessary for function $w_1(t)$, $w_2(t)$, $w_3(t)$ which are the solution of the equations (2), to translate in function $w_x(t)$, $w_y(t)$, $w_z(t)$ using the matrix of the directing cosines between axises of coordinate systems *Oxyz* and $On_1n_2n_3$.

In this case, determination of spacecraft's rotary motion for the segment $[t_{ac}, t_{br}]$ consists in a finding of such parametres of motion model (the pattern model) and solutions of the equations (2), which allow to coordinate in the best way, in a sense of a method of the least squares, the measured (counted under the telemetric information) and calculated values of components w_i ($i = x, y, z$); here t_{ac} is the time of a termination of acceleration stage; t_{br} is the time of the beginning of braking stage.

3. Results of a solution of the identification problem

Let's take for the analysis, processing and solution of the identification problem the turn presented at fig.1. We accept, t_B is the moment of manoeuvre beginning, and t_E is the moment of manoeuvre ending. Interval from $t = t_B$ to $t = t_E$ represents a interest. We notice, that all time interval $[t_B, t_E]$ can be broken into three basic phases: a increase of angular rate (an acceleration), a decrease of angular rate (a braking), and an interval between acceleration and braking. It is clearly visible from fig.1. For the moments of time corresponding to stages of increase and decrease of angular rate, a linear interpolation is sufficient. At time interval between the specified stages the number of measurements is a nonlarge, owing to this a interpolation was carried out by the polynoms.

Feature of the turn chosen for research is the seeming at first sight unregularity of angular motion. However such behaviour of angular velocities easily to explain and to understand, if we will consider that axes of sensitivity of measuring instruments of angular velocity do not coincide with the principal central axes of the ellipsoid of spacecraft inertia.

For definition of true character of spacecraft motion, it is necessary to check up presence of regular properties of rotation during time interval between acceleration (increase of angular rate) and a braking (decrease of angular rate). In particular, we will ask a question: whether there is a direction, motionless in the related coordinate system with respect to which the vector of absolute angular velocity w is rotated with almost constant angular velocity? If yes, it makes sense to determinate and investigate more in detail motion of the vector w in new coordinate system $Om_1m_2m_3$ which axises are directed as follows: axis Om_1 coincides with the specified direction, around which a vector w does precession; axes Om_2 and Om_3 are in a plane which is perpendicular to axis Om_1; they supplement system $Om_1m_2m_3$ to right coordinate system and are located so that the angle of final turn between the trihedrons $Oxyz$ and $Om_1m_2m_3$ was minimal.

In example shown by fig.1, the motionless axis around which the vector of absolute angular velocity w does precession exists. We take the mathematical model (2) as the pattern model (for use the method of trained models [6]). Pattern model in the form of dependences (2), where variables w_j are projections of a vector of angular velocity w onto axes of system $Om_1m_2m_3$ ($j = 1, 2, 3$), is closest to real process. After the recomputation we have data about the vector w as projections onto axis of system $Om_1m_2m_3$ in the form demonstrated at fig.2.

Programmed spacecraft motion is described by the variables w_i ($i = x, y, z$), which are translated from the functions $w_1(t)$, $w_2(t)$, $w_3(t)$, being the solutions of the equations (2), in functions $w_x(t)$, $w_y(t)$, $w_z(t)$ using the matrix of the directing cosines between axises of coordinate systems $Oxyz$ and $On_1n_2n_3$. Resulting functions for this concrete example of spacecraft turn are shown in the fig.3. A construction of approximation of spacecraft's actual motion with respect to center of mass at the segment $[t_{ac}, t_{br}]$ consists in a finding of parametres $\dot{j}$, $\dot{y}$, J and the solution of the system (2), delivering a minimum of the functional:

$$\Phi = \sum_{i=x}^{z}\sum_{k=1}^{N_i}\left\{w_i^{(k)} - w_i\left(t^{(k)}\right)\right\}^2$$

The use of the functional Φ fairly because in our case (for our concrete sensors of angular velocity) the measurement errors of components of all vectors $w(t^{(k)})$ in the system $Oxyz$ are independent random variables with zero average value and an identical standard deviation. If systematic error of measurements of component w_i is distinct from zero then we include it into the approximating function $w_i(t)$ as one more unknown constant parameter.

For this case of realisation of a programmed turn, we had following indicators of angular motion: $\dot{j} = -0{,}03933$ deg/s, $\dot{y} = 0{,}1769$ deg/s, $w = 0{,}5518$ deg/s. Turn angle has made $a = 158{,}5$ degree. Thus, received values $\dot{j}$, $\dot{y}$, J are equal to nominal values of parametres of control law of a turn. Nominal value of nutation angle (its estimation): $J = 118{,}6$ degree. If to accept function $j(t)$ in the form of polynomial dependences, for example, $j(t) = j_0 + j_1 t + j_2 t^2 + j_3 t^3$, required values of approximation coefficients will turn out the following:

$j_0 = -38{,}56$ deg, $j_1 = -0{,}03933$ deg/s, $j_2 \approx -3\cdot 10^{-7}$ deg/s^2, $j_3 = 0{,}000$ deg/s^3.

Actual values of the elements $\dot{j}$, $\dot{y}$, w, J during the turn of an orbital complex are practically constant. Presence of insignificant deviations from their nominal values speaks unideal of control system. It is considered to be, a measure of inconstancy of the estimated parametre P is a relative deviation δP from its average value $\overline{P}$. Degree of a constancy of the parametres $\dot{\varphi}$, $\dot{\psi}$, ω is defined by the standard technical norms: $\delta P \le 0{,}05$, where δP the maximum relative deviation of parametre P from the set of a rating values. A constant value, satisfying to an inequality, is considered:

$$P_{\max} - P_{\min} \le 0{,}05 \left| P_{\max} + P_{\min} \right|$$

where $P_{\min} = \min P(t)$, and $P_{\max} = \max P(t)$ are the minimum and maximum values of parametre $\boldsymbol{P}$.

In the accepted designations, we have following indicators of realisation quality of control method of turn (they is received by results of processing of the available telemetric information):

$$d\dot{\psi} = 0{,}030\ ,\ d\dot{\varphi} = 0{,}005\ ,\ d\omega = 0{,}028$$

As criterion of reliability of identification of spacecraft’s motion type in the form of the precession of solid body around some motionless direction in space η with constant angular velocities $\dot{\psi}$ and $\dot{\varphi}$ we accept conditions: $d\dot{\varphi} \le 0{,}05$, $d\dot{\psi} \le 0{,}05$, $d\omega \le 0{,}05$ inside the time interval with duration t_{nom}, under condition $t_{\text{nom}} \ge \left(T - t_{\text{ac}} - t_{\text{br}}\right)/2$, where t_{nom} is supervision time; T is general time of a turn; t_{ac} is the duration of acceleration phase; t_{br} is the duration of braking phase.

Programmed motion $\omega_{\text{pr}}(t)$ restored after the solution of the identification problem of angular motion has a form:

$$\omega_1(t) = -0{,}03933 + 0{,}1769\cos\vartheta(t), \qquad \omega_2(t) = 0{,}1769\sin\vartheta(t)\sin(-0{,}03933t - 38{,}56^0),$$

$$\omega_3(t) = 0{,}1769\sin\vartheta(t)\cos(-0{,}03933t - 38{,}56^0).$$

Returnable recalculation of a vector ω_{pr} from the coordinate system $Om_1m_2m_3$ into body-fixed coordinate system $Oxyz$ will give the required functions $\omega_{i\,\text{pr}}(t)$ which reflect programmed motion of orbital station during a turn. The fig.3 gives evident representation of results of reconstruction of calculated motion of station at the phase of nominal rotation. Continuous lines correspond to spacecraft motion by the method [9]; the markers correspond to direct measurements of angular velocities $\omega_x, \omega_y, \omega_z$. The given figure demonstrates that the consent of the measured values with a modeled variation of parametres of rotary motion is high enough. Root-mean-square deviations (as approximation errors) have turned out equal to: $\sigma_{\text{x}} = 0{,}0006$ deg/s, $\sigma_{\text{y}} = 0{,}0018$ deg/s, $\sigma_{\text{z}} = 0{,}0023$ deg/s.

The resulted estimates σ_{x}, σ_{y}, σ_{z} include measurement errors and errors of control (including the execution errors of control commands). Taking into account that an admissible error of attitude system $\Delta\omega = 0{,}01$ deg/s, we receive acknowledgement of the accepted law of motion: $3\sigma < \Delta\omega$

Oscillatory character of the constructed functions ω_i near their programmed values is caused by inconstancy, in particular, fluctuations of parametre ϑ which are caused by errors of execution of control commands and by nonlinearity of executive devices of spacecraft's attitude system. The range of change of key parametres $\dot{\varphi}$, $\dot{\psi}$, ω is insignificant, and we can speak about their insignificant fluctuations which can be neglected in considered approximation.

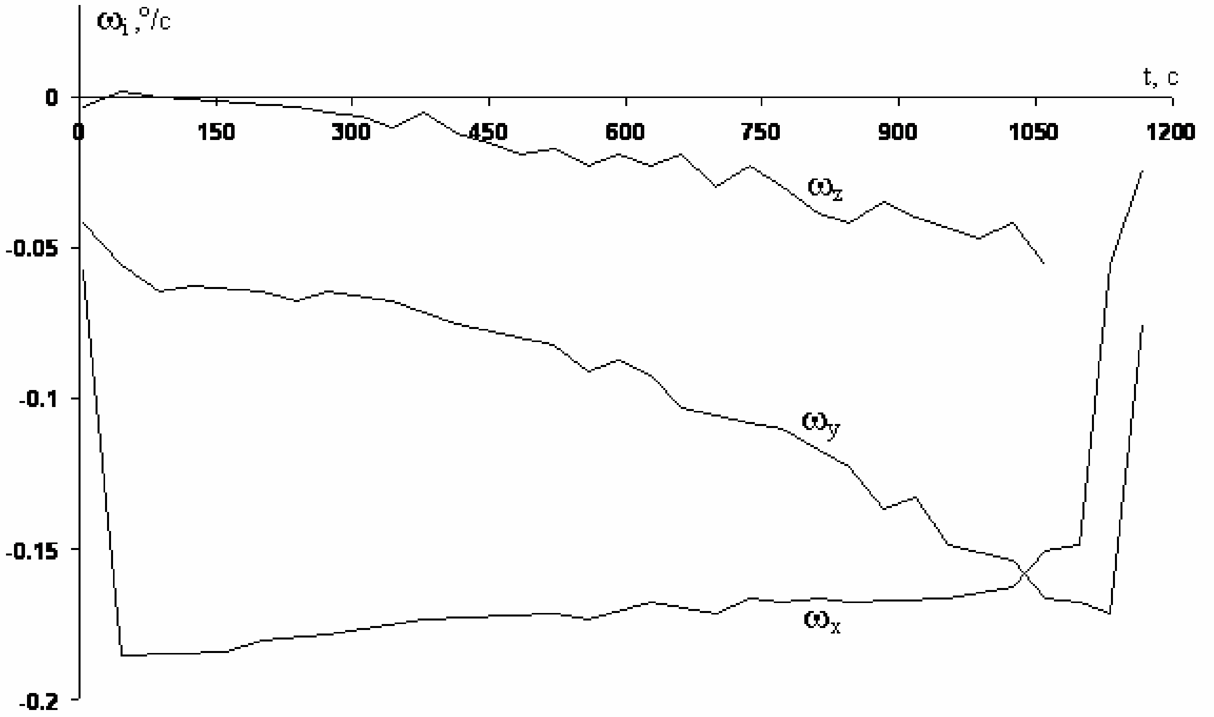

Fig.1. Angular velocities of multimodular complex

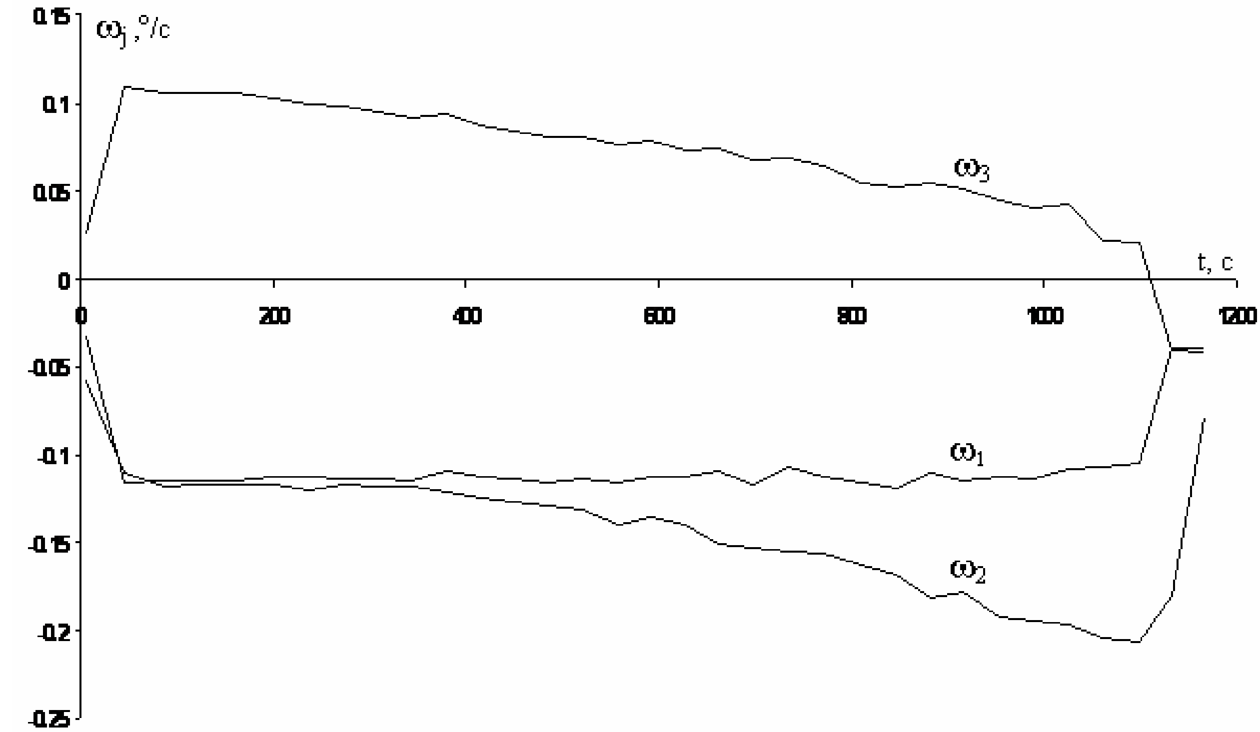

Figure 2. Result of recalculation of angular velocities

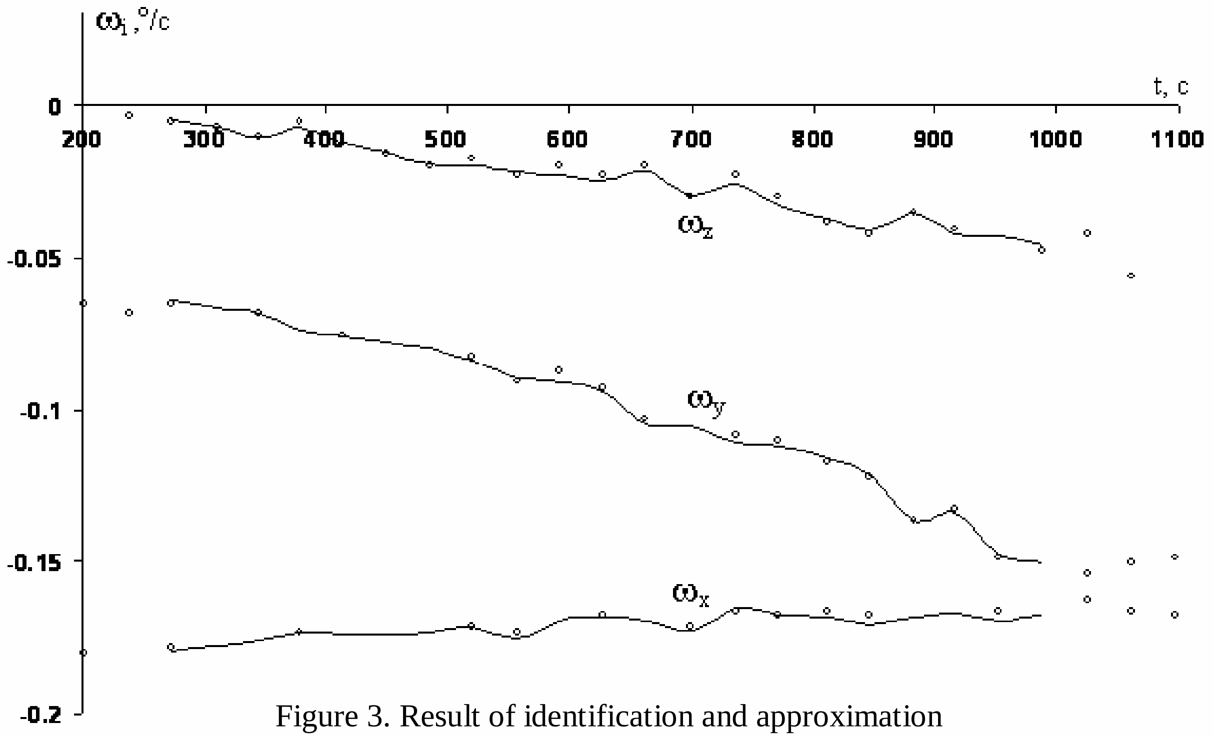

Figure 3. Result of identification and approximation

We have considered the dynamics of turns of the orbital scientific complex which moments of inertia are not known precisely, and we have investigated a character of its motion. Data processing of onboard measurements was executed by a method of trained models [6]. As a result of processing of the information on angular motion of multimodular spacecraft, actual motion around the centre of mass in the course of a three-dimensional turn is reconstructed. The presented processing results of the telemetric information about angular velocities of orbital complex allow to conclude that its reorientation has been made in the form of solid-body precession at which the angular velocities $\dot{\varphi}$, $\dot{\psi}$ are constant, and the angle of nutation ϑ varies slightly. Actually takes place subregular precession of orbital complex as solid body.

Conclusions

The study of rotary motion of an orbital complex has allowed to solve two primary tasks: a) restoration of nominal motion of angular-velocity vector formed according to a law realised by a control system; b) identification of control mode of spacecraft turn. Not less important problem consisting in a definition of numerical values of parametres of control algorithm of an orbital complex in the regime of the spatial turn, defining a steered (a targeted) motion, has been in passing solved.

Results of processing of the measuring information about parametres of angular motion on turns of orbital station are adduced. The development of a method of trained models has allowed to reconstruct programmed motion of multimodular spacecraft in a regime of a spatial turn and authentically to identify a method by which the turn was carried out. Results of mathematical processing of onboard telemetry convincingly show that the perspective method [9] has been used for turns. Total process of a turn includes the following basic phases: acceleration, rotation with a constant size of the angular velocity, a braking. And, spacecraft motion inside main site of a turn (between a acceleration and a braking) occurs in the form of simultaneous rotation about some motionless axis in the inertial space, making with a longitudinal axis of a spacecraft a calculated angle ϑ, and about longitudinal axis of a spacecraft with constant angular rates of precession $\dot{\psi}$ and of own rotation $\dot{\varphi}$. Control of a turn of orbital complex was carried out by jet engines of orientation (as attitude control means) which operate in an impulse regime. Because of it occurrence of errors of working off by a control system of programmed angular velocities is inevitable. Estimations show that deviations of actual angular rates from their calculated values caused by nonlinearity of executive devices can reach $0.005 - 0.01$ grad/s for orbital station. For this reason, all deviations between the reconstructed functions of angular velocities and their telemetrical values, not exceeding this size, can be fairly carried to errors of execution by attitude system of operating commands. Comparison of the analysis results of processes of orbital complex turn leads to a conclusion that control of spacecraft reorientation was executed with necessary accuracy. Exact determination of numerical values of parametres of control algorithm of programmed turn of difficult spacecrafts is important for the practice.

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Conceptual evaluation of multi-purpose aerospace plane

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This paper deals with conceptual design of aerospace plane, intended for delivery of 5-7 people or 3 tonnes of cargo to near-earth orbit. One of the main questions is concerned with the thermal protection system.

Introduction

Year 2013 had two token anniversaries in world astronautics – 25 years of the first flight of reusable transport Energiya-Buran system (November 15, 1988) and 10 years from the date of the accident of aerospace plane Columbia of Space Shuttle system (February 1, 2003). The first date was met as a hope of new prospects, but unfortunately, this flight remained the only. The second date saddened by death of seven astronauts, in essence became a main reason for the early ending of one of the most grandiose programs in astronautics.

Carriage capacity on the highway of Earth-Space, which started on October 4, 1957 by sending the first satellite with mass of 83.6 kg into orbit, has been steadily developing year by year. At the first decade of a development of the practical astronautics, the cost price amounted 1500 dollars for 1 kg of payload to be transported into the low earth orbit by using single-mission systems. So it is urgently needed to make cheaper delivery vehicles for military and civil purposes, and for scientific and technologies tasks, which can be solved only in space conditions. With the creation of reusable transport system “Space Shuttle” that was launched on April 12, 1981, exactly twenty years after the first manned flight into space, it seemed that the astronautics was transferring to a new generation of flight vehicles very successfully. This system can launch an aerospace plane (ASP) with mass more than one hundred tonnes including about 30 tonnes of payload and returns from orbit 14.5 tonnes of payload in cargo compartment. It has been forecasted that this system could reduce the cost of insertion of payload 3-4 times. NASA planned 40-45 launches a year at the beginning of Shuttle program. These planned numbers have been decreased twofold after the first launches. But the maximum number of starts that was reached before "Challenger" accident was only eight (January, 1986). It became obvious that all expected economic benefits were accompanied by huge expenses.

Today disposable systems have not lost their positions and especially by the reason of the complete closing of the program of Space Shuttle in 2011. Nevertheless, the idea of reusable space transportation systems will in any case exist, grow, and seek its better solution.

Researches and works of the last 20-25 years have shown convincingly that initial optimism associated with the hopes of aircraft (horizontal) launch of reusable systems with the continued use of hypersonic ramjet (scramjet), and hence the use of the cheapest and affordable oxidant – oxygen of the atmosphere, is still far from practical applications. As yet problem of providing high-temperature of both the engines and load-carrying structure is unsolved and even more distant prospect of a single-stage with scramjet. In this regard, it is expected that in the next decade reusable space transportation systems will be considered, and still largely follow the path trodden by "shuttles" with their 135 missions (from 12.04. 1981 to 8.07.2011), plus one flight of the Soviet shuttle "Buran" in automatic mode (15.11.1988). Similar types of ASP in this respect will be discussed further.

Now the need of ASP much lighter and more operational than Space Shuttle is obvious, and this is clearly seen from the regular delivery of cargo and crew between the International Space Station (ISS) and the Earth. And perhaps one of the most pressing problems of this future ASP is associated with emergencies, i.e., rescue operations. Looking back on the tragic event of 1 February 2003, when the crash of ASP “Columbia” occurred, it is obvious that a similar rescue vehicle could prevent that disaster. After that event, a new term appeared in the classification of ASP – Crew Transport Vehicle (CTV).

Creation of new ASP needs to be considered in an integrated complex with the carrier providing its orbital injection. For economy, apparently, it is necessary to use existing carriers, or the ones that will appear in the nearest future. From analysis of existing or advanced launch vehicles, it is possible to estimate the maximum weight of ASP for the ascent into the low Earth orbit.

By evaluating design variables of ASP we consider flight vehicle (FV), which begins its independent movement after separation from the carrier with the velocity that is usually somewhat less than the orbital velocity, so that in case of emergency, it is possible for FV to return to Earth by a suborbital trajectory. The mass of ASP at the beginning of separation $-m_0$ is one of the main design parameters of the FV.

We use the equations of motion of ASP in the velocity coordinate system to determine and select the path at the preliminary stage of design. We consider the approximate equations of moving mass center of ASP (fig. 1), in form (1) (it is approximate mathematical model):

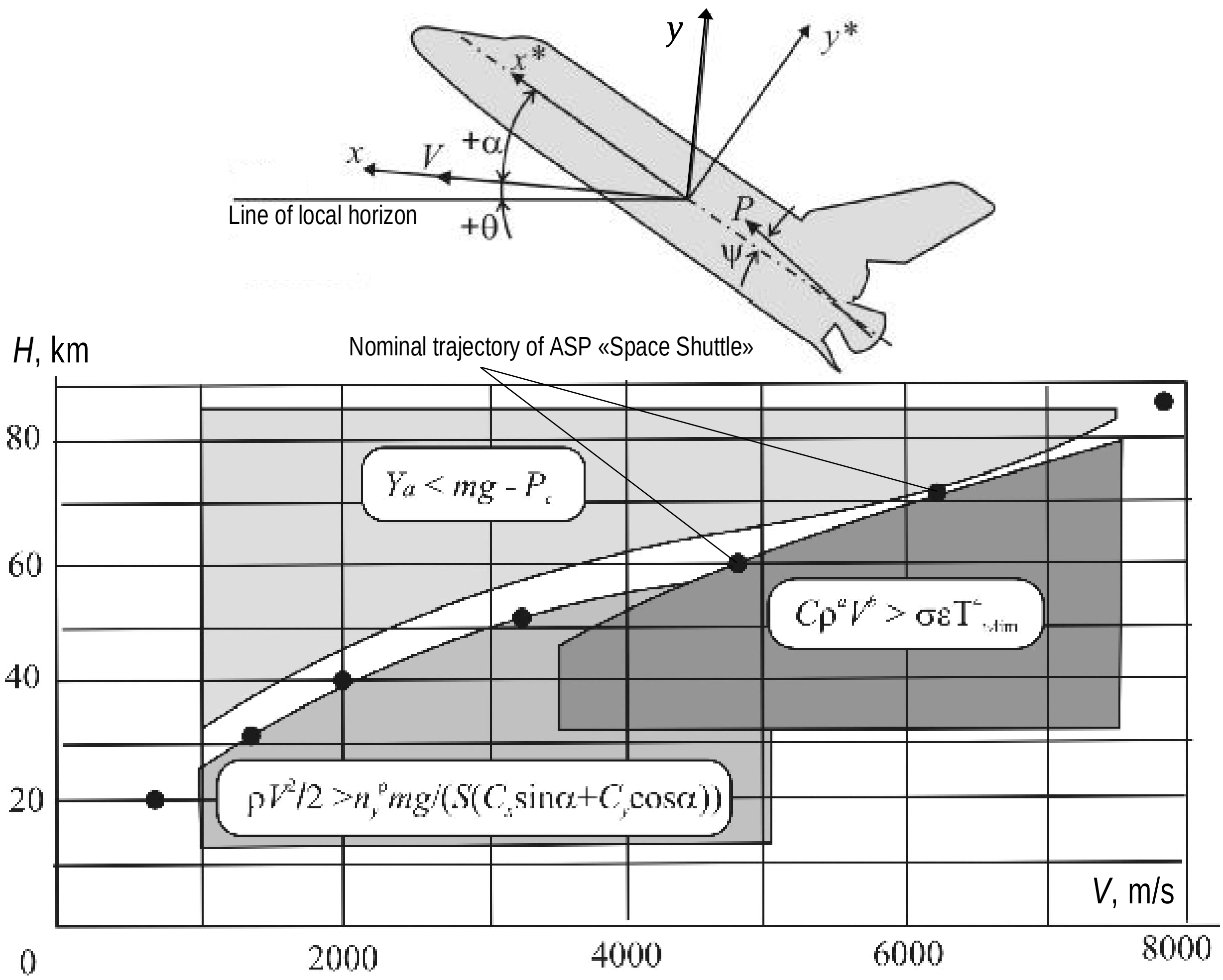


Fig.1.To the equations of movement of ASP and "corridor" of its descent in a hypersonic mode with three types of operating restrictions.

$$
\begin{aligned}
& m\frac{dV}{dt} = P\cos(a + y) - X_a - mg\sin q + m\frac{[V\cos q \pm w_E(R+H)\cos j]^2 \sin q}{R+H} \\
& mV\frac{dq}{dt} = P\sin(a + y) + Y_a - mg\cos q + m\frac{[V\cos q \pm w_E(R+H)\cos j]^2 \cos q}{R+H} \\
& \frac{dH}{dt} = V\sin q \\
& \frac{dL}{dt} = V\cos q
\end{aligned} \tag{1}
$$

m – current mass [kg]; P – thrust [N] acting at an angle y to the longitudinal axis of the FV; a – angle of attack; q – angle of pitch; w_E – Earth angular velocity, here the radius $R \approx 6.32\times10^6$ m, $w_E = 2\pi/(24\times3600\text{sec})$; X_a – drag force [N], $X_a = C_x ½\rho V^2 S$; C_x – drag coefficient; Y_a – aerodynamic lift force [N], $Y_a = C_y ½ r V^2 S$; C_{ya} – lift coefficient; V – speed of FV [mps]; S – typical (carrier) area of FV [m^2]; L– range [m]; H – height [m]; r – the density of air at observed height H, which can be approximated as exponentially depending on H

$$r_\infty \approx r_0 e^{-bH}, \text{ kg/m}^3 \tag{2}$$

where r_0=1.225 kg/m^3; b= 0.000139 1/m.

In the design of ASP, all stages of its life cycle are under consideration, from the preparation of launch to the end of the flight. However, the key concept of ASP, as well as its main design problems, is in the stage of the return from the orbit. Obviously, we have $P = 0$ and $m = \text{const}$ in the hypersonic flight regime that is the main part of flight. To ensure the necessary high-crossrange of ASP, the angle of bank γ is introduced to consideration. Note that the angle of pitch is very small (q» –1…–3°), its time derivative and Coriolis force can be ignored, and also considering that $H \ll R$, the system (1) can be rewritten in the form,

$$
\begin{aligned}
& \frac{dV}{dt} = -C_x \frac{rV^2}{2m} S \\
& C_y \frac{rV^2 \cos g}{2m} S + g\left(\frac{V^2}{gR} - 1\right) = 0 \\
& \frac{dL}{dt} = V
\end{aligned} \tag{3}
$$

We integrate the first equation of the system (3) to obtain the time of equilibrium gliding of ASP at hypersonic flight regime, which occurs from height H≈80~90 km. To the engineering estimate, the time of quasi stationary gliding in hypersonic region can be obtained from the approximate dependence [1], [2]

$$t_H \approx 2300\, K \text{ [c]} \tag{4}$$

where $K = Y_a/X_a = C_y/C_x$, is the lift-drag ratio of ASP on hypersonic flight. For ASP “Space Shuttle” and “Buran”, here exist $K_H \approx 1.1$ at a≈40°.

We integrate the third equation of the system (3) to estimate the distance of ASP in hypersonic gliding phase, which in the approximate variant [1], [2] has the form:

$$L_H \approx 13800\, K \text{ [km]} \tag{5}$$

In the optimization of the angle of bank, the approximate dependence for maximal crossrange has the form [1], [2]:

$$L_{H\ бок} \approx 1400\ K^{1.5}\ [\text{km}] \tag{6}$$

Let us dismount basic aerodynamics, strength, and heat restrictions to implement a project of ASP.

With the aid of the second equation of the system (3), the minimum density of air can be determined, which provides equilibrium gliding:

$$r = \frac{2(1-V^2/(gR))}{s_y V^2 \cos g} = \frac{2(1-\overline{V}^2)}{s_y \overline{V}^2 V_c^2 \cos g} \tag{7}$$

Formulas (7) and (2) define the upper limit of the "corridor" of movement, and the possible regime of equilibrium level flight with the velocity V_∞ and the angle of bank g

$$H = \frac{1}{b} \ln \frac{r_0}{r}\ [\text{m}] \tag{8}$$

To calculate the lift coefficient C_y in the hypersonic flight phase as a zero-order approximation, the ASP can be considered as a flat plate [2], with the angle of attack a. And then according to Newton theory for incompressible liquid

$$C_y = 2 \sin^2 a \cos a \tag{9}$$

The angle a can be obtained from the relation, in which the coefficient C_y reaches the maximum value in the hypersonic flight C_{ymax} =0.77.

The next equation can be used to calculate the lift coefficient C_y in hypersonic flight phase for the ASP type like “Space Shuttle” [3]

$$C_y = C_{y0} + C_{y1} a = 0.1449 + 0.02924 a \tag{10}$$

In hypersonic flight phase corresponding to Mach number M ≥ 12 the angle of attack is a = 39°, and then gradually decreases to a = 10°.

FV must also have required landing aerodynamic properties. The most important parameter is the landing speed,

$$V_L = \sqrt{\frac{2}{r s_y}} \tag{11}$$

which usually makes $V_L \approx 100$ mps and the angle of the landing glide path

$$q_L \approx \arctan \frac{1}{K} \tag{12}$$

We list some characteristics for “Buran”: K_{max} = 5.6; $q_L \approx 12°$; s_y = 0.000235; C_{yL} = 0.76; for ASP “Space Shuttle”: K = 4.4, C_y = 0.9 at a = 18°.

It is interesting that the decision was made for the first test flight of ASP "Buran" to change the project and abandon two jet engines. The experience of this ASP showed that the use of the propulsion system which allows to make level flight at a speed of M <2 is a big problem. Although it would require a lot of work including the conditions of orbital flight, according to the authors' opinion, this selection of project has the prospect of use of the propulsion system.

Strength limits are specified overloading normal to the longitudinal axis of the aircraft (in the associated coordinate system), n_y, and it is given by

$$n_y = \frac{X_a \sin a + Y_a \cos a}{mg} \tag{13}$$

here we can define constraints on the value of the dynamic pressure,

$$\frac{rV^2}{2} \le \frac{n_y mg}{S(C_x \sin a + C_y \cos a)} \tag{14}$$

We use again the data from ASP "Space Shuttle":

$$C_x = C_{x0} + C_{x1}a + C_{x2}a^2 = 0.07854 + 6.1592\times10^{-3}a + 6.21408\times10^{-4}a^2 \tag{15}$$

$$n_y \le (1.5....2.5) \tag{16}$$

Bottom border of the descent motion from orbit will also be determined not exceeding the maximum temperature on the surface of the aircraft. This restriction is the most important and the most difficult feasible one/

ASP slows down by 30-50 mps after the braking pulse and moves about 30 minutes to "touch" the boundary of atmosphere, where the conditions of flight become very tough. The temperature before leading edges of fuselage and wing in the shock wave can reach up to 10,000°C. The most part of generated heat dissipates in the atmosphere, but its small part, reaching FV surface, causes its considerable heating. The time of movement at peak of thermal loading amounts about 15-17 minutes. For a preliminary estimate of the temperature on FV surface, T_w, it is possible to use specific heat flux q which is often the case in the design of hypersonic aircraft [4], [5]

$$q = Cr^a V^b \tag{17}$$

where q is the heat flux on the surface [W/m^2], and r is the density of the air flow at the estimated height [kg/m^3], and C [m$^{0.5}$], a and b are values depending on the point of the surface, the flow pattern, temperature and other factors.

Maximum temperature on the surface will be reached in the case of full heating structure when all convective heat flux q_c falling on the surface and heating are reflected into space. This assumption is adopted when calculation is simple enough to get results with allowed deviation,

$$q_c » q » \sigma\varepsilon T_w^4 \tag{18}$$

where $\sigma = 5.67\times10^{-8}$ W/(m^{2}K^4) – Stefan-Boltzmann constant, and e is the emissivity of the surface, depending on the material processing and surface temperature; $e = 0.8$ for considered types of ASP.

$$T_w = \left(\frac{Cr^a V^b}{es}\right)^{1/4} \le T_{w\lim} \tag{19}$$

We set some of initial parameters C, a, and b for different parts of ASP. For the heat flux in the complete stagnation areas (leading edges of the fuselage and wings), q_N can be derived from the relations in [4]:

$$C = 0{,}000183\frac{1-\frac{h_w}{h_0}}{\sqrt{R_N}}; \quad a=1/2; \quad b=3 \tag{20}$$

where R_N is the leading edge radius [m], and h_w, h_0 are enthalpy on the surface ($h_w = c_{pw}T_w$) and of free stream ($h_0 = V_\infty^2/2 + c_p T_\infty » V_\infty^2/2$), respectively.

Since the temperature T_w is not calculated, and considering $h_w << h_0$, we can use a simple equation substituting Eq. (20)

$$C = 0{,}000183\frac{1}{\sqrt{R_N}}; \quad a=1/2; \quad b=3 \tag{21}$$

The heat flux on the upwind surface of the aircraft (q_{FP}), which is treated as a flat plate, is in accordance with [5] in the case of laminar flow and $M_\infty \sin f > 1$:

$$C = 2{,}53\times 10^{-5}\frac{\sin f\sqrt{\cos f}}{\sqrt{x}(1-h_w/h_0)}; \quad a=1/2; \quad b=3{,}2 \tag{22}$$

where f is the local angle of the longitudinal axis relative to the free stream (the local slope of the surface plus the angle of attack), x is the distance from the critical point, as measured along the surface of the body.

When assessing the heat transfer at the leading edge of swept wings and tail, we calculate the heat flux q_{LE} associated with the sweep angle c and angle of attack α [5]:

$$q_{LE} = \sqrt{\frac{(q_N\cos c)^2}{2} + (q_{FP}\sin c)^2}\cdot\cos a \tag{23}$$

for the wing of ASP “Space Shuttle” and “Buran”: $R_N \approx 0.15$ m, $\chi = 45$ °, in the area of extension on leading edge, $\chi = 81°$.

Thus allowing for the determined trajectories and chosen the parameters of aircraft, which provide the required path, the lower limit of the entrance corridor of ASP will be determined by the dependence of $r_\infty^{\,a}\, V_\infty^{\,b}$.

Fig.1 shows the calculated “corridor” of reentry to the given equations and rating data for the trajectory of the ASP “Space Shuttle”.

As important as the specific heat flow, the integral characteristics of heat flow that determine the warm-up design are still a key factor to the concept and construction of ASP.

The problem of unsteady heat conduction is usually solved in one-dimensional equation,

$$\frac{\partial T}{\partial t} = a\frac{\partial^2 T}{\partial n^2} \tag{24}$$

here the boundary conditions are

$$q_c = -seT_w^4 + l\,\frac{\partial T}{\partial n}, \quad n = 0 \tag{25}$$

$$\frac{\partial T}{\partial n} = 0, \qquad n = d \tag{26}$$

where Eq. (25) represents the heat balance on the outside of thermal insulation and the Eq. (26) suggests adiabatic condition on the inner surface of the heat shield; n – normal to the surface; a – coefficient of thermal heat protection $a = l/c\rho$; l – thermal conductivity [W/mK]; c – specific heat capacity [J/(kgK]; r – density of the heat-shielding material [kg/m^3]; d – thickness of heat protection [m].

According to Eq. (24)-(26) and the condition that the temperature at the boundary of the inner surface of the heat shield (for load-carrying construction) $T_{n=d} = T_s$ is within the limits of temperature allowed for the skin construction – T_{slim} which is determined by the required thickness thermal protection,

$$Q = \int q dt \Rightarrow T_S \le T_{S\,\text{lim}} \tag{27}$$

We can estimate many parameters of ASP including feasibility of the project as a whole and the "weighted" balance equation. For this end, if we consider a normal airplane, it is convenient to use five main components of the mass, m_i, i.e.

- m_{St} – mass of the structures;
- m_{En} – mass of the engine;
- m_{Fu} – mass of fuel;
- m_{Im} – mass of the equipment, supplies, instrumentation, service load;
- m_{PL} – mass of payload.

The first three components are directly dependent on m_0. The fourth component is determined for the flight mission of the aircraft and it can be estimated at the stage of technical proposal. The fifth component is an independent one that is defined from the requirements of the project. In the case of the application of thermal insulation, there is additional component that also depends on the total mass – m_{TPS}. Thus, in general, the initial mass of the ASP can be written as follows:

$$m_0 = m_{PL} + m_{Im} + m_{St} + m_{En} + m_{Fu} + m_{TPS} \tag{28}$$

This equation expressed in terms of relative mass, can be significantly more useful to solve design problems, and it has been called "the equation of weight (mass) existence" of FV

$$\sum m_i = 1 \tag{29}$$

where $m_i = m_i / m_0$ is the relative masses of the ASP components.
Using Eq. (21) we can perform a preliminary assessment of the mass of the aircraft using statistical data

$$m_0 = \frac{m_{PL} + m_{Im}}{1 - (\overline{m}_{St} + \overline{m}_{En} + \overline{m}_{Fu} + \overline{m}_{TPS})} \tag{30}$$

To estimate m_{Eq} in a new project, we can conditionally classify this value to the category of mass related to m_0, and then use other equation written below

$$m_0 = \frac{m_{PL}}{1 - (m_{St} + m_{En} + m_{Fu} + m_{TPS} + m_{Eq})} \tag{31}$$

Obviously, the project can be realized only if

$$m_{St} + m_{En} + m_{Fu} + m_{TPS} + m_{Eq} < 1 \tag{32}$$

By analyzing the average value of characteristics of ASP “Space Shuttle”, $m_0 \approx 100$ tonnes, then mass balance equation will be the following:

$$m_{St} + m_{En} + m_{Fu} + m_{TPS} + m_{Eq} + m_{PL} = 0.25+0.03+0.1+0.1+0.22+0.3 = 1 \tag{33}$$

Thus for “Space Shuttle” three sustainer rocket engines weighing about 12-13 tonnes should be classified to m_{Im}. And two jet engines AL-31 on the "Buran" weighing 1530kg×2 to be used for landing should belong to m_{En}.
Let us consider the mass of the heat shield, as the least studied, which accounts for about 10% of the mass of ASP (for all five ASPs of “Space Shuttle” this mass is different). Heat shield

covering the entire outer surface of ASP, works on the effect of radiation of heat from the outer surface and retention of internal heating due to the low thermal conductivity of thermal insulation, which allows using traditional materials in aircraft construction. The entire wetted area A_w of the FV can be represented consisting of five components (see fig. 2):

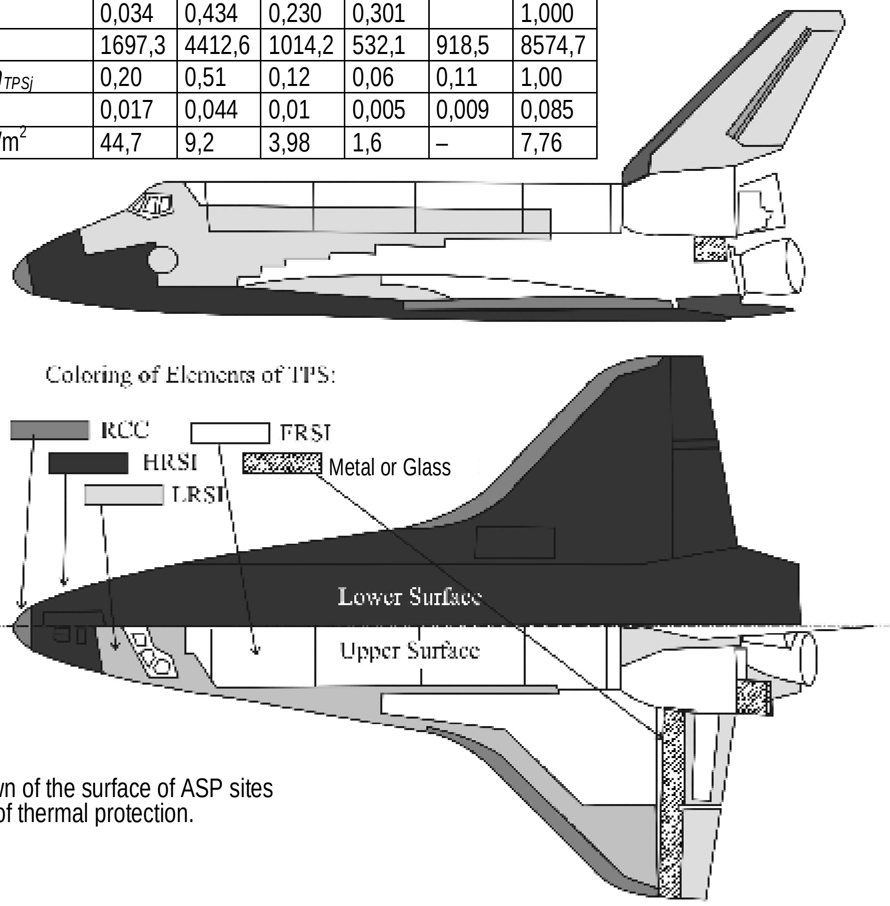
– the front edges suffering the maximum heat and shock (area A_1);
– zones of "upwind" side with area A_2 which account for the bulk of the heat load;
– zones partially "windward" and where necessary to ensure high standards for aerodynamic shape of the unity (A_3);
– areas "downwind" (shadow) with area A_4;
– special (non-standard) zones (A_5)

So,
$$A_w = A_1 + A_2 + A_3 + A_4 + A_5 \qquad (34)$$

Each region of ASP uses a different type of heat protection, and designed maximum temperature and operating area of each are listed in Table 1.

Table 1 Characteristics of Thermal Protection System (TPS) of ASP "Columbia" of 1996

Symbol of Zones	A_1	A_2	A_3	A_4	A_5	Total
$T_{w\,lim}$, °C	1650	1260	648	371	–	
Type of TP	*RCC*	*HRSI*	*LRSI*	*FRSI*	–	
Area – A_j, m^2	38	479,7	254,6	332,7		1105
The relative area – $\bar{A}_j = A_j / A_w$	0,034	0,434	0,230	0,301		1,000
Mass – m_{TPSj}, kg	1697,3	4412,6	1014,2	532,1	918,5	8574,7
The relative mass – $\bar{m}_{TPSj} = m_{TPSj}/m_{TPS}$	0,20	0,51	0,12	0,06	0,11	1,00
The relative mass $m_{TPSj} = m_{TPSj}/m_0$	0,017	0,044	0,01	0,005	0,009	0,085
Specific mass $\rho^*_{TPSj} = m_{TPSj}/A_j$, kg/m^2	44,7	9,2	3,98	1,6	–	7,76



RCC – Reinforced Carbon-Carbon;
FRSI – Flexible Reusable Surface Insulation;
HRSI – High-temperature Reusable Surface Insulation;
LRSI – Low-temperature Reusable Surface Insulation.

Fig.2. The breakdown of the surface of ASP sites with different types of thermal protection.

The values from Table 1 can be used to estimate the mass of the new ASP for this type of thermal insulation and layout scheme. On the face it is fairly straightforward, but we must remember the so-called law of the "square-cube" raised by Galileo more than three and a half centuries ago, who explained the zoom feature - two objects that are similar in shape but different in size will have a different ratio of the area of external surface to volume (at the

same density); the larger objects have smaller surface to volume ratio than smaller objects. In aviation, this law is always very important to designers, as the size of the aircraft proportionally increases, the unit load on the wing and the relative weight of the construction linearly increase. Creating a giant aircraft to overcome the law of the "square-cube" is managed by new scientific and technological developments in the aviation industry.
Consider the function of the law of the "square-cube" for mass thermal protection which changes the dimension of the new ASP at the side of "Space Shuttle" having input scale coefficient

$$k_l = \frac{l_{New}}{l_{SS}} \tag{35}$$

where l_{New} and l_{SS} are the characteristic dimensions of the new ASP and "Space Shuttle" respectively. Obviously, in the case of the same type of thermal insulation or other equal specific characteristics, there is a change of relative mass m_{TPS}

$$m_{TPS} = \frac{m_{TPS\,New}}{m_{0\,New}} = \frac{r^*_{TPS}\,A_{wNew}}{r_{BKC\,New}\Theta_{New}} = \frac{r^*_{TPS}\,k_A(k_l l)^2}{r_{BKC\,New}k_\Theta(k_l l)^3} = \frac{m_{TPS\,SS}}{k_l}\frac{r_{TPS\,SS}}{r_{BKC\,New}} \tag{36}$$

where k_A, k_Θ are coefficients relating the surface area A and volume Θ with the characteristic size l: $A = k_A\,l^2$, $\Theta = k_\Theta l^3$.

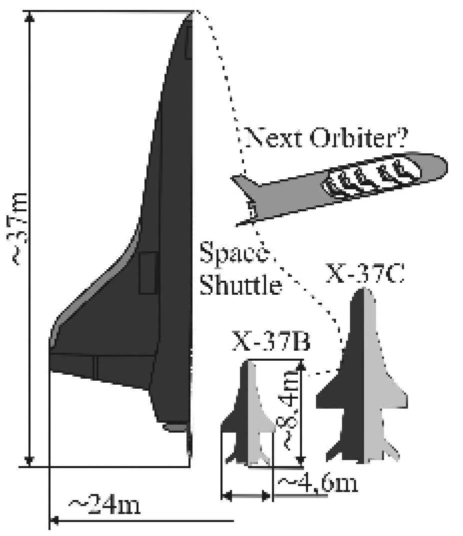


Fig.3. Comparison in scale of different types of ASP

To verify the relationship, we assess unmanned ASP X-37B, which is similar to its "big brother" Space Shuttle, but has a much smaller scale: such as length of 8.4 m and wingspan of 4.6 m (see fig. 3). Experts see into X-37B, developed by Boeing, a prototype of future space interceptor. This test FV having the mass about 5 tonnes represents convenient means for working off of the concept of new ASP and its first successful flights in terms of correctness of the chosen technical solutions.
Come back to the top of this article and notice the question of linkage between a project of ASP and missile-rocket, so it is impossible to miss the successful use of commercial transport system Atlas-5, developed by Lockheed Martin in the initiative, to deliver X37-B to the orbit. The main distinguishing feature of the Atlas-5 is the modular approach, providing cheaper launches. The decrease in the cost of the carrier is aiming at orienting thrust motor and search engines, used to search landing airport of ASP. At the first stage, Atlas-5 adopts the well developed bicameral Russian RD-180, based on the four-chamber RD-170 and RD-171 used in the missile-rockets "Energy" and "Zenith". Taking length and wingspan as characteristic sizes, we get scale ratio of X-37B to the ASP "Space Shuttle":

$$k_l = \frac{L_{X-37}}{L_{SS}} = \frac{8{,}4}{37}\dots\frac{4{,}6}{24} \approx 0{,}27\dots0{,}19 \tag{37}$$

When we reduce the size of ASP, the relative mass of thermal protection will increase in accordance with Eq. (36), technical problem is raised as well. Seeing this, size of ASP can not decrease easily, on the contrary causing many problems. The situation equals providing a higher density of FV, reducing the volume and, consequently, the area of the outer surface.

Analysis of smaller ASP through Eq. (20-23) shows that the proportional reduction of the leading edge radius will increase heat flux, and consequently increase the temperature on the outer surface of the ASP heat shield. This will require other, more heat-resistant or heat-proof materials. Radius of fuselage fairing of X-37B is 0.7 m, thus the surface temperature will increase by about 200 ° C compared to “Space Shuttle”. This will require other, more heat-resistant or heat-proof materials. Given that X-37B began three decades after “Space Shuttle”, it definitely has an impact on the new features in the study of thermal protection. Smaller curvature of leading edges will reduce the drag coefficient and hence increase the aerodynamic qualities, and thus increase the equilibrium time for aerospace vehicle in hypersonic flight phase in accordance with Eq. (7), at last it will expand the working range. But the increase of warm-up time will make the aircraft apparently abandon aluminum alloys, and require more heat-resistant materials in the primary structure (titanium alloys, stainless and heat resisting steel).

We estimate the possible values of the relative masses of X-37B with reference values from Eq. (33). In comparison with ASP "Space Shuttle" it will concern mainly a heat-shielding. In compliance with (36), having chosen from (37) k_l = 0.2 and $\rho_{\text{ASP SS}}/\rho_{\text{ASP New}}$=1/2.5, we will receive $m_{TPS\ \text{X-37B}}$ =0.2.

More dense arrangement for X-37B is quite obvious, as there is no so huge cargo bay with density $\rho_{\text{C.B SS}}$ = 29500/340 [kg/m^3] and pressurized cabin of volume 75 m^3, occupying a large part of the aircraft. As time of X-37B flight can reach nine months, and missions of shuttles were limited only to two weeks, more fuel is required, for this purpose we will double m_{Fu}. The rest of the relative masses remain unchanged. We estimate the mass of payload X-37B using Eq. (31)

$$m_{Pl} = \frac{m_0}{1-(m_{St}+m_{En}+m_{Fu}+m_{TPS}+m_{Eq})} = \frac{5000}{1-(0{,}25+0{,}03+0{,}2+0{,}2+0{,}22)} \approx 500\text{кг} \quad (38)$$

The obtained value is in good agreement with published data about this aircraft.

Consider the possibility of creating a conceptual ASP, delivered to low reference orbit by launch vehicle of the middle-heavy class such as "Proton" and "Atlas-5", the characteristics of which are shown in Table 2.

Table 2. Characteristics of carrier rockets "Proton" and "Atlas-5"

Launch vehicle	Maximum mass output pay load, tonnes	Start up cost, $ millions
«Proton»	~ 22	~100
«Atlas-5»	~ 30	~187

Conclusion

The students of Nanjing University of Aeronautics and Astronautics have developed a conceptual design of ASP “Orbiter Salvor” with using of systems CATIA, ANSYS, and Fluent. Fig.4 shows the placement of ASP on the rocket (4*a*) and its 3D model (4*b*).

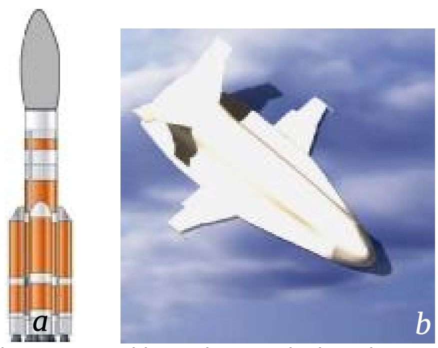


Fig. 4. ASP “Orbiter Salvor” on the launch vehicle (*a*) and its projection in the 3D model (*b*)

The change of height and speed during descent of ASP from height of 120km to speed M=3 is presented in fig.5. Taking the space for the staff of 5-6 people and adapter module into account, the volume of the pressurized cabin will be 25-30 m^3.

Total length and payload of ASP are intended to be 18m and 3t. After analyzing the relative masses of the same category, we take corresponding relative masses in the

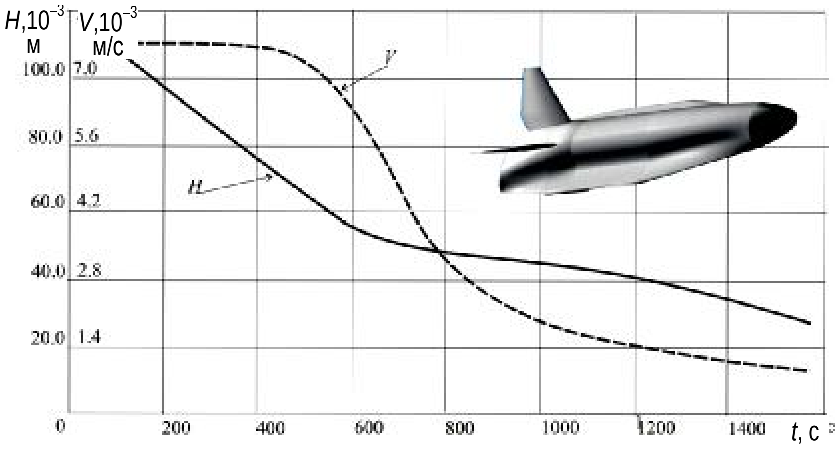


Fig.5. The time history of the altitude and velocity in the reentry ASP "Orbiter Salvor" on a hypersonic mode of moving.

following values: m_{St}=0.3; m_{En}=0.1; m_{Fu}=0.2; m_{TPS}=0.15; m_{Eq}=0.1, we obtain approximate initial mass $m_0 \approx 20$ t, which is well within the carrying capacity of considered rockets.

The main features of the project are the following:

1. The used heat-resistant power screen, which is the structural basis to store all the components of ASP (fig. 6*a, b, c*).

2. Modular design of aircraft, allowing a minimal cost to rebuild the ASP in different ways: unmanned flight, manned transportation, lifesaving, travel (fig.6, *c* – removable payload module).

3. Telescopic pull-out aerodynamic bearing surface (fig. 6*a*, *b*), resulting in a working state at speed to appropriate M <2…3.

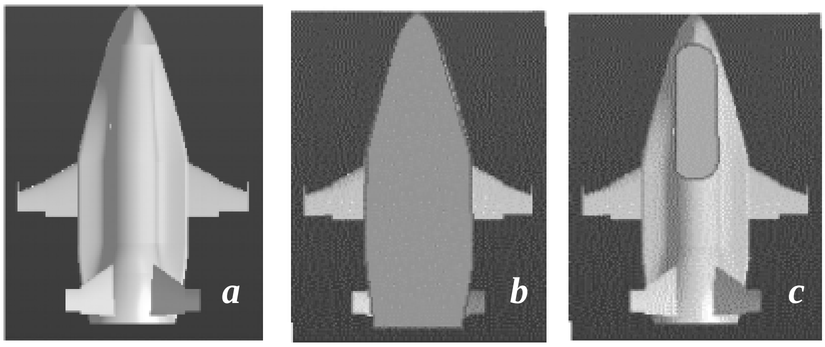


Fig.6 Project "Orbiter Salvor"

4. The turbojet engine RD-33 with turning vectored thrust (fig.7), which has been successfully used in the plane MiG-35.

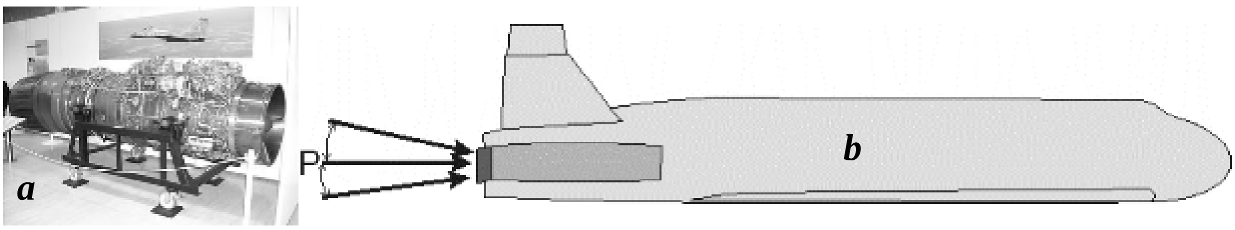


Fig.7. Turbojet engine RD-33 with turning vectored thrust control (*a*) and its layout on the ASP (*b*).

The modular approach will certainly lead to an increase in structural mass (m_{St}=0.3), but will provide a multifunctional ASP as well.

Turbo engine RD-33 installed inside ASP with the maximum thrust of 50 kN and mass of about 1 tonne will provide the complete aircraft capabilities. Lift-drag ratio for subsonic flight regime is K_a = 6-7, which will be enough to use 70% of the maximum engine thrust for a level flight. The relative mass of power plants and volume of fuel will increase: m_{En} =0.1, m_{Fu} =0.2. Vectored thrust control improves the maneuverability of the aircraft, which is normally limited to the fixed control surfaces such as wing and V-tail (after their extension). Sliding consoles are necessary for increase of aerodynamic quality of FV on a super- and subsonic modes of flight. Despite essential complication of the design, it will allow to save the mass of TPS as on the inside load-carrying construction in the hypersonic regime. Besides, FV dimensions are decreasing that is important for the launch by means of the carrier rocket.

From fig. 8, there is an example of placing the X-37 under the fairing of the launch vehicle Atlas-5, designed for a maximum diameter of 5 m.

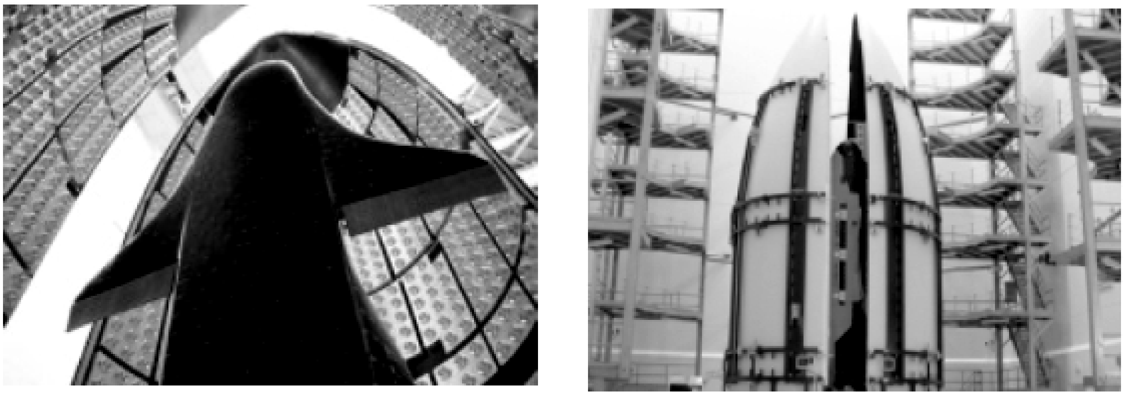


Fig.8. Unmanned ASP X-37 under the fairing of the launch vehicle Atlas-5.

The use of heat-resistant shield-screen, designed for a maximum working temperature up to 1800 ° C, will allow to expand the initial "corridor" descent of ASP in the atmosphere and make this part of the movement easier than “Space Shuttle” and “Buran” (fig. 1).
Performed numerical experiments showed good aerodynamic opportunities of this ASP (fig. 9).

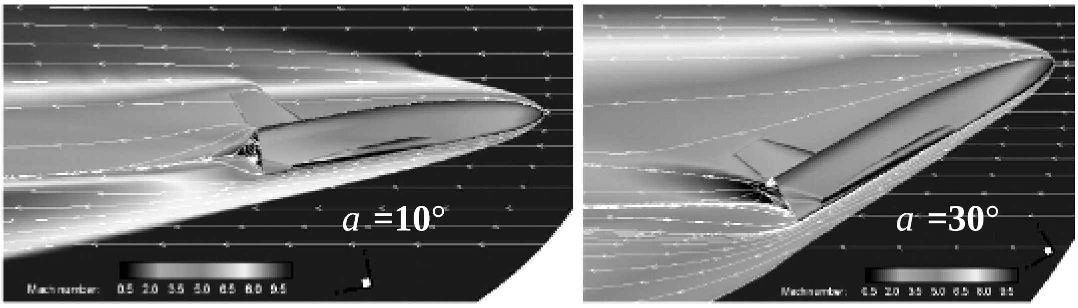


Fig. 9. Calculations of aerothermodynamics of ASP “Orbiter Salvor” at the angle of attack *a* – α = 10 °; *b* – α = 30°.

The versatility of this project of ASP will allow to use it for space tourism. Now the cost of a full-fledged space tour (it is not a sub-orbital flight of Virgin Galactic and Space Adventures) is about 30-40 million dollars. Also a new service is developing - space tourist spacewalk which will cost about 15 million dollars. Even under the circumstances of this ASP used only for space tourism, all the costs will be paid back in 3-4 years.

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To problem of modelling bolides flight in Earth atmosphere

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The subject of work is connected with modelling bolides flight in Earth atmosphere. It is considered on example of study of trajectories of the mass centre of a non-homogeneous solid ball, under the assumption that resistance by the surrounding medium is the only external force present. Interplay between translational and rotational motions is taken into account in the analysis. The system of differential equations describing the motion of the ball is decomposed into three independent subsystems via a convenient change of variables. Thus the initial problem is reduced to analysis of one nonlinear second-order dynamical system and subsequent quadratures. Solutions of the second-order system are analyzed, and steady regimes of motion are found, including motion in a straight line, self-exciting oscillations and autorotation. Bifurcation points defining these regimes are obtained. Qualitative phase portraits are constructed and their interpretation is given. An analytical representation of the trajectories of the mass centre is obtained for typical values of parameters.

1. Introduction

Describing the movement in air of the so-called “poorly streamlined” bodies remains a relevant problem in the context of qualitative description of trajectories of meteors and their fragments [1, 2]. High-velocity motion of an absolutely rigid body in a homogeneous medium at rest, with no other forces present (deceleration) has been discussed previously in [2, 3]. A complete model of the flight of a bolides requires accounting for multiple factors (such as heat and mass transfer, loss of mass, change of shape of the body, formation of non-stationary aerodynamic reaction, etc.). It is therefore of special interest to study this problem for a relatively simple body, such as a non-homogeneous solid ball whose mass centre does not coincide with its geometric center. In this case, it is possible to obtain qualitative descriptions of the trajectories of the mass centre using methods of classical mechanics.

In the description of the aerodynamic reaction on a ball, a phenomenological approach was used in [4], taking into account only the main qualitative features of the formation of this reaction. It was shown in [3] that for a body of general shape, no translational straight-line deceleration regime is possible. Here, we study planar motion of a non-homogeneous solid ball (i.e., not a general-shape body). In this case, the abovementioned regime is possible; however, other regimes also appear. Parametric analysis and construction of the corresponding trajectories of the mass centre constitute the essence of the current study.

2. Formulation of the problem and equations of motion

A non-homogeneous solid ball moves in a homogeneous fluid (air), which is at rest, subject exclusively to aerodynamic forces. We assume that neither the mass, nor its distribution within the body, nor the geometry of the body change in the process of motion.

The mass centre G of the solid ball does not coincide with its geometrical center C (fig. 1), and the distance r between them is larger than a certain positive value. Also assume that one of the principal central axes of inertia of the ball is orthogonal to the line CG. In this case the ball can execute plane motion, with both points C и G moving in this plane. We restrict our investigation to a family of such plane motions.

Introduce a fixed coordinate system Oxy in this plane and also the König’s coordinate system Gx^*y^*, whose axis are parallel to the corresponding axes of system Oxy.

To describe the reaction of the medium on the ball, we use the quasi-static approach [3-5]. The line of action of the aerodynamic force $\boldsymbol{R}$ passes through the center C of the ball. The

direction of this force is opposite to that of the velocity $\mathbf{V}_c$ of the point *C*, and the magnitude of this force is proportional to the square of the absolute value of V_c.
Introduce the following notations (fig.1) for <u>constant quantities:</u>

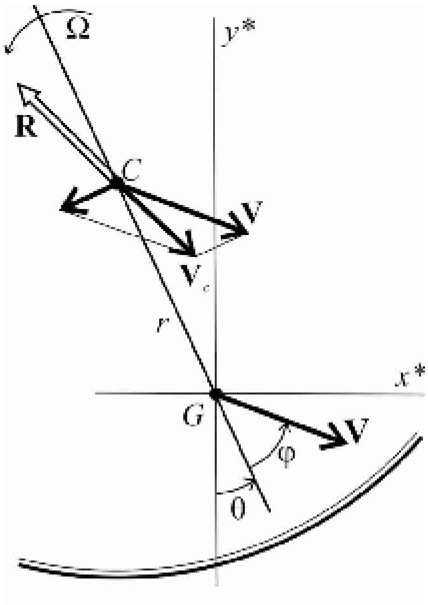


Fig.1

m – is the mass of the solid ball;
J – is central moment of inertia about the axis orthogonal to the plane *Oxy*;
r – is the distance between the points *C* and *G.*

Furthermore, introduce notation for the following <u>variable quantities:</u>

V – is the velocity of the mass centre of the ball;
V_c – is the velocity of the geometrical center of the ball;
R – is the magnitude of the total aerodynamic force, with $R = sV_c^2$, where *s* is a constant;
j – is the angle between vector ***V*** and line *CG*;
q – is the angle of rotation of the ball in the plane *Oxy*,
Ω – is the angular velocity of rotation of the ball about the axis orthogonal to the plane *Oxy*;
x, *y* – are the coordinates of the mass centre in the fixed coordinate system *Oxy*.
The dot denotes the derivative with respect to time *t*.

Without loss of generality assume that the axis *Ox* is follows the vector $\mathbf{V}(0)$, so that $q(0) + j(0) = q_0 + j_0 = p/2$.
Equations of plane motion of the body can be written in the following form*:

$$\begin{cases} m\dot{V} = -sV_c(V - r\Omega \sin j), \\ mV(\dot{j} + \Omega) = srV_c\Omega \cos j, \\ J\dot{\Omega} = srV_c(V \sin j - r\Omega), \\ \dot{q} = \Omega, \\ \dot{x} = V \sin(q + j), \\ \dot{y} = -V \cos(q + j) \end{cases} \tag{1}$$

Equation (1) is a closed system of coupled nonlinear differential equations. Using a known transformation [1-3] this system can be written in dimensionless parameters. Let the following relation hold for the "new" time variable t : $dt = Vdt/r$. Introduce the following new dimensionless variables:

$$w = r\Omega/V \quad \text{and} \quad u = V/\overline{V} \tag{2}$$

where $\overline{V}$ is a certain characteristic value of speed – for example, the speed of sound. Introduce new parameters ***a*** = *sr/m*, ***b***=*mr*²/*J*.

*) Three first equations of the system were obtained in [3]. There was, unfortunately, an error on page 72, where the term $\sin j$ was "missing" in the third equation. However the final results in [3] are right.

Note [3] that the density of the body significantly exceeds the density of the medium, so the dimensionless parameter a is positive and a << 1. The second dimensionless parameter b characterizes the displacement of mass centre relative to the geometrical center.

The following relationship holds: $V_c = V\sqrt{1-2w\sin j + w^2}$, and the system (1) is separated into three independent subsystems:

$$\begin{cases} j' = -w(1 - a\cos j\ \sqrt{1-2w\sin j + w^2}), \\ w' = a\sqrt{1-2w\sin j + w^2}\ [w - w^2\sin j + b(\sin j - w)] \end{cases} \tag{3}$$

$$\begin{cases} q' = w, \\ x' = \sin(q + j), \\ y' = -\cos(q + j) \end{cases} \tag{4}$$

$$u' = -au(1 - w\sin j)\sqrt{1-2w\sin j + w^2} \tag{5}$$

Here, prime denotes the derivative with respect to t , and x, y are normalized coordinates of the mass centre.

Clearly, system (3) must be solved first to find $j(t)$, $w(t)$, following which each of the equations in system (4) is solved consecutively, in quadratures, to provide the trajectory of the mass centre. Note that due to the choice of the coordinate system and change of variables, this trajectory does not depend on the value of dimensionless velocity of the mass centre. The velocity of the mass centre is determined from equation (5), also via quadratures, after solving system (3). Thus the main task is to study system (3).

The phase space of system (3) is a phase cylinder, and its phase trajectories are symmetric about the origin; therefore, it is sufficient to study phase trajectories in the domain Q: $-p \le j \le p$, $w(t) \ge 0$.

3. Stationary points

Let us first find the stationary points of system (3) in the domain Q. These points correspond to motions of the body with constant angle of attack and a fixed relation between angular speed of the body and the speed of its mass centre.

Coordinates of the stationary points solve the following system transcendental equations:

$$\begin{cases} w(1 - a\cos j\ \sqrt{1-2w\sin j + w^2}) = 0 \\ w - w^2\sin j + b(\sin j - w) = 0 \end{cases} \tag{6}$$

It is easy to see that (6) has three trivial solutions in the domain Q, which correspond to three stationary points:

$$\text{O}\,(w = 0,\ j = 0),\quad \text{N}_1\,(w = 0,\ j = p),\quad \text{N}_2\,(w = 0,\ j = -p) \tag{7}$$

(Clearly, the points N_1 and N_2 represent images of the same point N, which is “cut” on the phase cylinder.)

The system (6) has exactly one more nontrivial solution j_*, w_*, which corresponds to two stationary points A(j_*, w_*) and B($-j_*, -w_*$). This solution can be approximately represented in the following form:

$$w_* \approx 1/a,\quad j_* \approx a(1-b) \tag{8}$$

Thus for any values of the parameters, there are four stationary points of the system (3) on the phase cylinder: O(0, 0), N(0, p), A(j_*, w_*) and B($-j_*, -w_*$).

It is important to find domains of stability of these points in the plane defined by parameters a and b. The following conditions for stability of the point O(0, 0) were obtained in [3]:

$$a<1, \quad b>1 \tag{9}$$

As it was mentioned above, the first inequality always holds. The second condition will be fulfilled if the mass centre is sufficiently far from the geometrical center of the ball. Note that if conditions (9) hold, then the point O(0, 0) is a stable focus.

It was also shown in [3] that the second stationary point N(0, p) is always unstable, as expected. The point N(0, p) is a saddle point (points N_1 and N_2 in the domain Q are also saddle points).

For the points A(j_*, w_*) and B($-j_*, -w_*$), denote deviations from stationary values of the angle of attack and the angular speed as g, s , respectively. First-order approximation equations for the point A(j_*, w_*) (cf. first equation of (6)) can be represented in the following form:

$$\begin{cases} g' = -(\mathrm{tg}\, j_* + a^2 w_* \cos^3 j_*) w_* g - a^2 w_* \cos^2 j_* (\sin j_* - w_*) s \\ s' = -(w_*^2 - b) g + ((1-b)/\cos j_* - 2w_* \,\mathrm{tg}\, j_*) s \end{cases}$$

The corresponding characteristic equation can be written and exact conditions of stability of the point A(j_*, w_*) can be obtained. Here we use the approximate relations (8) to obtain simplified first-order equations:

$$\begin{cases} g' = -(2-b) g + s \\ s' = -1/a^2 g - (1-b) s \end{cases}$$

From these relations the following approximate conditions of stability of deceleration with rotation can be derived:

$$b<1.5, \quad (1-b)(2-b)+1/a^2>0 \tag{10}$$

The second of these inequalities always holds due to the assumptions made, while the first one restricts the displacement of the mass centre relative to the geometrical center. For the statio-nary point B($-j_*, -w_*$) approximated conditions of stability coincide with inequalities (10).

Henceforth we use the superscript "+"to denote a stable stationary point, and "–" for an unstable stationary point. The following configuration of dependence on the parameter b shapes up from the analysis of stability of stationary points. If $b<1.5$, then we have O^+, N^-, A^-, B^-; for $1<b<1.5$, it is O^+, N^-, A^+, B^+; finally for $0<b<1$, we have O^-, N^-, A^+, B^+. Note that in the second case, when $1<b<1.5$, there are three attractors on the phase cylinder (O^+, A^+ and B^+) and one saddle point (N^-). Hence there has to exist at least one repeller, or, more precisely, a pair of symmetrical repellers which separate the basins of the two attractors. These repellers could either be cycles entirely contained within the net of the phase cylinder, or cycles enveloping the phase cylinder.

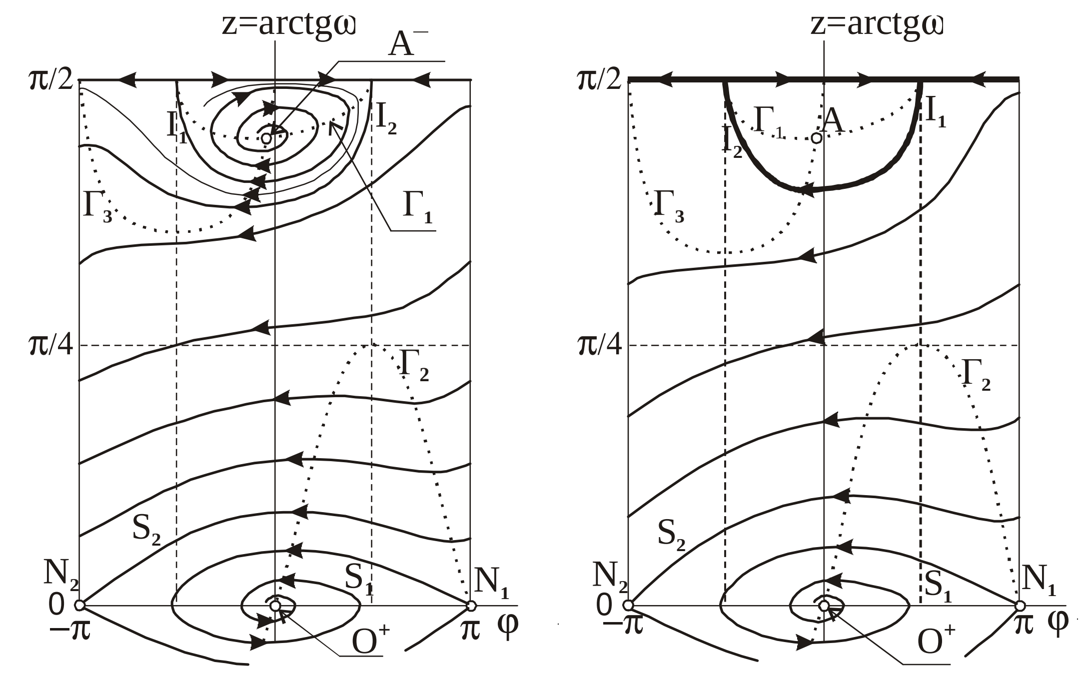
4. Parametric analysis

For the parameter a the following holds a << 1, and variation of the value of this parameter has only a very small effect on the behavior of the system. Thus we fix the value $a=0.001$

and focus on a detailed discussion of the impact of the parameter b on the evolution of the phase portrait. As it was established above, there are at least two critical values of this parameter, $b = b_5 \approx 1.5$ and $b = b_3 = 1$ (the reason for this particular enumeration will become clear below), which trigger qualitative changes of the structure of the phase portrait. Numerical integration is used to find other critical values, for which structural changes of the phase portrait occur.

Fig. 2 – Fig. 4 show sketches of phase portraits for different values of the parameter b. For convenience, the value $z = \mathrm{arctg}\, w$ is plotted along the y-axis. This allows to map the phase cylinder net to the strip $|z| \le p/2$, preserving symmetry. Since the phase portrait is symmetric about the origin, only its upper half is usually shown. Dotted lines represent the curve Γ_1, where $j' = 0$ holds, and the curves Γ_2 and Γ_3, where $w' = 0$ holds. Solid lines denote the following phase trajectories: S_1 (the separatrix coming out of the point N_1), S_2 (the separatrix flowing into the point N_2) and two special trajectories: the trajectory I_1 originating from the point $(-p/2,\ p/2)$ and the trajectory I_2 originating from the point $(p/2,\ p/2)$. Slim lines denote other ("regular") phase trajectories. Note that while the segment $[-p,\ p]$ of the line $z = p/2$ is the "edge" of the phase cylinder, it is also equivalent to a single point, as it represents an "inflated" singular point on the phase space, where the velocity of the mass centre, V, vanishes (however according to (1), acceleration is non-zero, so the motion continues) and the value of the angle j is arbitrary. Thus the trajectory I_2 is the continuation of the trajectory I_1.

We start with the case $b > b_5$. In this case we have O^+, N^-, A^-, B^-. The corresponding phase portrait is shown in Fig. 2a. The trajectory I_1 which flows into the abovementioned "inflated" point for $j = -p/2$ leaves it as the trajectory I_2 when $j = p/2$. All phase trajectories, except for the separatrix S_2 which flows into the point N_2, are drawn towards the origin.



a) b)

Fig.2.

The point A^{-} is an unstable focus. Thus in the case $b > b_5 \approx 1.5$, for almost all initial conditions, the ball ends up in the regime of stable translational straight-line deceleration, with the mass centre in front of the geometrical center of the ball.
As the value of the parameter *b* decreases, there is little variation in the trajectories S_1 and S_2, while trajectories I_1 and I_2 "converge". For a certain value b=b_4, close to b_5, trajectories I_1 and I_2 merge into one (Fig. 2b). It corresponds to a trajectory enveloping the phase cylinder and closed through infinity ($w = \infty$). Thus this trajectory can be treated as a cycle in the band $-p/2 \le j \le p/2$ of the phase plane or as a cycle enveloping the phase cylinder. Even the smallest value of w along this closed trajectory is so large that detailed study of motion of the ball in this situation would require a revision of the model of aerodynamic reaction. For this reason, the analysis of the phase portrait for values of the parameter *b* close to b=b_4 is skipped here.
The next figure (Fig. 3a) shows the configuration of the phase portrait for values of the parameter *b* in the interval (b_3, b_4). In this case we have: O^{+}, N^{-}, A^{+}, B^{+}. Here trajectories I_1 and I_2 have effectively crossed over with respect to the situation for large values of *b* (Fig. 2a). The point A becomes stable; in particular, the trajectory I_2 now tends to A. The stability of the point A may change according to various possible scenarios, but a detailed study of this process is skipped due to the reason mentioned above. The origin O remains stable. The basins of these two attractor points are separated by a repeller trajectory R^{-}, which corresponds to an unstable rotational regime of motion of the ball. The figure shows how this unstable cycle R^{-}, enveloping the phase cylinder, originates from a limit closed phase trajectory. This cycle "descends" from infinity as the value of the parameter *b* decreases from b_4 to b_3. The ball tends to the regime of stable translational straight-line deceleration only for those initial conditions which correspond to the phase points located below the trajectory R^{-}. The set of such initial states becomes smaller as the value of the parameter *b* decreases from b_4 to b_3.

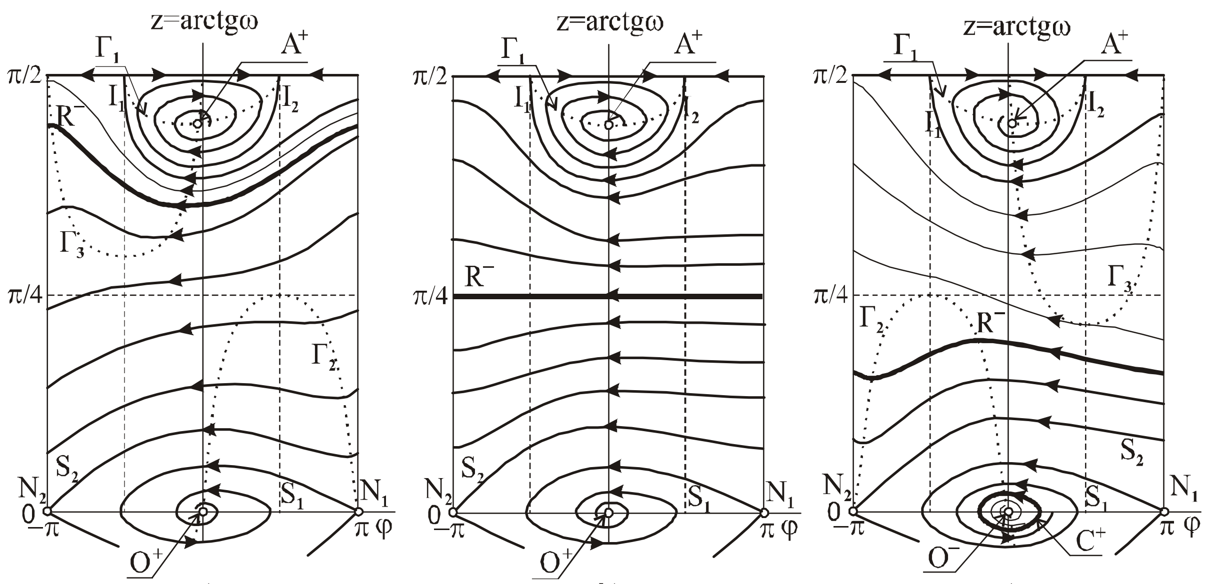


Fig.3.

A remarkable structure emerges when b=b_3=1: the dimensionless angular velocity is constant ($w(j)\equiv 1$, corresponding to $z(j)\equiv p/2$) on the cycle R^{-}, and a Hopf bifurcation occurs in the origin O, which is approximately a center. More detailed analysis of stability of this point for b=1 is of no interest. The phase portrait is shown in Fig.3b.

For $b<b_3$ the origin is unstable, and further decrease of the value of b causes the expansion of the attracting limit cycle C^+ created by the bifurcation mentioned above (Fig. 3c). In this case we have: O^-, N^-, A^+, B^+. The stable limit cycle C^+ separates point O^- and two unstable R^-. This configuration of the phase portrait persists, with further decrease of the value of the parameter b, until it reaches $b=b_2 \approx 0{,}653$. This means that when $b\in(b_2, b_3)$ we have, for all initial states from the phase domain below the trajectory R^- (except for the origin O), the ball tending to a stable self-exciting oscillation regime with a finite amplitude of angle j . This amplitude grows monotonically with the decrease of the value of b.

The trajectory R^- descends further as the parameter b becomes smaller. For $b=b_2$ this trajectory "lands" on the separatrices S_1 and S_2 and forms a loop out of them. This is shown on Fig. 4a. Thus stable self-exciting oscillations are produced only for those initial states where the corresponding initial phase points are located within this loop.

For $b<b_2$ an unstable cycle C^- is created from the loop of separatrices. This cycle shrinks as the value of the parameter b decreases. For $b=b_1\approx 0{,}648$, the phase portrait changes its structure one more time. The structure of the phase portrait for $b\in(b_1, b_2)$ is shown in Fig.4b. As the value of the parameter b decreases towards b_1, the cycle C^- shrinks and the cycle C^+ continues to expand. For $b=b_1$, these cycles merge, and the regime of self-exciting oscillations disappears. For $b<b_1$ all phase trajectories except S_2 and O^- tend to one of the stable points A^+ or B^+.

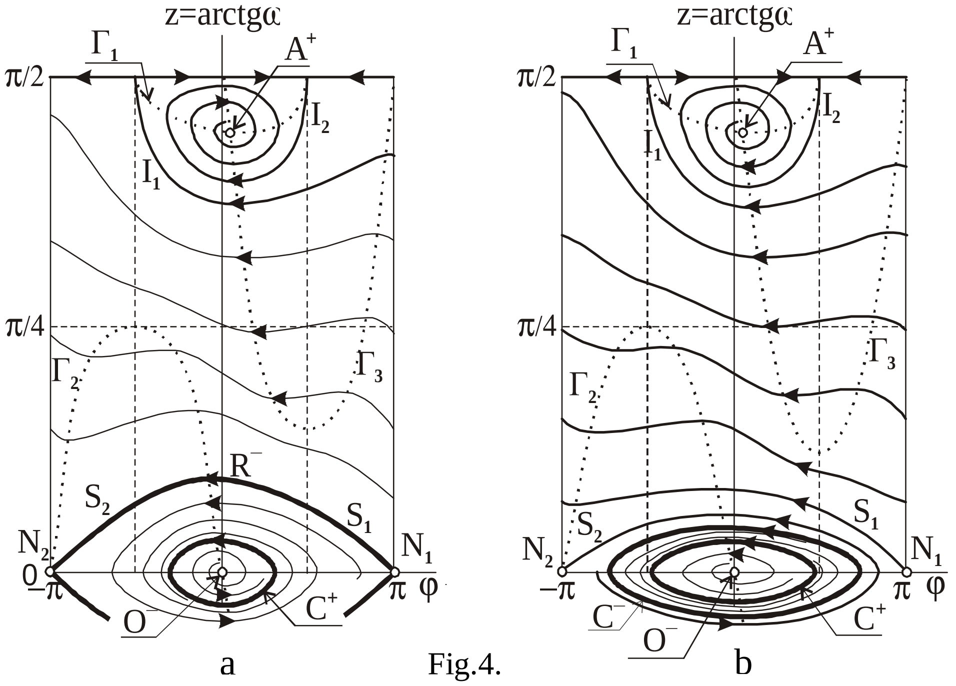


Fig.4.

For $b<b_2$ an unstable cycle C^- is created from the loop of separatrices. This cycle shrinks as the value of the parameter b decreases. For $b=b_1 \approx 0{,}648$, the phase portrait changes its structure one more time. The structure of the phase portrait for $b\in(b_1, b_2)$ is shown in Fig. 4b. As the value of the parameter b decreases towards b_1, the cycle C^- shrinks and the cycle C^+ continues to expand. For $b=b_1$, these cycles merge, and the regime of self-exciting oscillations disappears. For $b<b_1$ all phase trajectories except S_2 and O^- tend to one of the stable points A^+ or B^+.

Note that the results of our analysis of the phase portrait of system (4), obtained for $a = 0.001$, are robust, so that the qualitative representation remains the same even if the parameter a varies within a certain interval.

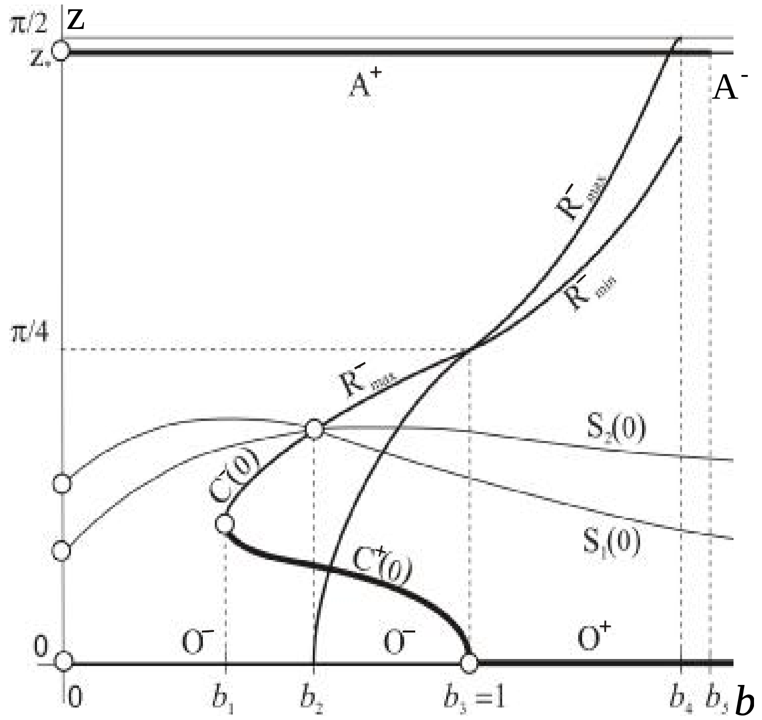


Fig.5.

All the bifurcations discussed above are collated and presented qualitatively in Fig. 5 (drawn not to scale). Here the parameter *b* is on the *x*-axis, while the *y*-axis shows characteristic values of the variable $z = \operatorname{arctg} w$ (e.g., its minimum value along a periodic trajectory, with respect to an angle j , or its value for $j = 0$) for main "skeleton" trajectories S_1, S_2, R^-, C^+, C^- and at the stationary points O^+, O^-, A^+, A^-. Solid lines correspond to stable states and regimes of motion.

This integrated representation allows seeing clearly how the important features of the behavior of the system depend on the parameter *b*.

The neighborhood of the point $b = b_4$ is shown in a quite schematic way following the comment above about high values of the variable w, which are beyond the area of applicability of the assumed model of aerodynamic reaction.

5. Trajectories of the Mass Centre

As it was shown in [3], the point O corresponds to the regime of translational straight-line deceleration for which the mass centre is in front of the geometrical center, and the point N corresponds to a similar regime, but when the geometrical center is in front of the mass centre. In both of these cases, the velocity decreases and tends to zero exponentially (in distance traveled), as it can be seen from equation (5).

Stationary points A and B correspond to the motion with a constant angle of attack (although in different directions) and a constant dimensionless angular velocity (so that the ratio of the absolute values of angular velocity to that of the velocity of the mass centre is constant). In addition, the velocity of the mass centre in this regime decreases and tends to zero, as it follows from the equation (5), so this regime corresponds to deceleration with rotation. It could be easily seen, following the integration of equations (4), that the mass centre of the ball moves in a circle of constant radius of order *a*. Such regime has hardly any practical meaning, but it should be taken into account in the description of the tendencies of the behavior of the trajectories.

Finding the trajectories of mass centre corresponding to periodic phase trajectories is of particular interest, and especially for the unstable trajectories R^-, C^- and the stable trajectory C^+, since they represent, in a sense, boundary cases.

Let us study the case $b = 1$ in more detail, when the phase trajectory $w(j) \equiv 1$ exists. A special feature of the motion of the ball in this case is the existence of isolated time instants when the center of the ball momentarily stops, causing the aerodynamic force to vanish as well. For the ease of further calculations, introduce a new variable $y = p/2 - j$. Equations (3) – (4) for the given trajectory become

$$\begin{cases} y' = 1 - 2a\sin y \left|\sin\frac{y}{2}\right|, \\ q' = 1, \\ x' = \cos(y - q), \\ y' = -\sin(y - q) \end{cases} \qquad (11)$$

Each of the variables in equations (11) can be found, in succession, as functions of time. Let an initial value $q(0) = q_0$ be given. Using the above we obtain: $y(0) = y_0 = q_0$, $j(0) = j_0 = p/2 - q_0$ (Fig. 6).

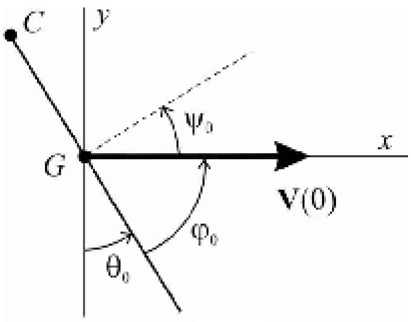


Fig. 6

Given that $a << 1$, we construct an approximate solution, in the form $y^{(0)}(t) \equiv t + q_0$. Substituting this function into the right-hand side of the equation gives

$$y(t) = t + q_0 - 2a\int_0^t \sin a \left|\sin\frac{a}{2}\right| da$$

The integrand is a $2p$ -periodic function. After integration, the approximate solution to the first equation in (11) can be represented in the following form:

$$y - q \equiv y(t) - q(t) = -\frac{8}{3}a\left(\left|\sin\frac{t + q_0}{2}\right|^3 - \left|\sin\frac{q_0}{2}\right|^3\right)$$

Write the first approximation (with respect to the parameter a) of the solution of the third and fourth equations in (11):

$$x(t) = t\ , \quad y(t) = \frac{8}{3}a\int_0^t \left(\left|\sin\frac{t + q_0}{2}\right|^3 - \left|\sin\frac{q_0}{2}\right|^3\right)dt \qquad (12)$$

The Fourier series for the first term under the integral sign is:

$$\left|\sin\frac{x}{2}\right|^3 = \frac{1}{p}\left\{\frac{4}{3} + \frac{1}{2}\cos\frac{x}{2} - \frac{4}{5}\cos\frac{2x}{2} - \frac{5}{6}\cos\frac{3x}{2} + \frac{4}{35}\cos\frac{4x}{2} + \frac{1}{2}\cos\frac{5x}{2} + \ldots\right\}$$

Substituting this expansion into (12) gives

$$y(t) = \frac{8a}{3}\left\{\left[\frac{4}{3p} - \left|\sin\frac{q_0}{2}\right|^3\right]t + f(t)\right\} \qquad (13)$$

where the following notation for the periodic part of the integral is used:

$$f(t) = \frac{1}{p}\left[\sin\frac{t + q_0}{2} - \frac{4}{5}\sin\frac{2(t + q_0)}{2} - \frac{5}{9}\sin\frac{3(t + q_0)}{2} + \frac{2}{35}\sin\frac{4(t + q_0)}{2}\ldots\right]$$

Using relations (12) and the secular term in (13) we obtain the following functional representation of the averaged trajectory of the mass centre,

$$y = \frac{8a}{3}\left(\frac{4}{3p} - \left|\sin\frac{q_0}{2}\right|^3\right)x \qquad (14)$$

In particular for a=0.001 and q_0=0, the equation for this trajectory has the form $y \cong 0,00113x$. Thus for the chosen initial conditions, the mass centre moves "almost" along a straight line directed at a small angle to the left relative to the initial velocity (this is also the limiting case). The geometrical center of the ball rotates around the center of mass, and the angular velocity of the ball is constant, $w \equiv 1$.

As the initial value q_0 increases, this angle decreases and reaches zero when $q_0 = \pm 2\arcsin\sqrt[3]{4/3p} \approx \pm 1.7$ (note that this value does not depend on a). For larger values of q_0 the straight line (14) begins to deviate to the right, and the maximum angle is reached when $q_0=p$. The “furthest right” straight line is described by $y \cong -0{,}00153x$.

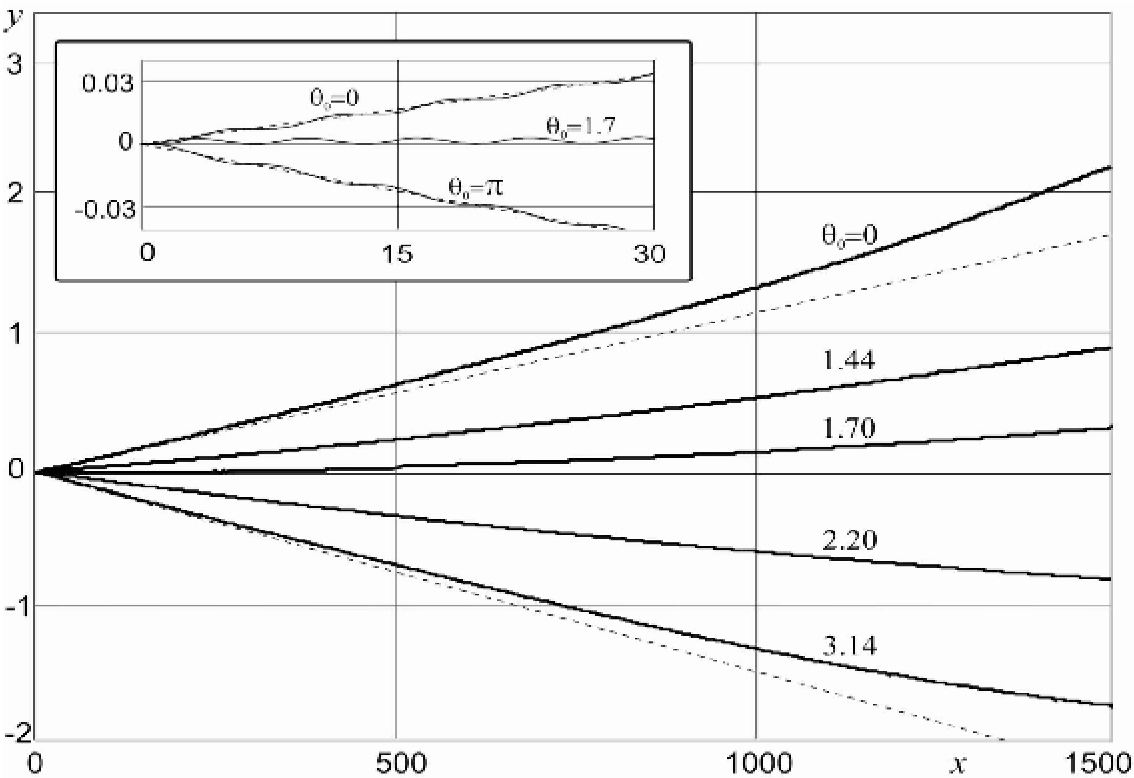


Fig. 7

Formulas (12)–(14) define the first-order approximation of the trajectory of the mass centre, with respect to the parameter a. They are valid for a starting interval $t \sim 1/a$. Rather than construct further approximations analytically, we turn to numerical methods.

Fig. 7 shows a family of trajectories for different values of initial angle q_0, which appear next to the corresponding trajectories. Solid lines represent trajectories obtained via numerical computations and dashed lines represent those obtained via the formula (14). The box shows the initial segments of these trajectories in larger scale. In all cases, a deviation to the left from the initial “averaged” direction, given by expression (14), can be detected. Note that the direction of this deviation is determined by the direction of the rotation of the ball and in fact coincides with it. This is natural, since for $w > 1$, the resulting motion is a rotation of the mass centre of the ball in a circle in the same direction.

Remark. Recall that the quantity w characterizes the difference in direction between the velocities of points C and G. When w is too large, the center of rotation is located inside the ball. In such cases the assumed model of aerodynamic reaction is hardly applicable. Nevertheless the stationary point (7) serves as a basic element for the construction of the phase portrait of the dynamical system (3).

6. Conclusions

Application of the classical quasi-static approach [3 – 5] to the motion of a non-uniform solid ball in fluid allowed to identify some nontrivial properties of this motion. In particular, instability of the translational motion and tendency towards an increase of amplitude of oscillations can be a possible explanation for the following well-documented phenomenon: cannonballs shot from medieval (smoothbore) weapons continued to rotate even after falling on the ground. Rotation and resulting oscillations of the velocity were probably responsible for the effects found in the experiments [6] with high-speed flying balls. Studying the periodical trajectories for other values of the parameter $\boldsymbol{b}$ is beyond the scope of this work.

Note that although the force $\boldsymbol{R}$ is only partially dissipative, it is still potent enough to cause the angular velocity of the ball to decrease, too. Note as well that the curving of the trajectory in this problem is similar to the one caused by the Magnus force, yet this force has not been taken into account in our model. We note the all these results are important for problem of modelling bolides flight in Earth atmosphere.

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About modelling interaction of Earth with large space object: the script with explosion of Phaeton and the subsequent evolution of Mankind (part I)

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This work is devoted to problems and methods of modelling in a problem of interaction of large space object with the Earth, including processes of capture of a body by the Earth, dynamics of a body and the Earth, geodynamics, dynamics of Earth atmosphere, dynamics of oceanic masses, … and the subsequent evolution of a human society on the Earth [1-89]. On the basis of careful studying an extensive historical material, with the description of the physical and social processes occurred on the Earth and in near Earth Space, the author builds model of interdisciplinary processes, considering corresponding natural-science and sociopolitical subsystems as parts of Unity in whole. Thus all technique is applied to the processes connected with catastrophic event of super-Tunguska class, namely the explosion over southern Denmark of the space object known in Greek mythology as Phaeton. The Deucalion Flood and the demise of the Minoan civilization are also explained within this context. The Phaeton explosion may be seen as the final event of the interaction of Earth with a captured external body, lasting possibly a few months, resulting in the disasters known as the Ten Plagues of Egypt and in worldwide migrations, particularly the Indo-Aryan migration from north-western Eurasia to India and Iran.
Also in this paper we consider the passage of the Red Sea by the Hebrew tribes during Exodus, as described in the Bible. Using additional information from the *Antiquities of the Jews* by Josephus Flavius, a crucial passage in *Historiae Adversus Paganos* of Orosius, and other classical sources, we claim that the passage of the Red Sea was made possible by local effects in the Gulf of Aqaba of a indicated catastrophic event in the super-Tunguska class.
In this Journal issue it is published the article part (part I); part II of article will be presented in next issue (No.2, v.19, 2014), with Appendixes, with discussion of mathematical modelling problems in considered processes.

Some preliminaries

The second book of the Bible, named Exodus, contains some of the best known and most extraordinary tales of the whole Bible. The book deals with Moses who aged 80, returns to Egypt after an absence of 40 years, mainly spent in the Arabian region of Madian. His return is motivated by the proposal to lead the Hebrew away from Egypt, where they were being mistreated, into the land of Canaan, i.e. the *land of honey and milk.* This is the land that God promised to Abraham and his descendants, wherefrom they had left some 200 years before, at the time of a great food shortage, when Joseph, son of the patriarch Jacob, had a high position in Egypt. The task to lead the Hebrew away from Egypt was given to a recalcitrant Moses by God, who had spoken to him on a certain *Mountain of God*, from a *burning bush*. Moses obtains permission to leave Egypt against the initial opposition of the Pharaoh after ten disasters, the famous Ten Plagues of Egypt, strike Egypt, apparently after Moses invoked the power of his God against the refusals by the Pharaoh. Moses takes the Hebrew to the direction of the land of Canaan by a much longer way than the usual one. While the Hebrew are still far away from Canaan, they discover that an Egyptian army is pursuing them, in a point where apparently there is no escape. A windy night descends, and before sunrise they see that the level of the sea has lowered, allowing them to walk on former seabed. Once they have passed the sea, they watch the Egyptian troops pursuing them over the seabed. Then, apparently after Moses lifted the special baton that God had given to him on the Mountain of God, they watch as first the chariots of the Egyptians are destroyed, losing their wheels, then the whole army is drowned by the returning waters.
There have been different explanations in the literature about the extraordinary facts told in the Exodus story, the withdrawal and return of the waters of the Red Sea being particularly of interest for exegesis. Here we recall some:

– the orthodox/fundamentalist claim, where the events are seen as pure miracles, performed by Moses who had the power to modify the laws of nature;

- the symbolist explanation, typical of many Fathers of the Church, see e.g. Gregory of Nissa *Life of Moses* [1], and albeit to a lesser extent Philon [5], where the events are considered essentially as allegories related to virtue or sin;
- the approach of several modern scholars, like Finkelstein and Silberman [2] or Liverani [3], who deny the Bible the traditionally attributed antiquity, claiming that it was composed after the Jews returned to Jerusalem (following the permission given by Cyrus to return home to all people that had been deported by the Assyrians or the Babylonians). Reason to compose the Bible, where many events are pure inventions according to this approach, was the desire of the Jews to show that they too had an ancient history as the people they had met during the exile;
- the approach of scholars who think that the events appearing as miracles may have been special natural events; among such scholars we recall Ricciotti [4], Barbiero [6], Goedicke [7], Velikovsky [8], De Grazia and Milton [9], see de Vaux [10] for an extensive list of such approaches.

The solution that we propose in this paper belongs to the last category. It is based upon the following working hypotheses:

1) the considered ancient documents are basically faithful descriptions of real events, apart from generally not important corrections to be made for errors in the translation or in the transmission; omissions, more than plain falsities, are more typical features;

2) in ancient times our planet underwent catastrophic events of external origin; the events associated with Exodus, in particular with the passage of the Red Sea, correspond to the last of the three great catastrophes (among many others) that according to Plato affected the Earth, namely the Deucalion catastrophe. Notice that the first catastrophe in Plato is the one associated with the destruction of Atlantis (also ending the last Ice Age, see Spedicato [11]), while it can be argued that the second catastrophe was the Universal Deluge associated with Noah, Ziusudra/Utnapishtim, Manu…

A connection between Exodus, Deucalion, Phaeton and the migration of the Aryans into India was suspected by Velikovsky [12], who apparently had never read Orosius [16], where such a relation is provided, albeit in an implicit form. We use this connection to a fuller extent arriving at a natural explanation of the above events, at the light of the present knowledge about the consequences of the explosion in the atmosphere of a super-Tunguska object. Our solution apparently has never been considered before. It is consistent with the geographical and physical information in the Bible. It gives also a new explanation for the end of the Minoan civilization, removing the eruption of Thera as the main cause of such an event. It confirms the claim of Velikovsky that the Amalekites are the Hyksos who ended the Egyptian Middle Kingdom, to be further identified with the Amu people who often attacked Egypt during the Middle Kingdom. We provide a geographical origin for the Amu and a motivation for their attack to Egypt.

1. Textual information about the passage of the Red Sea and related events

Our solution of the problem of the passage of the Red Sea, namely where and how it happened, is based upon the following ancient documents. It is likely that there are additional significant data that we have not considered, since we have read only part of the *Legends of the Jews* collected by Ginzberg [13], we have not looked at Jewish texts as Midrash or Talmud, we have only skimmed the huge corpus of the Fathers of the Church and have ignored the Islamic scholars; also investigation of Indian, Chinese and Mayan documents may be useful. However it appears that a satisfactory solution can be obtained on the basis of the textual information that we give here.

From the second book of the Pentateuch, Septuaginta Version, our translation from the French version in [14], section 14, lines 15-31:

And the Lord said to Moses: Why do you call me? Tell the sons of Israel to move the camp. And you, lift you baton, direct your hand towards the sea and open it, so that the sons of Israel enter in the middle of the sea walking on dry seabed. And I will harden the heart of the Pharaoh and the Egyptians, who will enter the sea after them. And I will be glorified due to the Pharaoh, his army, his chariots and his horses. The angel of God who moved in front of the camp of the sons of Israel changed position and went behind them. The column of smoke also changed position and passed behind them, stopping between the camp of Israel and of the Egyptians. Darkness descended and the night passed without contact between the two groups. And Moses lifted his hand over the sea, and the Lord pushed away the sea by a strong wind from the south, for the whole night, which dried the sea and divided the water. The sons of Israel entered the domain of the sea walking on the dry bottom, the water being for them a wall on the right and a wall on the left. The Egyptians started to follow them and entered the domain of the sea after them, all the horsemen and the chariots. Now it happened, at the morning watch, that the Lord looked towards the camp of the Egyptians, within the column of fire and clouds, and put the camp of the Egyptians in disarray, blocked the wheels of their chariots and agitated them with violence. And the Egyptians said: Let us run away from Israel. Because the Lord is fighting against us on their behalf. The Lord said to Moses: Stretch your hand over the sea, so that the water comes back and covers the Egyptians, their chariots and their horsemen. Then Moses stretched forth his hand over the sea and by sunrise the water came back to its former place; the Egyptians were running against the water and the Lord threw them in the middle of the sea. And the returning water covered the chariots, the horsemen and all other part of the army that had entered the sea after these; not a single man survived. But the sons of Israel walked over the dry seabed, the water being for them a wall at the right and a wall at the left.

From the Book of the Psalms, from Edizioni Piemme (1989), based upon the CEI text of 1974, our translation, Psalm 113A/114:
When Israel left Egypt
….
The sea saw and withdrew
The Jordan inverted his course
The mountains jumped as rams,
The hills as the lambs of the flock.

From Josephus Flavius, *Antiquities of the Jews*, [14], II, 3:
(Moses)... did not lead his people by the direct route to Palestine, but decided to take a long and difficult way through the desert to invade Canaan. He was also motivated by the order given by God to lead his people to Mount Sinai to make there sacrifices to Him. However the Egyptians caught up with the Hebrew, closing them in a restricted area … they blocked all roads wherefrom they thought the Hebrew could escape, constraining them between the sea and inaccessible mountains; it was the sea where the mountain ended, a quite steep one; they thought it was impossible to escape by this way. Stopping close to the point where the mountain joined the sea, they blockaded the Hebrew….

From Ginzberg *Legends of the Jews*, volume 4 of Adelphi edition, [15], pp. 140-165:

Joseph had divided into three parts the riches made when selling the grain during the time of food shortage, one part being deposited in the sanctuary of Baal Sefon; from here it was taken away by the Hebrew [led by Moses].
…when he arrived to the sanctuary of Baal Sefon the Pharaoh was happy to notice that the statue of the God had not been destroyed, contrary to what had happened in the other temples; he offered sacrifices thinking that Baal Sefon agreed with his aim to destroy the Hebrew.
…..
Moses addressed God: Lord of the world! ... I do not know how to save my flock. Following me is the Pharaoh, north is Migdol, south is Baal Sefon, and in front of us is the sea.
……
The people of Israel left the sea ….they moved towards the desert of Sur, full of snakes and scorpions … they began protesting because of scarcity of water … they found a source but the water was bitter … [Moses] threw a branch of laurel in the water and it became sweet … this place Mara became famous … from Mara the Hebrew moved to Elim, where there were seventy palms and twelve springs, a very dry and sandy place … They stopped there several days …
The *Legends* contain interesting material, to be used in a forthcoming paper, on the following events occurring on the way to the Land of Canaan, after the episodes described here:

- Moses goes to Horeb where he makes the miracle of the water pouring out of a rock;
- Moses defeats Amalek;
- Moses meets his father in law Iethru;
- Moses gets the laws from God on Mount Sinai.

Now we quote statements from Orosius [16], *Histories against the pagans,* which have been crucial for our understanding of the passage of the Red Sea, the Ten Plagues of Egypt and other events. Orosius was a friend of St Augustin. He wrote this work, once famous but now essentially neglected, on the invitation of Augustin in the peace of his villa in the Balearic islands, when the Roman empire was under attack by German tribes. The quoted passages are from Book 1, 8-10, our translation.

810 years before the foundation of Rome Amphithion was king in Athens. At his times a flood destroyed most of the people of Thessaly. Only a few could save themselves on the mountains, in particular on the Parnassus which was under the jurisdiction of Deucalion … Plato states that at that time Ethiopia was affected by many terrible diseases, which almost destroyed the whole population … at that time Father Liberus conquered India shedding lot of blood and killing many people … against a nation that was never hostile to others and lived peacefully …
Pompeus [Trogus] and Cornelius [Tacitus] state that 805 years before the foundation of Rome, terrible disasters and diseases affected the Egyptians … they expelled Moses … he stole the sacred objects of the Egyptians … Cornelius Tacitus refers that … a pestilence deforming the bodies developed in Egypt at the time of king Boccoris, who after consulting the oracle of Ammon was ordered to deport out of Egypt certain people disliked by the gods … Moses, one among the expelled people, admonished his people to confide only in him, as a leader sent by the celestial power …
There were extreme heats, long lasting and unbearable; it was unusually hot in Ethiopia and the Scythians were unable to bear the hot weather.

This was also the reason why some people, not willing to recognize God's absolute power, have invented the ridiculous fable of Phaeton, in order to provide an explanation that is however lacking of basis.

On Deucalion:

From Plato's Critias, see [19], and notice that from the Greek way of counting inclusively the sentence *the third before that of Deucalion* means three deluges including the one of Deucalion *(the one of Atlantis)…the third terrible deluge before that of Deucalion.*

In other authors, e.g. Ovid's *Metamorphosi*, see [36], the Deucalion story appears to be mixed with the story of a previous more severe flood, where few people survived in boats, a type of survival not compatible with the events that we associate with Phaeton.

On Phaeton:

From Hesiodus, *Theogony*, 984-989, our translation from [45]
…Aurora … generated a glorious child to Kephalos, the powerful Phaeton, wholly similar to the gods … he was still a young boy…when Aphrodites who loves the smiles stole him and fled with him…

From Plato's Timaeus, the Egyptian priest of Sais speaking to Solon, see [19]:
Your own story of how Phaeton, child of the Sun, harnessed his father's chariot but was unable to guide it along his father's course and so burnt up things on the Earth and was himself destroyed by a thunderbolt…

From Ovid's *Metamorphoses*, I, 751 passim:
Phaeton, the son of the Sun … he moves below the Moon … higher parts of Earth burn … towns burn with their walls … the mountains with their forests … rivers boiled … the crust of Earth broke … then the all powerful father sent a thunderbolt against Phaeton, destroying him, and stopping the fire with this fire … the chariot disintegrated … and fell over the great Eridanus…

On the Eridanus river:

From Herodotus, speaking of the extreme tracts of Europe towards the West, Book III, 115, see also Cunliffe on the voyage of Pytheas [17]:
I cannot speak with any certainty; for I do not allow that there is any river, to which the Barbarians give the name of Eridanus, emptying into the northern sea where, as the tale goes, amber is produced…

From Lucianus *Dialogues of the Gods*, 24-25, our translation from [20]:
What have you (Helios) done, most disgraced of the Titans? You destroyed everything on Earth, by giving the chariot to a stupid youngster who burnt parts of the Earth … and ruined others with cold … if I would not have stricken him with my thunderbolt mankind would have been destroyed … let his sisters put him to rest near the Eridanus, exactly where he fell when thrown out of the chariot, let them cry tears of amber and become poplars…

From the above texts we extract the following geographic and physical information leading to our proposed explanation:

1 Before the passage of the Red Sea Moses and the Hebrew were located in a place between the sea and impassable mountains, with the Egyptians blocking the escape way (from Josephus *Antiquities*); the place was located between Baal Sefon, at the south, and Migdol, at the north (from Ginzberg *Legends*). While the Hebrew was desperate considering the difficulty of their situation, a strange phenomenon was observed in the

sky: the *Angel of God* and the *column of smoke* appeared to stop and darkness came. During the night a strong wind flew from the south; close to the end of the night the sea had dried and the Hebrew could walk over the seabed. By morning time the Egyptians too entered the seabed. Then their chariots began shaking; Moses lifted his baton, the waters came back and destroyed all Egyptians who had entered the seabed (*Exodus*).

2 Mountains and hills *jumped* (*Psalm 113A*).

3 Phaeton crashed on Earth after a period of wild movement in the sky, first burning forests then being destroyed by a strike of Jupiter (Plato, Ovid, Lucianus).

4 Phaeton is said by many to have crashed over a northern river named Eridanus, in a place associated with the production of amber (Herodotus, Lucianus).

5 Phaeton is considered by many to be responsible of several catastrophic events that appear to have happened at the same time, or at close times, including an invasion of India by people who slaughtered many of its inhabitants, the Flood of Deucalion, extreme heats in Ethiopia and Scythia, and the Exodus events (Orosius).

In the next section we give our explanation of the events related to the passage of the Red Sea, within the context of a special super Tunguska type event that took place at that time. In the following sections we will briefly discuss other important consequences of the event, namely the migration of the Aryans to Iran and of the Hindi to India, the migration of the Amu-Turanians-Amalek to Egypt, the Deucalion event and the destruction of the Minoan civilization. In the Appendices we briefly consider the chronology of the events and the geography of Hebrew route under Moses.

2. Phaeton and the Exodus event: the model of Red Sea passage

We will provide here a scenario explaining the Exodus events, and the other related events quoted by Orosius, in terms of the interaction of Earth with an external object of significant size, probably a few km diameters, that we propose was the object named *Phaeton* in Greek traditions. The object was captured by our planet, entered an unstable orbit around Earth, was subject to several fragmentation episodes that sent dust to our atmosphere and pieces to explode in the atmosphere or impact on continents and oceans. The core of the object finally exploded as a super Tunguska event over the river Eider in Denmark. The effects of the explosion reached the shores of the Red Sea and appear as the wonderful events that are described in the above quoted Exodus passages. In particular such effects allowed the Hebrew to escape from an impasse while destroying the pursuing Egyptian army. We recognize that the idea of an external body being responsible for the Exodus events was present in Velikovsky [8] albeit in terms a planetary entity (a young Venus being a giant comet) that passed close to Earth. We do not attribute the considered events to a close passage of a planetary size comet, albeit it is quite possible, even likely, that the captured body was a former small satellite of the young Venus in the radical solar system scenario proposed by Velikovsky and later developed by Ackerman [27, 28]. We believe that Velikovsky, a scholar of immense erudition and unusual and balanced insight, missed the scenario that we propose because apparently he never read Orosius (one of the few classical authors who escaped his voracious reading). Moreover, he was not aware of the effects of a cometary-asteroidal impact that have been studied only later, when the existence of Apollo-type objects in orbit of collision with Earth became well known, following the important paper of Whetherill [29] in Scientific American in 1979. Our theory validates all main points in the biblical texts, explains the data from Greek and Latin mythology about Phaeton and Deucalion. It identifies the most recent of the three great catastrophes that according to Plato affected our planet (the Atlantis event being the most ancient, to be associated in our opinion, see [11], with the catastrophic end of the last ice age), and provides a motivation for the great migrations that took place in Eurasia at the time of Exodus (Hindi-Aryans, Amu-Amalek-Hyksos, Danai-Achaeans-Trojans). It follows from our scenario that the claims of Finkelstein et al. that the Exodus story is later invention are unfounded. It also rejects the attempts made to explain the Exodus events in terms of a great eruption of the Santorini/Thera volcano, whose explosion may have occurred at the time of the described events.

According to Exodus, Moses obtains from the (unnamed) Pharaoh permission to leave Egypt after the last of the Ten Plagues that affected Egypt during a period of probably several weeks. It is not here the place to discuss the plagues in terms of events related to the action on Earth by a body that was captured in an unstable orbit around Earth, got probably fragmented when entering the Roche limit, so that several fragments hit the Earth, causing earthquakes and leading many volcanoes to erupt, while associated dust obscured the Sun and led to dramatic drop in temperature at the high latitudes. An eruption at Santorini, located some 950 km from Eliopoulos, the very ancient sacred Egyptian centre, is possible, but it is unlikely that it was the cause of phenomena like the waters of the Nile becoming red and poisonous or the sky completely darkened. There are indeed a few volcanoes in the Mediterranean, almost all of them in Italy (*Italia* being a word probably derived from the Greek *Aithalia*, meaning the *smoking land*, from volcanic activity, see Vinci [21]), but we must take into account the existence of several volcanoes in the Arabian peninsula and especially in the Danakil depression between Ethiopia and Eritrea. Here, at a distance of about 2100 km from Heliopolis, there is the highest concentration of volcanoes in the world, about one hundred, many of them of small size indicating a recent origin, Part of this region is called *Afar*, a name also applied to a local tribe, a word that in Acadian and Hebrew and generally in Semitic languages means *dust*, see Semeraro [22]. It is quite possible that the word *Africa* originates from *afar,* therefore meaning *the land of (volcanic) dust*, and that the Biblical word *Ophir* indicates the horn of Africa, the place of origin of dust that in ancient times was produced by the volcanic eruptions in the area, probably happening with a higher frequency than now. We could also suggest that the word *Red Sea*, *Erythreum Mare*, now applied to a sea that is remarkable for the deep blue and clarity of his waters, goes back to when frequent eruptions in the Danakil depressions led to a reddish color of its waters. One hundred volcanoes certainly could obscure the sky more that the few volcanoes in the Mediterranean might do, even if at twice the distance. Moreover since winds in Ethiopia originate from NE and SE, they would push the volcanic dust over the Ethiopian plateau, which is mostly washed by rivers ending up into the Nile. Hence during a period of intense volcanic eruption in Dankalia the waters collected in Ethiopia would be full of volcanic dust, containing poisonous components and deeply coloring them. This would thereby explain the first plague, an explanation virtually impossible if the dust came from Santorini, since such dust would mainly settle in the Egyptian desert and just remain there, no rivers entering the Nile from the Egyptian territory.

At the moment Moses leaves Egypt we assume that the core of the captured body was still orbiting around Earth, moving, as seen by the Goshen area in the Delta where most of the Hebrew were located, on an orbit that let it appear from a SE direction, i.e. from over the Indian Ocean and SW Arabia and moving towards a NW direction, i.e. over Greece and northern Europe. The SE direction is compatible with the identification of the Land of Canaan, the *Land of Honey and Milk*, where Abraham settled and Moses wanted to take back his people, that has been given by the Lebanese historian Salibi in several books [23, 24, 25] as the region of SW Arabia now called *Asir*. The identification of the land of Canaan by Salibi, based on the geographical analysis of toponima in the Pentateuch, is totally at variance with the standard identification with Palestine. It has been completely ignored by most researchers (perhaps afraid by the political implications), despite the great scholarship of Salibi, professor in the American Lebanese University in Beirut, founder of the Institute for Interfaith Studies in Amman, and widely considered as the best historian of Arabia. Our opinion that Salibi's arguments are sound has been reinforced by our analysis of the Hebrew distribution around 1175 AD according to Binyamin of Tudela, see [26]. Salibi's work is also important in removing many of the objections to the historical validity of the Bible by the quoted Finkelstein et al.

By our assumption on the orbital movement of Phaeton we have a natural explanation of the properties of the *pillar of light and smoke*. The core had to be active, as a normal nucleus of a comet close to the Sun, emitting therefore ionized dust that appeared during the day as smoke, and with plenty of thermal and electrical activity that made it source of light during the night. It is very unlikely that Phaeton was on a stationary orbit over Earth. Hence the direction where to move was given to the Hebrew by the point in the sky where the core would appear, a fact that repeated itself several times during the 24 hours, once the distance from Earth was less than the distance (circa 45.000 km) corresponding to a stationary orbit.

We will discuss in a later section our proposed itinerary for Moses that takes into account both the fact that the *pillar of light and smoke* was followed and that the route was long and difficult. We consider here the crucial day when Moses, faced by destruction from the Egyptian army, was able to cross the Red Sea, while the pursuing Egyptian army was destroyed.

From Josephus we know that Moses found himself in a restricted area between the sea and impassable mountains. This crucial passage in Josephus (a man of great knowledge to whom Titus gave the library of the Jerusalem temple, certainly containing many documents now lost) is important for two reasons:

– Moses was in a place with impassable mountains reaching down to the sea. This geographic information excludes that the event took place along the coasts of the Mediterranean, as suggested for instance by Goedicke [7] or Anati [30], since here the Sinai coast is quite flat and completely lacking of “impassable” mountains. It excludes the area of Suez or the Sinai coast along the Suez gulf, as suggested e.g. by Barbiero [6]. Phillips [31] and Manher [32], where either there are no mountains or they do not reach close to the coast (assuming that the sea level has not changed significantly since the Exodus time). It also excludes most of the coast of Arabia, which is characterized by a long narrow plane, the Tihamah, rising steeply by a series of escarpments to the western Arabian plateau, that reaches over 3000 meters in the Asir (the name of the escarpment, quite difficult to cross, is *Jordan*; a very intriguing name that is an important point in Salibi's work; quite intriguing is also that most atlases do not show this escarpment, with the exception e.g. of the Times Atlas, 1976 edition). A coast satisfying the requirement of Josephus is however the Sinai coast facing the Aqaba gulf. About half way this coast, moving north from present Ras Muhammad, the mountains, that were rising a few km inland letting a narrow coastal plain now heavily exploited as a resort area, reach down the coast, so that from near Nuweiba the road to Eilat goes inland by an inner valley crossing a pass of modest elevation (I took this way by bus in 1975 and still remember the beauty of the scenery and the pinkish color of the sands). So the passage in Josephus suggests for the crossing of the Red Sea some place about midway of the eastern coast of the Sinai facing the Gulf of Aqaba; see the section on the itinerary for a more detailed geographical proposal.

– Moses most probably had personal knowledge of the road he decided to take when leaving Egypt, which was not the usual and shortest way to Canaan. He had lived many years in Arabia after marrying Sipphorah, daughter of Iethru, a man of religious and political power in

Madian, possibly present Iathrib/Medina, not too far from the Sinai Peninsula. Notice that Sipphorah was not his first wife, since according to the ***Legends*** he had taken another wife, named Adoniah, in Kush, when he was there for military reasons; we will argue later that Kush is not Ethiopia as usually assumed, but more probably present Badakshan. As shepherds often move their flocks over long distances (Tibetan and Mongolian shepherds even recently used to move thousand km during a year), it is quite likely that Moses had traveled widely in Arabia and surrounding regions. Moreover he certainly had knowledge of regions not visited personally by talking with other shepherds or merchants, and by his previous experience as a military officer. So the fact that he found himself blockaded between the sea and impassable mountains cannot be explained by ignorance of the route he had taken. Our explanation is that since his last visit to that place, a catastrophic event had occurred, blocking the road. The event was very likely a landslide that closed the road in a point where it was passing by a narrow defile between mountains and sea. Landslides certainly occurred in the Sinai mountain area due to the earthquakes that must have affected the region during the Ten Plagues. In particular earthquakes must have occurred during the ninth plague, when there were three days of darkness, that can be explained either by volcanic dust of catastrophic eruptions (Santorini? The Arabian and Danakil volcanoes?) or by dust associated with an episode of fragmentation of Phaeton or even by impacts in the area of fragments of Phaeton (several craters of relatively recent origin are known in Iraq, Arabia and Oman, not to say of an extensive tektite field in northern Arabia; see for instance S. Master [83] about a recently found crater of a date compatible with our Exodus date). A landslide from an unstable mountain slope can be produced by a moderate earthquake, so that it is not a problem the lack of reference to an earthquake in the description of the Ninth Plague; the experienced absolute darkness was terrifying by itself. Now a landslide blocking a road requires plenty of work for removal, a feat that cannot be accomplished in a few hours or days. Even if the depth of the sea was only a couple of meters, bypassing a landslide which must have entered the sea for a certain distance would have been virtually impossible.

We have now a scenario where Moses and the Hebrew (whose number will be discussed later) were stranded in a place where they had from one side the pursuing Egyptian army and on the other side impassable mountains and the sea. Now the following sequence of events took place that will be interpreted within the context of the Phaeton event:

1. *The angel of God who moved in front of the camp of the sons of Israel changed position and went behind them. The column of smoke also changed position and passed behind them, stopping between the camp of Israel and of the Egyptians. Darkness descended …*
2. *The mountains jumped as rams, the hills as the lambs of the flock ...*
3. *And Moses lifted his hand over the sea, and the Lord pushed away the sea by a strong wind from the South, for the whole night, which dried the sea and divided the water. The sons of Israel entered the domain of the sea walking the dry bottom.*
4. *The Egyptians started to follow them and entered the domain of the sea after them, all the horsemen and the chariots. Now it happened, at the morning watch, that the Lord looked towards the camp of the Egyptians, within the column of fire and clouds, and put the camp of the Egyptians in disarray, blocked the wheels of their chariots and agitated them with violence.*
5. *The Lord said to Moses: Stretch your hand over the sea, so that the water comes back and covers the Egyptians, their chariots and their horsemen. Then Moses stretched forth his hand over the sea and by sunrise the water came back to its former place; the Egyptians were running against the water and the Lord threw them in the middle of the sea. And the returning water covered the chariots, the horsemen and all other part of the army that had entered the sea after these; not a single man survived.*

The above statements are taken from the Septuaginta version of Exodus, except for statement 2 that is from Psalms and that we have entered here because of the logical temporal sequence in our scenario. We provide the following explanation of the above events.

1. The Angel of God, associated (during the day) with smoke, is the celestial body captured in an unstable orbit around Earth, as assumed above, the Phaeton of Greek mythology. The Exodus passage appears to describe the final stage of the evolution of this body. We think it describes a final fragmentation of the body, one large piece pursuing its north-western movement that will end up in an explosion over Denmark, other pieces appearing to stop or move back over the Egyptian army, located south of the place where the Hebrew were camped, darkening the sky in the direction of the Egyptians. The event must have taken place in full day.

2. A short time after the fragmentation episode, Phaeton enters the uppermost layers of the atmosphere probably over the Mediterranean, moving however on an almost tangential orbit (a feature that characterized also the Tunguska event in 1908, the fire trail of the body having been observed over western China, hence for thousand of km). The contact with the air sent initially a heat wave to the surface of Earth. Crete was probably on the path of the body, hence fires started in its cities. Continuing on his way, Phaeton passed over Greece, the Balkans and Central Europe, at those times heavily forested. Here the heat wave led to fires in the forests. As the elevation of Phaeton decreased, the effects of air pressure and of the extremely high temperature of the body led finally to its explosion, over Eridanus. It had to be an immense explosion, incomparably more powerful than the Tunguska explosion, one that could be observed at great distance, with a bright tail extending along the temporary tube made by the body in the atmosphere (hence the claim that it had been destroyed by a thunderbolt of Jupiter). The explosion took place on the Eridanus river that can be identified with the present Eider River in Schleswig Holstein, i.e. a river in northern Europe, not the Po river of Italy. The identification with the Eider is based upon the following consideration:

a – from Lucianus, see above quoted passage, and other authors, the sisters of Phaeton cried his death by tears of amber. Now amber is found in the Northern Sea near Denmark and in the Baltic Sea, but not in the Mediterranean. The explosion must have broken the upper sedimentary layers of the sea around Denmark, freeing amber that was embedded at depths that would not be disturbed by normal waves. Hence a good byproduct of the event must have been an increase in the availability of amber. Notice that from Spanuth [33] we know that in the Middle Ages amber was more easily found that now. Even large blocks were found, that were burnt for heating if not of the best quality.

b – until the 14-th century, according again to Spanuth, the Eider river and the Schlei river were essentially connected, providing a direct access to the Baltic sea from the North river that avoided circumnavigating the Jutland peninsula. The passage was difficult in medieval times, but may have existed and been easier in earlier times and so represented one of the most important ways for navigation. Now it has been claimed by Wirth [25] that the constellations in the sky which are named usually according to animals or heroes have these names only as popular names, while their real meaning is not related to animals or heroes. They represent in reality “secret” maps of the coasts of the Atlantic and the Mediterranean or of important passages for navigation. In other terms the stars of a constellation are grouped in order to form a celestial map useful to the navigators. There is a constellation named *Eridanus*. Its shape bears no relation with the Po river but has an uncanny similarity to the profile, zigzagging, of the Eider river.

The above elements support the identification of Eridanus with the Eider river, in Denmark. We do not know at which height Phaeton exploded nor his energy. Detailed discussion of the effects of the explosion requires of course such knowledge. To leave such a memory of disaster, related as we will discuss later to the Deucalion Flood, i.e. to one of the three great catastrophes alluded to by Plato, it must have been an event of enormous power. While we discuss later some of the local effects that must have taken place in northern Europe, the following consequences are important for the analysis of the Exodus text:

A – the explosion must have compressed the soil in Denmark, originating an enormous earthquake, to be felt over much, if not all, of Eurasia and Africa, hence in Sinai. Seismic waves travel fast, between 2 and 6 km/sec depending on the type of rock they traverse. The Gulf of Aqaba being about 3500 km from the Eider river, the earthquake would have reached there say after about 20 minutes.

B – the explosion would lead to the radial propagation of a pressure wave in the atmosphere, generating a hot wind, whose temperature and speed would decrease with the distance from the point of explosion, while the duration would increase. Detailed computation of these effects is a very complex mathematical task, requiring, in addition with the information on the height and the energy of the explosion, detailed knowledge of Earth surface features and sea bottom. Preliminary estimates, but for the case of an object impacting an ocean, are given for instance in Strelitz [35]. For more discussion on this problem see Appendix 3.

From A we have an immediate explanation of the above sentence 2 in Psalms: the earthquake due to the explosion reaches Sinai with great violence shaking the mountains.

From B we have the explanation of the wind that flows during the night, for several hours. The Septuaginta text says that it was a wind from the south (while the Masoretic text refers to a wind from orient). It was neither from south nor orient (the difference in the texts being possibly explained by the strangeness of the wind that *should* have come from south, but somehow appeared as coming from another direction). Now a wind coming from the south should be a *hot* wind, since in Egypt hot winds come from south, cool winds from north, a truth by default, as we read in a passage of ***Pistis Sofia*** [34], where Jesus is supposed to speak:

… when the wind comes from the north, you know that it will be cold, when the wind comes from the south you know that it will be hot and dry …

Before proposing our explanation of the crossing of the Red Sea, we have to observe that an inspection of the terrestrial globe shows that the Red Sea, about 2000 km long, 200 km wide, ending in the narrow (about 30 km now, possibly less at time of Exodus) Bad el Mandeb straights, is perfectly aligned with the direction of radial propagation of an atmospheric wave, i.e. of a wind originating from a point say in the area of the Eider river. This means that a strong wind active for many hours over the Red Sea would push consistently the waters in the direction of its narrow exit, with two effects:

– lowering of the water level in the northern part, particularly in the Gulf of Aqaba (and of Suez);

– increase of the water level in the southern part.

In other terms we expect that the Phaeton explosion generated along the Red Sea effects similar to those today generated by the wind in the Adriatic sea (the high waters and low tides that so annoy the people in Venice), but on a much larger scale. We have therefore here a mechanism that provides for the lowering of the waters of the Red Sea, and the explanation to the statement that the sea bottom was dry, an obvious effect of the flowing of a hot wind. How much the sea lowered is impossible to say without a computation of the explosion effects (where energy and elevation of the explosion should be given as parameters) but it is clear that if the problem of Moses was how to bypass a landslide, even a lowering of the sea level by a few meters might have been enough to allow the passage.

Therefore in our interpretation the passage of the Red Sea is not intended as the Hebrew going from one coast to another, but as them bypassing a landslide by moving over a seabed suddenly become accessible and dry.

We are however unable to fully explain the passage saying that …*the Lord … divided the water. The sons of Israel entered the domain of the sea walking on the dry bottom, the water being for them a wall on the right and a wall on the left.*

However we can propose at least a partial explanation, allowing for parts of the passage to be an inaccurate rendering of the event that was experienced by people certainly bewildered by what they could interpret only as a miracle performed by the Lord on the request of Moses. The Gulf of Aqaba is mostly very deep, with a depth around 1600 meters; however in front of Nuweiba, where the passage most likely happened, the sea bottom rises reaching a level quite close to the sea surface. We cannot certainly be sure now how the Gulf of Aqaba bathymetry was at the time of Moses, this region been tectonically very active, belonging to the northern part of the Great African Rift. However we cannot exclude that the wind reduced the sea level so much as to let at least part of this rise to emerge, hence dividing the Gulf of Aqaba into two separate basins. This fact would explain the “division” of the sea. Our imagination of the event is unable now to explain the formation of the “walls”. Perhaps a different vocalization or translation of the original Exodus text that was used by the 72 senior scholars in Alexandria or by the Masorets one thousand years later might remove the problem, as is certainly the case, discussed in Appendix 2, with the number of people who followed Moses.

Once the landslide was bypassed, Moses could continue some distance on the road on the other side, likely the road to Eilat passing inland by a low pass. There is now a modern road close to the sea, built along a rocky and steep coast. It is unlikely that here a road existed at Moses time, where several thousand people could pass. So it is likely that Moses took the road inland, which moved up from the sea level, allowing safety from the return wave that led to the destruction of the Egyptian army. Also along this road there were probably good points to look at what was happening to the Egyptian army.

We now consider the destruction of the Egyptian army (whether it was a full destruction also involving the death of the Pharaoh is not stated in the Exodus text, which only claims the destruction of those who had entered the seabed). The Egyptian army saw the Hebrew walk on the dry seabed and moved in their direction. Exodus text says that the wind flew during the night, so we may now assume that it had stopped. This means that the waters pushed south towards the Bab ed Mandeb started to return to their normal position. The return of the waters was a catastrophic event itself, whose mathematical modeling would be a fascinating challenge for today’s algorithms and computers. The waters returned as a kind of rebound tsunami, probably with a turbulent high front wave. The following features are expected to characterize the arrival of the waters:

A – a moderate earthquake with peculiar soil vibrations, which would explain the loss of the chariots wheels before the water arrived, terror striking the pursuing Egyptians; note that tsunamis are not necessarily accompanied by sound, which is not recorded in the text

B – the complete washing up of the Egyptian army (save people that might have been standing in high places; among them possibly the Pharaoh) into the Gulf of Aqaba. Hence archaeological support of this scenario should be based upon existence of objects in the sea bottom of the Gulf of Aqaba that may be related to the Egyptian army: weapons, pieces of chariots, gold objects ….

The waters came back after Moses lifted his baton, so the event appeared as a miracle performed by the Lord on his call. It was not only a wonderful event but a scaring one. The wave went down the whole Aqaba gulf and certainly rebounded, so that a sequence of waves, albeit of decreasing intensity, must have rocked the coast for several hours if not days. This must have led Moses to the prudent decision to stay for a number of days in a high place until the waters calmed.

In the next section we consider other effects of the Phaeton explosion, i.e. the Deucalion event, the demise of the Minoan civilization, the arrival of the Pelasgians and Minoans in Italy (central Italy and Salento) and the further destruction of the Egyptian delta, leading to the four hundred period of decadence of Egypt, under the power of foreign dynasties, the Hyksos dynasties.

We observed that archaeological support of the given scenario should be provided by findings on the sea bottom in the Gulf of Aqaba. Such findings are reported to have occurred very recently, by a Swedish expedition from the Karolinska Institute in Stockolm, see [72]. On the sandy sea bottom in front of Nuweiba the sub water archaeologists found a large number of coralline structures, in an area lacking of rock, where coral is not expected to grow. Corals to grow need a seed that may be a metal or a wooden object. Once the coral grows, the metal object might slowly decay by rusting and disappear, while leaving intact the coralline structure that has grown on it. Not only unexpected coral structures were found, but some of these have the geometric aspect of spiked wheels, same form and size of wheels of Egyptian chariots, or of other components a chariot. The investigated area is part of a submarine park, where objects cannot be removed, so radiocarbon dating has not yet been made. Metal detectors have shown the presence of metal inside the corals. Further investigation may possibly show therefore that here are the proofs of the violent destruction of the chariots of the Egyptian army.

3. The Phaeton explosion, the Deucalion Flood and other events

The Phaeton explosion over the Eider river in Schleswig Holstein that we have hypothesized allowed Moses to escape the Egyptians but, being an event of probably hemispheric extent, had enormous consequences on other parts of Eurasia and Africa, and even North America. Here we briefly consider some effects it had in Northern Europe and the Mediterranean. It would be very interesting to look at effects in other parts of the world, including China and the Americas, a work we leave for future investigation.

<u>A – Effects in Northern Europe.</u>

The Phaeton explosion must have destroyed everything within hundred of km of its epicenter. This means the destruction of most vegetation, animals and men in present Denmark, northern Germany and Poland, southern Scandinavia. Very heavy destructions also in Finland, Baltic States, Holland, Belgium, Eastern Britain. At the date of the event given by us, 1447 BC, in these countries the bronze civilization was in full bloom, as attested by the rich findings in many tombs. The extremely strong hot wind in the vicinity of the explosion must have flattened everything, thereby explaining why many great megalithic monuments of the Bronze Age are found in Ireland and western Britain, more distant from the explosion and moreover to some extent protected by the Pennine hills, while they are lacking in the eastern part of Britain. People may have survived in the Hartz, northern Germany, since mountains afford some protection from high winds and usually have caves where people can hide and temperature changes take place more slowly. The survival of people in the Hartz may explain why this area preserves the greatest richness of ancient traditions and myths of Germany that should be reconsidered at the light of the present scenario. People certainly could survive in the Norwegian fjords, protected by the explosion. The civilization that followed the event must have lost some features that had characterized the previous civilization, which had a significant urban life. Here we should recall the work of Vinci [21], who argued a Baltic origin for the setting of the Iliad and Odyssey, before people left the Baltic area to the south, due to climatic changes. Our scenario is apt to provide the motivation for the migration of the Baltic people (Danai and Achaeans from Denmark and Trojans from southern Finland, in particular). Indeed before the final explosion the object that had been captured into an unstable orbit around Earth had already significantly affected our planet by a sequence of disintegrations that sent pieces to impact on Earth and dust to darken the skies. These events happened during a period of several weeks if not months. While in Egypt they originated the Ten Plagues, with some terrific events, in northern Europe they must have led to no less dramatic effects, and in particular to a much colder weather than usual and possibly very intense snowing. These events terrified people so that those who had courage and strength, i.e. mainly young fit men, decided to leave to southern Europe, following possibly the great rivers of Russia and Ukraine, whose sources reach close to the Baltic (a way suggested by Vinci). Crossing Eastern Europe under these unusual conditions must have taken quite a few weeks, and it is likely that these migrating people were still inside the European continent when the explosion occurred. They were therefore saved from the effects of the tsunami that raged in the Mediterranean. The tsunami savaged the Mediterranean coasts, empting them of their former inhabitants, hence it should have been not a difficult task for these groups to occupy places that formerly belonged to other people.

Another effect that should be considered is that the immense pressure provided by the Phaeton explosion over the Denmark surface led to a significant compression and depression of it. So not only amber was liberated from consolidated sediments to appear in great quantities on the shores of North Sea and the Baltic, but the average elevation of Schleswig Holstein and nearby areas might have decreased. Hence the presently observed positive bradisism, which is usually attributed to a rebound effect originated by the melting of the ices circa 11.500 years ago, might be due, at least in part, to the Phaeton event.

B – Effects in Russia and Western Asia.

The climatic effects considered above, leading to the migration from the Baltic to the Mediterranean, were certainly present possibly at a more severe degree in northern Russia and north-western Siberia, considered by many, see for instance Tilak [37] and Godwin [80], to be the original “Arctic” motherland of the Indo-Aryans. These people invaded Iran and India around the mid second millennium BC, at a time that, on the basis of the above quoted passage of Orosius, we identify as the time of the Phaeton explosion and Exodus. We therefore propose the climatic effects of the explosion as the reason why the Indo-Aryans moved south, one group, the Aryans, towards Iran (where they gave name to the province Ariana), another group, the Hindi or Sindhi, towards India. The detailed story of the invasion is yet to be written; a difficult task since the invading people left no history and the invaded people were either destroyed or moved away and did not like to record the story of their defeat. Clues may be found in the Persian Shahnama, in the Indian documents in Sanskrit and Tamil, in the little known Kirghisian epic (6 million verses … hopefully to be fully translated by the Cenacolo di Bergamo …), perhaps even in Nonnus *Dionisiaca,* since from the Orosius passage Dionysius or Liberus appears as the leader of the people invading India.

Reaching Iran and India required the Indo-Aryans to cross the Syr Darya (the river of the Lion), possibly defining the southern border of the area controlled by them (notice the related names *Hindi, Sindhi, Syr, Sindh, Sundh, Singh, Senge, Simba,* all meaning *lion*, which suggests that at least part of the invading people called themselves ***the people of the lion***, an

obvious reference to their military prowess). Then they had to cross the territory of the Turanians, who lived between the Syr Darya and the Amu Darya, and finally the Amu Darya. Passage into Iran was then rather easy, while passage into India implied crossing the Hindukush, hence defeating the local Afghan tribes who have never liked foreign people in their land.
It is our opinion that the Turanians, who too had been scared by the celestial events, decided not to fight the invading Indo-Aryans, but to move before them to another far away land, Egypt. For their decision we see two reasons:

– while the Turanians were great warriors, as shown in the Shahnama [39], often attacking Iran (that in the Shahnama context probably defines a country whose borders are the Indus River, the Amu Darya with an Aral then joined to the Caspian, and the Tigris…), they probably did not posses the iron technology that had been developed by the Indo-Aryans. Such a technology was probably based upon the exploitation of the iron nodules that are found in the northern Europe marshes and on the bottom of the lakes in Scandinavia (recently the iron ore of the Kiruna mines has ceased to be exploited, being more convenient to use nodules from the Swedish lakes. A technology retrieved after 3500 years!). Iron appears, but as an uncommon metal, also in Homer, suggesting that it was a recently discovered metal whose technology was kept secret. Bronze weapons are no match for iron weapons, so the Turanians did not try to stop the invasion.

– the Turanians were the people living north of the Amu river, a large river, always full of water, not easily crossable, whose sources are found in a very special land, by us identified with the Biblical Edem and the Sumerian Kharsag, see [40, 41]. It is very likely that they are the people known in the Egyptian documents as the ***Amu*** and in Exodus and other Biblical passages as ***Amalek*** (to be interpreted as ***people of Amu/Amol, Amol*** being a very ancient town quoted in the Shahnama, near the Amu River, whose name has been changed only recently; ***Amu*** may be a word obtained by contraction of ***Adamu***, see [40]). It is known, see Cimmino [42], that the Amu invaded Egypt several times during the second kingdom. As a protection against their invasions a wall had been built near where is now the Suez Canal by Pharaoh Sesostris II, see Manher [32]. So the Turanians/Amu knew their way to Egypt, knew that it was a country with pleasant weather, with many riches to boot, and far away from the lands where the Indo-Aryans were directed. It is also our suspicion that they wanted to take revenge for a defeat suffered not many years before at the hands of the Egyptians, an argument that will now involve Moses. Lapis lazuli was an important item in Egyptian imports since they were used both as talismans and medicines. Lapis lazuli in ancient world (even until not many years ago) was produced in only one place in the world, the so called ***blue mountain*** in Badakshan, north-eastern Afghanistan. This mine represented an enormous value from the point of view of the income it produced and the sacred meaning attributed to the lapis lazuli. Protecting this mountain had to be a very important task for the local population, and may explain the extreme determination that Afghans have always shown in defending their country. Being located not far from the Amu Darya it is quite plausible that the Amu tried several times to conquer it. So the expedition that, according to the ***Legends***, the Egyptians carried on in Kush under the leadership of young general Moses may have been motivated by help to the Kushite against the invading Amu. The Amu was repelled and Moses married the local princess Adoniah. After several years Moses returned to Egypt, not having begotten sons from Adoniah (he later had two sons, Ghersom and Eliezer, from Sifforah). But we cannot exclude that he had daughters and that he kept good relations with the family of Adoniah. When arrival of the Indo-Aryans became known, it is possible his relatives in Kush informed him that the Amu would move towards Egypt. This time it had to be an invasion by most of the Amu people, which required some time to be organized, with the likely prospect of defeat and destruction of Egypt. Moses as the leader who had defeated the Amu some years before was certainly in the list of the persons to be punished, with his own people. So it is possible that the main motivation for Moses to take the unusual long and difficult way through the Sinai was to avoid the arriving Amu. A motivation of course not to be stated in writing since not “honorable”. It is also possible that his relatives realized that they too would be attacked by the Indo-Aryans and this time could not resist. So while a strong resistance was anyway put by the Afghans against the Indo-Aryans, which led ***Kush***, the ***place of the killing*** (of ***Abel*** we suggested in [40]) to be renamed ***Hindukush***, i.e. ***the place of the killing of the Hindi***, it is possible that some groups, especially important families, fled to safer places. Such places probably included over-sea regions in Africa (where both a ***Kush*** and a ***Meluhha*** are documented), in south eastern Asia (***Moluccas***) and in the mountains of northern India, at those times well protected by jungles, forests and narrow passes, not the type of terrain with which the Indo-Aryans, coming from Russia and Siberia, were familiar. About 150 km north of Srinagar in Kashmir a small village exists, named Hasbal (possibly a variation of ***Mosbal, Lord Moses***; also possibly the village named as ***Heshbon*** in Deuteronomy 4-46, where geographic details are given about the place where Moses died, all corresponding to places found in the Hasbal area). Here a dozen Hebrew families live and a so called ***tomb of Moses*** exists, of which the Wali Rishi family takes care since about 2700 years, see Kersten [43]. Notice that about 2700 corresponds to the years passed since the Ten Tribes of Israel were deported to the region of Halah, Habor and Gozan by Sargon II of Assyria. In a forthcoming paper we will argue that such a region is eastern Afghanistan, i.e. Kabulistan. In the Pentateuch no information is given about the tomb of Moses, whose whereabouts are said to be unknown. We conjecture that at the end of his mission, perhaps due to contrasts with the younger people, including his violent and mentally unstable son Ghersom, he left the Arabian desert to reach the relatives of the first family, and died in the far away Kashmir.

<u>C – Effects in the eastern Mediterranean.</u>

Eastern Mediterranean at the time of Exodus, 1447 BC according to our date, was an area dominated in the south by Egypt, in the north by the Minoan civilization and the Pelasgians located on the coasts of Greece and possibly of western Turkey. Egyptians were not particularly apt at navigation, their overseas trade being taken care in the Mediterranean by the Minoans and the Pelasgians (Phoenicia had not yet developed a basis of the Puni/Phoenici, albeit Byblos, whose existence is documented from the time of the First Kingdom, had certainly significant marine activity). The Red Sea was under control by Indian navigators, the Pani, see [70], who had mastered the knowledge of how to exploit the monsoons, hence were able to trade with Africa, Arabia, Iran, Southeast Asia, possibly even China and Australia (Egyptian objects have been found in several places in Australia). Trade in the Mediterranean was in the hands of the Minoans and the Pelasgians (whose basis was Athens), with possible contrasts among them, as suggested by the story of Theseus and the Minotaurus. The Minoan civilization, enriched by the profits of the trade (some of which coming from outside the Mediterranean, as tin from Cornwall, silver from Tartessus, copper even possibly from the Isle Royale in the Superior Lake…) had developed in the northern part of Crete, with several towns rich of splendidly decorated palaces. Less is known about the Pelasgians, see however Pincherle [44], possibly more devoted to piracy than trade. They were considered by classic authors, e.g. Herodotus, Hellanicus, Diodorus, Dionysius of Halicarnassus, as the ancient inhabitants of Greece, who partly moved to Italy. Here we quote a passage in Thucydides, *War of Peloponnesus*, I, 2-4

…before the Flood of Deucalion, Greece was inhabited by the Pelasgians: Then the Hellenes came…

And a passage from Herodotus, *Histories*, I, 3, 57
...the main people of ancient Greece were the Spartans and the Athenians … If we investigate their origin, we find that the first were Hellenes while the Athenians were Pelasgians … the Pelasgians were local stable populations while the Hellenes were nomads arriving from Thessaly … we do not know the language of the Pelasgians … on the fact that their descendants still live in Crestona (now Cortona) *near Tuscany and others … on the Marmara sea, it appears that they spoke a strange language made only of syllables. Therefore Greece changed language after the invasion of the Hellenes…*

Anyway Greece had at that time a number of cities that survived into later times, including Athens, which Pausanias [71] associated with the domain of Deucalion, who was also in charge of Thessaly, and where his tomb was located, and most probably several places in Peloponnesus as Argos, Mycenae, Tyrint.
So let us consider the effects of the Phaeton event on eastern Mediterranean. The south-eastern coast of the Mediterranean probably did not experience the heat wave that characterized the first contact of Phaeton with the atmosphere. It was rocked by the earthquake following the explosion and was affected by the surge of the sea due to the wind, that flew with about the same speed and duration experienced by Moses. The waters were moved from the north side towards the south side of the Mediterranean, with a surge that only mathematical modeling can evaluate, but that might have reached more than ten meters. So the waters would have invaded part of the coast of Sinai, destroying any army or persons that would be found there. More dramatically, the waters would have invaded much of the Delta, which is very low lying, with enormous destruction of life, cattle, fields, villages, towns, temples. Hence Egypt already severely beaten by the Ten Plagues would experience another dramatic disaster. Only the part of Egypt south of Memphis would have escaped the tsunamic surge. Rebound effects after the wind ceased certainly did additional damage. The surviving Egyptians found themselves in a country thoroughly devastated and must have thought to have been abandoned by their gods.
Let us consider now Crete. If Phaeton entered the upper atmosphere over the Mediterranean, it is possible that the signs of fires noticed in the ruins of the buildings in Crete are due to the heat wave produced by the attrition of Phaeton with the atmosphere. Notice that people inside buildings would have escaped the heat effects, as happened in Hiroshima where saving the life depended in many cases of being exposed directly or not to the heat wave from the atomic bomb. It is interesting to note that the Deucalion story makes no mention of fire, albeit Ovid in the *Metamorphoses* quotes the fires due to Phaeton in many places in Greece, including the Parnassus. This can be explained by Phaeton rebounding after his first encounter with the atmosphere, an effect that has been observed in the case of fireballs and that might happen also for bodies of substantial size. Then Phaeton re-entered the atmosphere, burning the forests over the Balkans and Central Europe, before the final explosion over Eridanus.
The earthquake due to the explosion reached Crete in a few minutes, with a strength probably greater than that experienced in Sinai, where hills appeared to jump. This event must have destroyed most of the buildings. It might also have influenced the Santorini volcano, either activating an eruption or being the event that led to the collapse of its caldera, if the eruption had been going on for enough. The problem of dating the Santorini event – actually several eruptions probably took place in the mid second millennium BC – is not yet settled by volcanologists, see [54, 55]. It is clear in our scenario that the Santorini eruption has to be

viewed only as an ancillary catastrophic event on a planet that had been for many weeks subject to an assault from the sky.
A few hours after the earthquakes the wind arrived, hotter and faster than in Sinai, but for a shorter time. So the north coast of Crete was invaded by the surge of the sea due to the wind. When the wind ceased additional rebound waves, also affecting the south coast, must have taken place. At the end of the event Crete had been thoroughly savaged, albeit people certainly were able to survive in the high places that form much of the surface of the island. Anyway it was the end of the Minoan supremacy, to be followed by the emergence of the Mycenaean city states, whose activity on the sea was however for the following centuries more based on piracy than on trade. The Mediterranean returned to be a sea of trade only about four hundred years later, with the birth of the Israel state under the great kings Saul, David and Solomon, the expulsion of the Hyksos (by Saul and Thutmosis in the Velikovsky chronology that we accept) and the great 18th dynasty in Egypt, the development of the marine trade by the Phoenicians, whose entrance in the Mediterranean, from their previous basis in the Red Sea (as stated e.g. by Herodotus I, 1) was, we believe, the result of a wise decision of the great Solomon.
Let us now consider the Deucalion event, that took place about 400 km north of Crete and was so well remembered that at the time of Solon it was considered as the most ancient event that could be dated *by counting generations* (albeit Plato does not give the number of generations). The event was stated by Plato to be the last of three great catastrophes. Deucalion was a man of power controlling Thessaly and probably part of Attica, where his tomb still existed at the time of Pausanias [71], who gives us important information. He survived, with his wife Pyrrha and other people, on the mount Parnassus. This mountain is about 2400 meters high, has steep walls, and is part of the mountain ranges that cover most of Greece. It is specially famous for the presence, on the south side at elevation about 600 meters, of a sanctuary that has been in use from very ancient times, predating the mid millennium time that we are considering now. It is likely that Deucalion was a high priest in Delphi, kingship and high priesthood being often joint in ancient civilization. He might have visited the sanctuary to inquire about the disasters that were affecting Greece as well as Egypt. The Deucalion story, as noted before, makes no reference to fires, which we have tentatively explained as due to Phaeton rebounding after the first contact with atmosphere. Deucalion must have seen the body moving in the sky as a fireball. Similar view was reported by people in western China, over a distance of some thousand km, in relation with the Tunguska explosion in June 1908; similar view may have also appeared to Genghis Khan, in relation with the multiple impacts in the Pacific Ocean that likely happened in 1178 AD, according to the evidence collected by us [46], following a likely major impact on the Moon, well described in Canterbury chronicles.
Then the earthquake came. This is also not related in the surviving description of the event, which can be explained by the fact that Greece is quite prone to earthquakes (possibly in the past more common than now) and that the sanctuary at that time probably had no sizable stone building, being an open place with sacred trees (as in Dodona) and a cave where the responses were given (stimulated, as recently discovered, by the presence of methane).
Then the wind came. Now Delphi is located on the southern side of the Parnassus. So it was shielded by the huge mountain from the unusually strong wind coming from north, hence explaining the lack of reference to the wind in Deucalion stories. Then the Flood came. It was due essentially to the action of the wind on the Adriatic sea, that is aligned quite well, albeit not almost exactly as the Red Sea, with the direction of the wind flowing radially from the explosion point over Eridanus. The Adriatic waters were pushed south; part of them rebounded on the high coast of Abruzzi and Molise and on the 50 km long promontory of Gargano, whose top is about 1000 meters. So there was an eastwards deviation that pushed

the waters towards the opposite coast of (present) Montenegro, Albania, and northern Greece. Parts of them entered the area between Corfu, Kefalonia and the Etolian coast and were pushed inside the Patras-Corinth Gulf, about 150 km long, mainly surrounded by steep mountains. Reaching the end of the Gulf part of the waters, with a front wave possibly a hundred meters high, were able to cross over the low lying Corinth isthmus, invading the Gulf of Salamis and destroying the area of Athens. Another part entered the small Amphissa plain, at the basis of the Parnassus, and ran up the Parnassus to a certain elevation. Delphi must have been too high for the waters to reach. So Deucalion witnessed a wonderful and terrible event that destroyed much of the people in his land and whose memory he was able to transmit due to his special position of priest and king.

Two more observations are interesting about the Phaeton effects in Greece. The Patras Gulf is bounded on the south by mount Erymanthus, 2224 meters high (visible in very special light conditions even from the coast of Salento!). The Erymanthus shielded the interior of Peloponnesus from the wave that entered the gulf. The region just south of the Erymanthus in the central part of Peloponnesus is called Arcadia. The inhabitants were considered to be the original people of Greece, see Pausanias [71], Book 5, 1-2, lending their name to the adjective that describes extremely ancient things. By our arguments, these were the people who escaped the destruction, not being affected by the heat wave and being shielded from the incoming waters by the Erymanthus.

What we have described is the initial wave due to the continuous action of the wind. When the wind stopped, rebound tsunamic waves must have raged for several hours, if not days. Since similar events occurred essentially over the whole Mediterranean, it is fair to conclude that most of the coasts were savaged with full destruction of the local settlements. It is also very unlikely that people on boat on open seas survived, due to the very strong wind (generally a tsunamic wave is not dangerous on high seas, since it has a long wavelength and a small surge; the wave swells dramatically only near the coasts, see Bryant [47a]). But the following two considerations are of interests:

– according to Herodotus VII, 170, Minos left Crete to get back Daedalus, who had returned to his native Sicily, where king Cocalus reigned. On the return from Sicily the fleet of Minos was destroyed by a storm in front of Iapygia (present Salento), but several of the men survived, founded a number of towns and changed their name to Messapian Iapygians. It is possible that they did not return to Crete having known that the island had been severely ruined by the described events. Cretans were known for the love of bull games. So perhaps the present town of Taurisano, close to Ugento, takes its name from the breeding of bulls (Latin *tauri*) to be used in games originated in Crete;

– there is evidence that Pelasgians settled in central and southern Italy, see Pincherle [44]. Since Pelasgians were involved in sea trade a number of them might have been visiting ports in Italy. Now settlements on the Adriatic coast of Italy were probably all destroyed by the tsunamic wave, in addition of being fully subject to the immensely strong wind. Settlements on the Tyrrhenian coast were in many cases shielded by mountains from the wind and, due to the geometry of Italy, they were subject to initial lowering of the water levels, being only after some time (say a few hours) affected by the return of the waters and the rebound waves. Hence it is likely that people living near the coast, who certainly were accustomed to tsunamis albeit of smaller size, understood the danger and escaped to the nearby hills, the Tyrrhenian coast being mostly hilly (here it is interesting to note that the aboriginals in the Andaman islands survived the great tsunami of December 2005 by running uphill when they noticed the lowering of the waters that precedes an earthquake generated tsunami). The survived Pelasgians later knew not only of the destruction of their settlements in Greece, but also that strongly armed people had arrived from the Baltic. So they began a new life in Italy, living in megalithic towns on the top of hills, perhaps to be safer also from another strong wind …

– There is evidence, see Arecchi [47b], that a huge lake existed in the second millennium BC in the interior of southern Tunisia. Arecchi has considered this vast inner basin in the context of a scenario for Atlantis located in that area, a hypothesis also considered by other authors. In our scenario the basin was certainly replenished during the Deucalion Flood. No theory of Atlantis can be accepted that sets Atlantis after Deucalion!

The following sentences in Pomponius Mela [64], VI, apply to Numidia, i.e. present Algeria, suggesting that a tsunami, possibly the one of Deucalion, reached over there: *in the interior, and quite far away from the sea, if you accept to believe, there is a wonderful finding: they say that on very dry areas one finds skeletons of fish, broken shells of mussels and oysters, smooth pebbles like those found on beaches, anchors fixed on rocks … all signs that the sea surged up to there.* The reference to anchors seems to exclude that the objects were ancient fossils, which are quite common in the rocks of the Mediterranean and would not be object of mention.

Some remarks

We have already considered some effects of the Phaeton explosion in northern Eurasia:

1) depression of the crust in the area near the explosion, implying that the present positive bradisism of the Baltic region may not be all due to a rebound effect after the melting of the glaciers;
2) breaking of the sediments on the sea bottom, leading to emergence of a large amount of amber from deep sediments, previously covered by later sediments. Amber material is usually extremely old, several million years, and should therefore not been found on the surface, unless this has been subject to disturbance or erosion;
3) a shallow crater was possibly formed, but was soon refilled by sediments brought be the rebound waves; this fact should be subject to geological investigation;
4) in a radius of possibly 1000 km or more forests were leveled, partly burned. Forest material may have contributed to the formation of the many turf formations in the area. Organic material in fine dust must have reached the upper atmosphere in the billion of tons, where interaction with material lost by Phaeton in the course of its frequent break-ups (if Phaeton was associated to a Venus that was born in the scenario described by Ackerman [27, 28], then it was probably partly composed of hydrocarbons) may have led to the formation of the whitish sweet and unstable substance named *manna* in Exodus;
5) in a probably large radius, order 1000 km, most people were killed. Pockets of survival were probably in well protected valleys and where people used caves. The high birth rate of man until very recently (even more than 7%) of course allows a population to recover soon. Forests growth covered again the area within half a century. Man returned within probably one or two generations. But the people who had created the great bronze civilization that is described by Homer, following Vinci's scenario, were gone. Their settlements, most of wood, had been destroyed. Stony buildings like menhir or dolmen could survive, larger structures would collapse. Perhaps this is the reason why the big megalithic monuments predating the mid second millennium BC are found in western Britain and Ireland, for instance, but not around the Baltic or even in eastern Britain. Here the wind and the earthquakes were too strong;
6) part of the local Baltic population must have decided to move south, before the final explosion, due to the terrible weather conditions that corresponded to the Ten Plagues of Egypt. As Vinci suggested, most of them probably followed the great rivers of Eastern Europe, Dnepr, Dniester, Don, avoiding the thick forests and the dangerous marshes on the way, to the Black Sea and the Mediterranean. The explosion must have taken place

when they were still on the move. The above rivers could not be affected by tsunamis and, moreover, they run often in valleys that while not deep, would protect from the strong wind. It is possible that some of the people decided to return to the original country after the explosion, when no danger was seen any more in the sky, thereby leaving the memory of the event in the many northern texts as the ***Edda*** or the ***Kalevala*** (where recollections of even more ancient catastrophes may be present). The people who continued found a Black Sea and an eastern Mediterranean whose coasts had been depopulated. It was therefore easy for them to resettle there, renaming settlements with the names of their original places around the Baltic. It is possible that most of the migrating people were young men. No problem certainly for them to find women among the survived people in the interior.

Again within Vinci's scenario, it is likely that people from southern Finland, particularly the region of present Toja, see also Harris [50], identified with the Troy of Homer, reached northern Italy, possibly by following the Vistula and then crossing over Moravia and Austria. A most important settlement at that time in Italy was Valcamonica, the valley where the Camunian civilization developed over a span of thousand of years, see Anati [48, 49]. Valcamonica was a centre of trade (iron and copper mines being present there) and certainly a very important religious centre influencing Northern Europe (we will claim in a forthcoming work the identity of the Avestan ***Manu*** with the German ***Mannu*** in Tacitus and that such person survived the second of the Platonic catastrophes, i.e. the Biblical Universal Flood, inside caves in Montisola, an island inside Lake Iseo, at the end of the Val Camonica). It is possible that the people from Toja came to this valley, which was well protected from the effects of Phaeton. Then they were given permission to settle in the Po valley, giving to the Po the second name ***Eridanus***, from the water passage that allowed direct passage to the Baltic from the North Sea. Notice that the city of Padova according to tradition was founded by Antenor, a Trojan leader.

4. Conclusions

In this paper, taking the hint from a forgotten passage in Paulus Orosius (briefly referred to in Clube and Napier [51], who wrongly date him at the 15^{th} century) we have developed a scenario that identifies the last of the three great catastrophes quoted by Plato with the Deucalion event, contemporary to great migrations and to Exodus. Orosius refers with criticism the pagans' opinion that Phaeton was the cause of these events. Using present knowledge about Tunguska type explosions of large objects in the atmosphere, we deem to have validated at least qualitatively the statements of Orosius. Using textual data in the Bible, in Greek and Latin sources, we have suggested the causes behind the events described in Exodus (especially concerning the passage of the Red Sea), the nature of the Deucalion Flood and the Indo-Aryan invasion of India. As a corollary of this invasion we have explained the migration towards Egypt of the Turanians/Amu/Amalek. As a corollary of the arrival of the Amu, about which we suspect Moses was informed by the family of his previous Kushite wife, we have a natural explanation of why he took his people by a long and unusual way in the Sinai Peninsula.

It follows from our scenario that the used ancient texts are fully compatible with expected consequences of a super Tunguska type explosion, an event which can certainly happen again. Therefore we claim, in contrast with many modern scholars, that such texts are a valuable source of hard information, even if they contain, due to their antiquity and transmission problems, some passages that are not correct. Such errors are sometimes recognizable and correctable; sometimes leave us in a deep puzzle. So, as far as the Bible is concerned, we claim that Finkelstein and others are wrong. However in order to fully retrieve the informational content of the Bible, it is necessary to take into account two facts, which are rejected by mainstream researchers, or even simply not taken into consideration, partly for political reasons, partly because their truth means that academia has taught for a couple of centuries scenarios that are wrong:

– that the chronology of Egyptian history, essentially established about two hundred years ago by Lepsius and Champollion who dated a certain Sothic year referred to in Censorinus *De die natali*, is wrong, by several centuries, as claimed by Velikovsky [18], and confirmed by the astronomers Clube and Napier [51], and other scholars, e.g. Bimson [81, 82]. Perhaps everyone should read the *opus magnum*, in his own judgment, of Isaac Newton, which is not the *Principia,* but the *Chronology of ancient people amended,* whose dates are close to those of Velikovsky. It says much that Westfall, the greatest biographer of Newton, wrote that reading this work is *the worst penance that can be inflicted to a man*. It is with great interest that the present author awaits the publication of the monumental work on chronology, a forgotten science, by the Australian scholar Dale Murphie, on the line of the work of Velikovsky;

– that some points in the interpreted geography of the ancient world are not correct. One is which river was initially called Euphrates (we claim this was the original name for the Indus; the name changed after the invasion by the Sindi, to the present form which is Sindh, Sundh, already documented in the *Peryplus Maris Erythraei*; quite incredibly scholars do not yet know how the Indus was named in Sumerian or Akkadian, as this author has learned from the sumerologist Pettinato). This is a fundamental point for the analysis of the story of Eden, see Spedicato [40, 41], and for the determination of the borders of the kingdom of Solomon, again a non-existing person according to several present historians. The second point is the location of the *land of honey and milk*, where Abraham settled and where Moses led back his people. We think that the identification given by Salibi [23, 24] is correct, even if we are doubtful of his analysis on the existence of several Abrahams and other people. Perhaps scholars, who have forgotten Orosius, should also reread that extraordinary book which is the *History of the Armenians* of Moses Koronesis. This historian visited the immense archives of the royal palace of Edessa where a room contained the list of genealogies of many families in the Middle East. He comments that before the time of Cyrus (about one thousand years before him) important families kept their ancient genealogies, but the fashion disappeared at the time of Cyrus. This suggests that when Ezra wrote the Bible (24 canonical books of the *Tanakh* and 70 secret books, see Manher [32]), genealogies were probably still known by many Judaic families, so that the overlapping of persons would have been a violation of an important tradition. Nowadays very few families know their genealogies (among them: the Ethiopian and Japanese imperial families, the Confucius family, the Mandel family, now represented by the great scholar and artist Jibril Khan Mandel, a Sufi leader: his family list originates with a chief of Bactriana who fought against Alexander the Great).

Finally a comment of interest from the theological point of view. We have treated the Bible and other ancient documents as texts with an authentic historical content, albeit the correct interpretation requires accepting rare events of extraterrestrial origin. Therefore events like the withdraw of the waters, their return after Moses lifted his baton, and other stories not considered here (as the water pouring out of the rock again after he lifted his baton), are seen as natural events, consequence of the special interaction of Earth with an external object. But Moses saved himself and his people because he was at the right place at the right moment, an event of very small probability. The waters returned and the water spilled out after he lifted his baton, again an event whose probability is extremely small. These facts suggest that either he could forecast the future, which is scarcely credible, or that a superior power acted on him, on his decisional processes, so that his actions appeared as actions of supernatural powers.

This approach can be rejected only under the postulate, to all purposes equivalent in our opinion to the postulate that the Earth is at the center of the Universe, that over man no superior powers exist or that they cannot or do not want to influence man. Superior Powers do not necessarily mean the Most Superior Power, God.

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This work is dedicated:

– to **Paulus Orosius**, whose neglected Historian Adverse Pagans gave the key to the proposed scenario;
– to **Giovanni Barbareschi**, whose lectures inspired this work;
– to **Nieves Hayat de Madarriaga**, for her encouragement in these researches.

Emilio Spedicato is professor of Operations Research at Bergamo University, Italy, having a degree in physics and a PhD obtained China in computational mathematics, the first ever in the math field given to a non-Chinese. In mathematics his main contribution has been leading the development of ABS methods that provide unification of a larger part of mathematics via a simple class of formulas. In this framework in collaboration with Prof. Nezam Ahmadi-Amiri he has obtained the general solution of Hilbert tenth problem in the most important solvable case. Having a special knowledge in geography and languages, his interests have extended also to other fields, like astronomy and even operatic music, where a book of 600 pages devoted to the stars of opera is due to appear soon. He has devoted over thirty years to the study of discontinuities within human memory, looking at their causes and their chronology. He has used ideas from Velikovsky, a great Russian scholar, and other people who followed him, especially Alfred De Grazia, reaching an apparently coherent scenario for the evolution of Earth and Solar system since about 12,000 BC.
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For discussion

Expeditionary space complex of new generation

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This article is based on materials, prepared to the 110th birthday anniversary of Myasishchev Vladimir Mikhailovich, General Designer, and 85th birthday anniversary of one from scientific advisers of this theme of Karrask Vladimir Konstantinovich, - Professor, and Doctor of technical sciences. The foreground place in the development history of this direction takes the "Salyut" DB M.V.Khrunichev SRPSC [1-16].

"Vladimir Mikhailovich Myasishchev's name is forever entered in history of aviation engineering. He created the design bureau structure as per a principle of responsibility for each phase of airplane creation. He inspired such mass enthusiasm that practically all collective "spent the day and spent the night" in the engineering buildings: first at documentation development, then at manufacturing and tests of separate systems and airplane as a whole. The results of the above were the record terms which could not be repeated then anywhere in the world. In the Soviet Union, practically within one and a half year, the absolutely new heavy strategic bomber with turbojets was developed, manufactured and prepared for the first flight. It received designation of M-4. After it (with interval of 3 years) 3M and 3MD airplanes with the deep updating of M-4 airplane flew up in sky. Tens world records were broken by these airplanes … The main results of Myasishchev's proceeding besides the fine airplanes, which advanced the time far and away, were the organization of creative collectives, their structuring, selection of skilled personnel and development of methods of advancing designing, used at any object creation" [10].
Let's apply this method for innovative achievement of breakthrough forward.
The modern conceptions of creating the Lunar orbital station, Lunar base and Martian expeditionary complex laid in the space programs of the leading countries assume building many expendable space-rocket means with total filled mass about one million tons and total cost about one trillion dollars. Besides all these objects will be scattered along the planet surface and in near-earth space as an anthropogenic debris and artificial asteroids which will be turned around the Earth for thousands of years.

As opposed to elements divided on expendable ones which make the anthropogenic space debris of modern SRC the supposed expeditionary space complex of new generation (ESCNG) combines all functions of spacecraft, orbital station and rocket in monoblock intended for a long-term existence of human in space without any support from the Earth and with capability of landing on the planets performing the functions of the on-planet base with further refilling from the planet atmosphere and other ESCNG with the reserves of the working media for launch from the planets performing the functions of the launch vehicle and flight to the other planet performing the functions of the interplanetary reentry spacecraft or reentry to the Earth performing the functions of the reentry spacecraft [2]. Other words one ESCNG replaces six or seven expendable space complexes.

In order to start the realization of this project it is available a considerable reserve of works in aviation, practical cosmonautics and atomic industry shown in Fig. 2

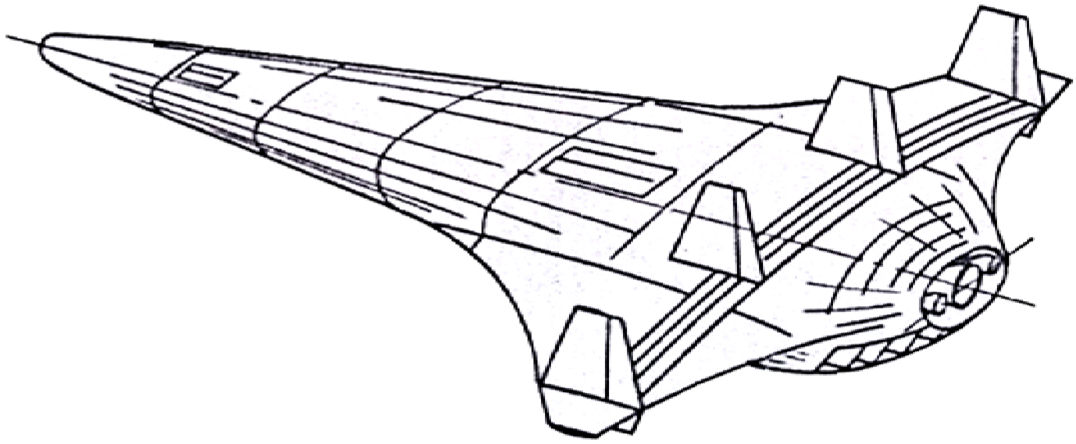

Fig. 1. Supposed ESCNG for Lunar (or Martian) expeditionary in shape of space plane.

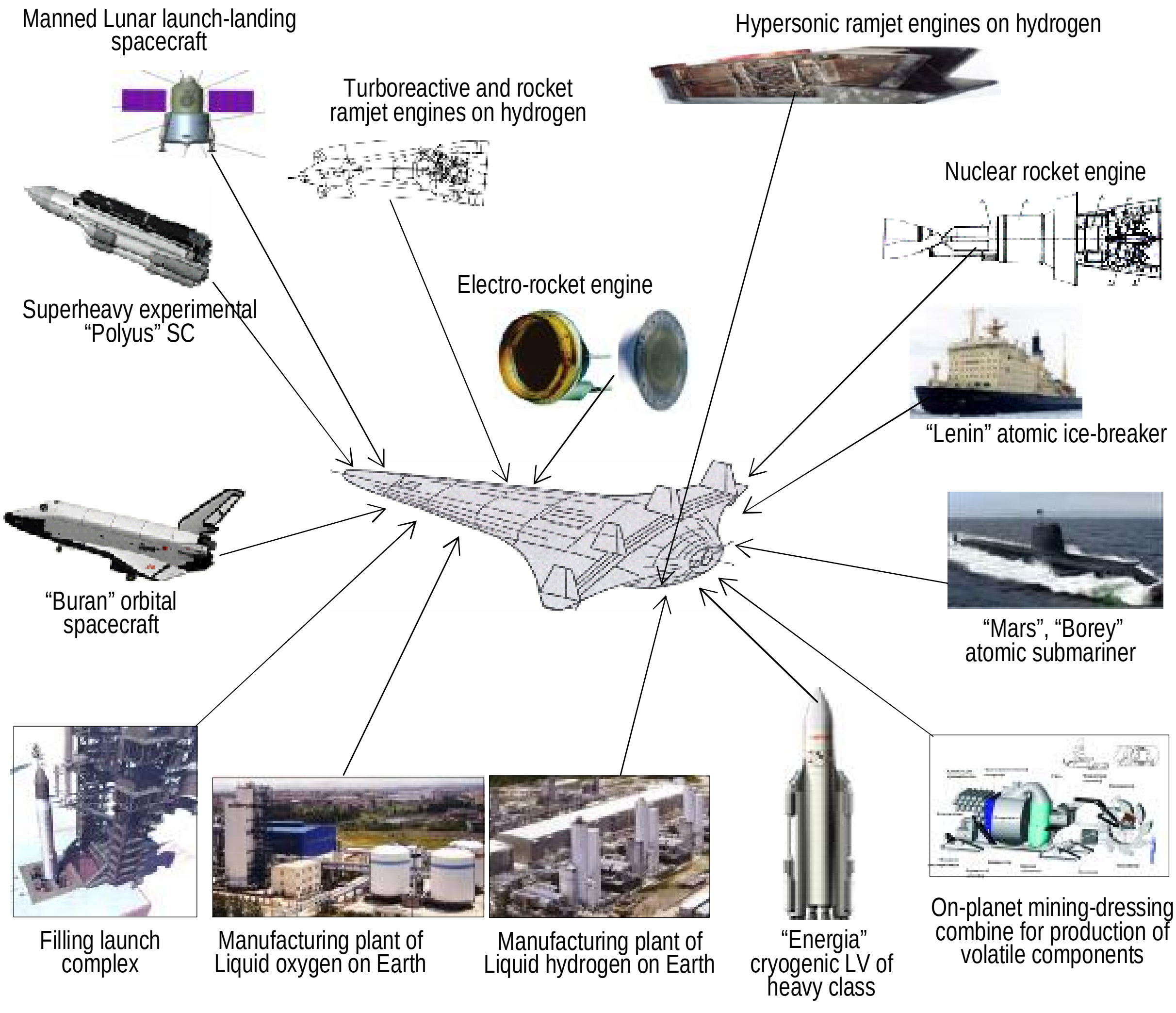

Fig. 2. Application of reserve of modern realized procedures for creation of ESCNG for Lunar (or Martian) expeditionary.

The analysis of reserve of modern realized procedures certifies that our Civilization is ready to create the monoblock atmosphere space expeditionary complexes. The closest analog of ESCNG on the modern level of technology is a project of multipurpose spacecraft M-19 described on the M.V. Myasishchev EMP's site and on the site of my scientific adviser of Gurko O.V. [1, 2 and 3].

Increasing the procedural level of structure and equipping spacecraft MΓ-19 by turbocompressor and turboexpander contours, by systems of transfer of cryogenic propellant from one spacecraft to another, by non-consumable system of artificial gravity and electronuclear, for example, magneto-plasma PP permit us to use it as expeditionary single-stage spacecraft for flight to Mars. At the first phase it is suggested to provide the refilling of tanks on the near-earth orbit and tanks of spacecraft for reentry to Earth fill from the Mars atmosphere and further from the planet soil, for example, with using the developments of the Institute of geochemistry and analytical chemistry named after V.I.Vernadskii (RAS) [16].

Features of interplanetary expedition with help of ESCNG

The Martian expedition with using the suggested ESCNG is described in papers [11 and 15] and has the following features:

- Usage of multilaunch configuration of start from the Earth with refilling of ESCNG on the Earth orbit.
- Usage of NRE for interorbital flight during the short-time manned expedition or ESCNG during unmanned expedition particularly during expedition of flying around Mars or Venus without refilling near Mars or Venus.
- Conditions of staying the human on Mars or Moon are prepared with the help of robots.
- ESCNG of the first unmanned expedition stays on Mars and reequips in on-planet base with using released volumes of the hydrogen tanks (about 3000 m^3 in each spacecraft) as rooms of base and free power of NPP (about 100 MW during work in closed condition) as on-planet energy source.
- Free volumes of ESCNG tanks are also used as vessels for accumulation of working media for the on-planet base, reentry complexes and consumable resources for operating the base with using its onboard facilities and delivered robots.
- Usage of multilaunch configuration of start from Mars with refilling ESCNG on the Mars orbit.

Economic efficiency of ESCNG and criticism of analogs

In order to estimate the efficiency of the expedition with using the space complex of a new generation it is required to compare it with the traditional space-rocket complexes in solution of comparable tasks of creating the lunar base or arranging the Martian expedition.

Let's review a creation of the Lunar base (LB) by the traditional means. The base consists of the living module, research module, energy module, transportation means for movement along the planet, reserves of propellant, water and food, communication means with the ground infrastructure and life saving means. The total mass of the above listed means together with the consumable materials will be about 100 t.

In order to deliver 100 t of cargo to the Moon the space-rocket complexes with the total mass about 500000 t should be launched from the Earth. Approximately the same number of complexes should be launched to maintain the bases for 20 years. Taking into account that the cost of each RSC kilogram is about 1000 dollars the expenses on their production will exceed 500 billions of dollars. The cost of the ground production, experimental and exploitative

infrastructure and its developments will be 40% in addition to this amount. See Table of the comparative performance and economic characteristics of options of expedition realization.
Let's review the dispatch of expedition to Mars with the help of rockets. It is known that the modern conception of the Martian expeditionary complex (MEC) requires the assembly on the assembly orbit with altitude about 800 km and MEC with mass of 900 t. In order to inject this complex it is required to launch about 90000 t of SRC from the Earth. Approximately the same mass can be required for the double-rescuer. Meanwhile the expenses on production will be 180 billions of dollars and on creation and operation of infrastructure will be 40% in addition.
It is required to note that both in Lunar and Martian program all these hundred thousand tons of expensive and ecologically hazardous elements will be dispersed on million square kilometers of the planet surface, burned down in its atmosphere generating a difficult predicted biospheric load. Hundred tons of the artificial asteroids will be rotated around the Earth for hundred years preventing the flight of the next spacecraft and generating a ring of solar heat reflectors which in my opinion will cause a melting of the arctic glaciers and diving melting zones of permafrost on the ocean floor reducing the territory of our country on million square kilometers. However it is a mission of supercomputers.

Besides, it is generally known that the world community deploys ISS and operate it for more than 15 years and up to now the deployment of ISS is not completed. In-orbit ISS mass is only about 500 t, i.e. twice less than mass required for Martian expeditionary complex. So, how many years we are planning to integrate MEC by the traditional methods?

Table. Comparative performance and economic characteristics of expedition realization options

№	Name of performance and economic characteristics of options of expedition realization.	Lunar base with help of LV	MEC with help of LV	ESCNG for Mars
Mass resources, t				
1.	Mass of complex	100	900	500
2.	Launch mass	500 000	180 000	500×2
3.	Launch mass of space-rocket means of TTO or double-rescuer	500 000	180 000	500×2
4.	Dry mass of SRS	50 000	18 000	250×2
Economical indexes, billions of roubles				
5.	Expenses on project	**3200**	**2880**	**1470**
5.1	Expenses on production	1500	540	60×2
5.2	Cost of SC development, without LV	100	900	500
5.3	Cost of ground infrastructure	100	900	250
5.4	Operation and maintenance	1500	540	360
6.	Commercial potential of leasing free volumes of complex per year	**3**	**1,5**	**90**
7.	Commercial potential of selling free resources of electrical power per year	**0**	**0**	**600**
Difficult estimated expenses and losses				
8.	Procedural wastes of production, t	**5 000 000**	**360 000**	**10 000**
9.	Anthropogenic wastes falling and utilizing on alienable territories, t	**90 000**	**17 000**	**250**
10.	Space anthropogenic wastes and artificial asteroids, t	10 000	1 000	
11.	Area of alienable territories, thousands of km^2	900	900	1

Taking into account a high cost of orbital resources and resources of on-planet bases it is not so difficult to estimate the commercial potential of leasing free volumes of the comparable complexes estimated per 1 million dollars for cubic meter per year and free resources of electric power estimated per 2 thousand dollars per kW/h in the Earth orbit. The commercial potential of the ESCNG onboard resources exceeds one trillion dollars per year that can provide their quick payback. See comparative performance and operating (economic) characteristics.

The economic evaluations show that the expedition to Mars with the help of ESCNG can be twice cheaper than with rockets. Besides, as opposed to rocket firework, ESCNG can be used many times. The procedure of the project self-financing is described in [11].

The suggested monoblock space complex is beneficially differed from traditional one as it is fully integrated and tested on the Earth. I supposed that can be developed a unified ESCNG which is differed only by versions of sets of target equipment and removable cargoes. It can be equipped and used as a means for removal from plane of the ecliptic the hazardous asteroids threatening to destruct the Civilization. During the interval between the asteroid passages the ESCNG complex will be used for the space expeditions or as a standby near-earth and near-lunar orbital stations, replaceable communication and navigation complexes in the geostationary orbit as well as in the capacity of Lunar and Martian bases. It can be used for releasing the geostationary orbit from failed communication and navigation SC and as the communication-navigation complex periodically maintained on the Earth and used also for check of the asteroid situation in space.

Thus, this project can be attributed to the priority lines of developments of science, engineering and technologies of the Russian Federation and is able to make a most contribution in country safety, economic growth acceleration and competitive recovery of the Russian engineering [8].

The feasibility of the project is shown in this short survey. It is shown the direction for which the movement of branch can be oriented in order to retrench the inefficient expenses due to make no headway and reassessment of the dead lateral directions. It is used a system approach to the strategic planning of works intended for the long-time purpose.

In this short report it is difficult to reflect so large-scaled project within the frame of which more than hundreds volumes of design documents and dissertations have been developed currently by tens enterprises. This issue should be discussed at the history breakup groups of the scientific readings on cosmonautics.

Abbreviations

SRPSC	State Research and Production Space Center.
PP	Propulsion Plant.
МГ-19	Brand of project N19 of Myasishchev-Gurko.
SC	Spacecraft.
DB	Design Bureau.
SAC	Space aircraft (as to suggestion of Gurko O.V.).
MEC	Martian expeditionary complex.
LB	Lunar base.
SRS	Space-Rocket System.
EMBF	Experimental machine-building factory (named after M.V.Myasishchev).
ESCNG	Expeditionary Space Complex of New Generation.
NRE	Nuclear Rocket Engine.

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Vladimir D.Denisov works in “Salyut” DB within 47 years and now he is a chief of efficiency sector in department of designing the piloted space complexes that corresponds to his scientific specialty and hobby – development of reusable space expedition complexes, used the following resources. He is the senior lecturer of MATI. He is a holder of the higher awards of the Russian Federation of Cosmonautics Astronautics of K.E.Tsiolkovsky, S.P.Koroliev and Yu.A.Gagarin».

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Section 18 of G.N.Babakin name

Analytical survey

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On January, 31, the meeting titled "Automatic spacecraft for planetary and astrophysics researches. Engineering, design, tests and calculation" was held at Lavochkin Association. 65 scientists from 11 organizations of the field took part in the meeting, 26 of them made public reports for participants. Topics for discussion were the following:
- advanced planetary research projects;
- radar and optical monitoring of the Earth from space;
- improvement of spacecraft design;
- spacecraft flight dynamics, motion control on orbit and descent;
- study of the motion of celestial bodies in the solar system.

The meeting was opened by one of the leaders of the section – d.e., prof. V.Efanov. He reported that 2014 marked 100 years since the birth of an outstanding designer of space probes – **Georgiy Nikolayevich Babakin**, told about his career and activities to be held at Lavochkin Association on this occasion. Georgiy Babakin worked at a very active period in the study of the Moon and the planets of the solar system in 1960-1970. In 1965 Babakin was elected Designer General of Lavochkin Association. He successfully continued lunar program started by Sergey Korolev. Already in 1966, the station "Luna- 9" provided a soft landing on the moon, sent panorama of the landing site and explored the mechanical properties of the soil. In the same year "Luna- 10" was launched - the first satellite that determined the nature of the lunar surface rocks and updated the geological map of the moon. After a while the Soviet Union was defeated by the U.S. in Manned Lunar Program and Development Design Office led by Babakin got the problem of realizing lunar missions with comparable political importance. Urgently a new generation of lunar vehicles for automatic sampling of soil was created; work on remote-controlled self-propelled machines began. During these years all talents of Babakin as an outstanding designer of space technology were approved. Enormous cooperation with subcontractors was created, tens of thousands of people worked on the implementation of lunar mission. Launches of probes "Luna-16, -20, -24" delivered soil samples from marine and inland areas of the Moon, as well as long-term operation of mobile laboratories "Lunokhod-1 and -2" made an enormous contribution to the study of our natural satellite. Along with the creation of lunar probes, Babakin supervised the development of space probes for the exploration of Mars and Venus. In October 1967, "Venus-4" probe was launched - the first lander in the world to accomplish a descent by parachute in the atmosphere of this planet and to transmit to the Earth unique data on temperature, pressure, density and chemical composition of its atmosphere. With launch of "Venus-7" descendings of our landers on the day side of Venus has began. Original design and development of technical solutions provided the leadership of the USSR in the studies of Venus for many years. This was largely due to the great attention that Babakin gave to ground products testing. In 1971, station "Mars-3" made a soft landing on the surface of Mars; unfortunately, the communication with it stopped 20 seconds after landing. Babakin died suddenly in August

4, 1971 withdrawing from life full of creative plans and ideas that he constantly discussed with colleagues and dreamed of bringing them to life. During only six years of his management of Development Design Office it created half a dozen of first-class automated vehicles. Georgiy Babakin was a talented scientist, a great engineer and a great organizer. His engineering flair, vast experience in creating complex and unique automatic systems, the ability to find innovative solutions and courage in their implementation ensured the success of many projects.

The first report, *"Choosing the best option of landing on the planet"* was made by employees of JSC "CB Electropribor". The authors proposed a method of choosing the best landing system (LS) for the solar system planets and their satellites. To evaluate LS options the method of “morphological box” is used: first step is to develop root morphological matrix, then the matrix of the first, second and subsequent levels of the hierarchy are considered. The developed method takes into account the purpose of the LS scheme, landing, braking system, shock-absorbing system, layout and shape of the lander, control and communication systems. The task of choosing the best option of LS and its components is reduced to the hyper vector ranking. The authors carried out a mathematical formulation of this problem and presented the solution methods.

Next report *"The model of Doppler rate and range in projects with a soft landing on the Moon"* was presented by an employee of Keldysh Institute of Applied Mathematics D.Tuchin. Doppler velocity and range counter (DVRC) provides measuring of the rate and incline of distances by the antennae rays reflected from the moon surface. The device was designed for Lavochkin Association and is used in the final stage of landing on the Moon. The authors present an algorithm for recovery of unambiguous range for measurements at different modulation frequencies, statistical modeling algorithm to estimate the infallibility of his work in noisy environments. The authors also developed a device simulator for testing on-board control systems of landers.

The report *"The Development of architecture and algorithm of the active safe landing system on the Moon"* continued the theme of spacecraft control during the descent. This report was made by leading engineer of Lavochkin Association Ph.D. student A.Ivanov. The concept of safe landing system operation is in withdrawal of the lander from danger by detecting and analyzing risks in the landing zone, identifying safe landing spot and moving to it with lateral maneuvering. To solve the problem a number of subtasks have to be worked out:

- definition of a reliable model of the underlying surface terrain;
- analysis of existing hardware, allowing to identify dangerous areas of terrain, the choice of meter formed on the basis of quality indicators;
- operation modeling of the selected meter;
- development of a mathematical model of the center of mass of the lander using retargeting algorithm;
- assessment of the probability of successful implementation of the soft-landing spacecraft on the lunar surface using an active system and a safe landing without it.

The solution of the subtasks allows one to get a numerical assessment of the viability of this system for the implementation of soft landing on the lunar surface.

The report *“The method of visual trajectories for designing interplanetary missions with gravitational maneuvers”* presented by M.Shirobokov and S.Trofimov from Keldysh Institute of Applied Mathematics contained two classes of problems: with active and passive gravitational maneuvers. Effectiveness of the proposed method lies in the fact that the first most massive stage of calculation - building base virtual paths – has to be done once for each

planetary path, after that the resulting base is tabulated and used in the design of specific missions. Requirements for the duration of the mission and the start date are imposed during dropout and iterative refinement of virtual paths.
As an example, the authors show the numerical results using this method at designing missions to Jupiter.

The report *"Building of the angular motion of the spacecraft during the Earth-Moon flight"* considered the problem of constructing the angular momentum and its implementation by means of motor flywheels during the flight of spacecraft from the Earth orbit to the Moon orbit. The flight is performed using electric propulsion system. Desired angular movement (called reference) is based on the direction of the vector thrust and direction to the Sun, and the control of the asymptotic stability of the reference movement is built using the PD-controller. To construct the angular motion, the Poisson kinematic equations with quaternion are used. It is necessary to specify the quaternion spacecraft orientation at random time. Specifying the position of the thrust vector direction to the Sun, as well as the center of mass of spacecraft at some periods of time, one can start solving this problem. Splines are used to build the spacecraft orientation at intermediate points used. To construct a continuous angular motion spline should be smooth; quadratic spline satisfies this condition. Constructing spline for each of the four components of the quaternion orientation of the spacecraft one can get a smooth function describing its motion. Using this technique the cost of the working body to maintain the desired orientation of the spacecraft during the entire trip can be estimated. The researches were made by specialists of Keldysh Institute of Applied Mathematics and Lavochkin Association.

Several additional papers submitted by experts from Lavockin Association focused on the challenges of designing a spacecraft with the electric propulsion system (EPS). In *"The options for the design of an onboard control complex of small spacecraft with EPS"* the authors developed the basic requirements for an on-board control system (OCS) of the spacecraft and its parts. The research took into account the high requirements for compactness and low weight requirements to the system, as well as the presence of flight qualification in applied solutions. Particular attention was paid to the choice of the central computer (CC). The authors analyzed CCs from four Russian developers. According to the analysis the structure and the most rational way of developing CC were proposed. The authors of *"The development of EPS of small spacecraft based on SPD-100"* proposed an embodiment propulsion system (PS) of small spacecraft (SSC) in general, with the use of engine SPD-100 in the composition. PS consists of:

– motor unit on the basis of stationary plasma thruster SPD-100 with two flow control mechanisms;
– valves block connecting marching boosters with xenon storage unit;
– unit that feeds engine anode with xenon;
– unit that feeds engine cathode with xenon.

Also PS of SSC includes interconnecting cables and pipelines, pressure and temperature sensors, filters, twelve gas engines DG-50 to correct the orientation of the SSC and unload flywheels engines.
The use of gas engines DG-50 for correction, allows using in SSC one type of control working body - xenon. The authors estimated the cost of the working body during the flight of SSC from the Earth orbit to the Moon orbit and to the asteroid 2011UK10.

Report on *"The tools for providing thermal control to SSC with electric propulsion system (EPS)"* was devoted to the selection and construction of means of the temperature control system (TCS) for SSC with EPS. Given that EPS maintenance blocks have high heat emission and work almost constantly at the stage of flight, and since they are mounted in a small housing, the issue of the thermal regime is quite important. The proposed TCS are integrated into the design of the SSC and are designed with no pressurized SSC performance. Thermal honeycomb panels (TSP) on heat pipes base, angular axial heat pipes, heaters, temperature sensors control, screen-vacuum thermal insulation, radiators, heat register are used as a part of TCS. The thermal conditions of SSC are proposed to be provided by three independent TCS subsystems: temperature control of + *Z* and –*Z* panels are performed autonomously, the other four TSP are combined into a single heating circuit. Heat transmission into outer space is carried out with the external uncovered TSP surfaces. The authors developed a model to calculate the temperature by external heat fluxes, determined power and content of the radiators. Calculations show that the proposed TCS scheme guarantees temperature mode for SSC housing size 1000×1000×800(mm) and a total power capacity of 2100 Watt.

In the report *"The real trajectories of celestial bodies in the solar system and their description"* provided by the specialists of Lavochkin Association an urgent problem was announced. The motion of solar system bodies in celestial mechanics and astronomy is represented by Keplerian orbit, i.e. the path of a planet or asteroid. Upon that the current coordinates of bodies pale into insignificance or are calculated as ephemeris. Actual motion of celestial bodies and spacecraft occurs on orbit, which differs from the Keplerian due to various disturbances. The Keplerian osculating orbit is less obvious and its replacement by perturbed trajectory reflecting the current state of the bodies is even more justified.
The report discusses the kinematic trajectories of bodies, set of disturbances, a specific description of the perturbed coordinates and the resulting description of the real orbit tube, which is a spatio-temporal region encompassed many of the real trajectories. It also presents estimates of the characteristics of such tubes for certain celestial bodies and practical recommendations.

In *"Analysis of the quality of "Spektr-R" trajectory measurements"* the author described an algorithm for analyzing the quality of trajectory measurements in "Spektr-R" project. "Spektr-R" mission implementing ground-space interferometer demanded precision in determining the parameters of the spacecraft motion: better than 600m in position, 0.02m/s velocity and acceleration of 10^{-8} m/s^2. For these purposes the ground stations in Ussuriysk, Bear Lakes and Pushchino working in ***X-*** and ***S***-band were involved. The trajectory of the spacecraft orbit measurements and their processing involves several steps:

– obtaining primary measurements from ground stations;
– evaluation of the quality of measurements and rejection of anomalous;
– celestial mechanics interpretation of the measurements;
– SC vector calculation based on a series of measurements.

The algorithm begins by obtaining the residuals between the measured and calculated values. Time intervals corresponding to the residuals between measured and calculated values due to errors in the knowledge of the spacecraft orbit can be approximated by linear functions of time. On this basis the local processing is performed allowing estimating the rms deviation of the noise component of the measurement errors, and anomalous measurements are identified. Least square method is used to find a linear function of time approximating the residuals between measured and calculated values. Parameters of the linear function are determined iteratively. At each step, the two parameters are determined by a linear function and the matrix that characterizes the error in determining these parameters. Then the rms deviation difference between residuals and values that were obtained using a linear function is determined. Using these rms, the measurements are found that possess the outlying residuals. These residuals are removed and the next iteration is performed. If such measures are not found, the iterative process is terminated.

The work *"The Analysis of "Electro-L" satellite orbit correction at different flight stages"*, was performed by the specialists of Lavochkin Association and was represented by A.Nazarov. The report presents details on the step of bringing "Elekro-L" SC to the fixed position of 76°E after removing "Zenit" with "Fregat-SB" RB to a point at longitude near 55°E. Reduction took place in the period from 20.01.2011 to 10.02.2011; during this time there were five orbit corrections:

- the first was a technology operation of burning the correction engines and it did not affect the parameters of the orbit;
- second and third - major correction of SC orbital period;
- fourth and fifth - the combined correction of the period of rotation and eccentricity of the orbit for the "stop" at a given fixed position.

Correction was performed using four correction engines (CE) of rated thrust 0.5kg, the same engines are used to hold the inclination of the orbital plane of latitude in the range ±0.1° to the fixed position. SC longitude retention corrections are performed using two stabilization engines (ES) with a nominal thrust 0.05kg each.

The article presented the results of the analysis of the performed corrections, tables with their characteristics, including the predicted values of thrust, the duration of the CE and ES impulses, as well as error correction performance by changing the period of revolution and the magnitude of the vector inclination. The graphs show orbital parameters at the stage of bringing the spacecraft to a given GSO point and the trajectory of the spacecraft in the coordinates at the stage of holding at a given fixed position on GSO.

In the report *"Development of dynamic algorithm of "Fregat" booster with droppable tanks concerning the control system"* the authors described the design changes in "Fregat" caused by introduction of droppable tanks (DT); developed dynamic scheme that allows to analyze the motion of cosmic warhead with "Fregat" (RBF DT) and adjusted liquid fuel; described a method of determining hydrodynamic ratios of the dynamical scheme. As an the dynamic processes example were shown at the final stage of injection of the "Spektr-R" and "Electro-L" using RBF DT.

Several papers were devoted to the Earth monitoring (EMS) from space. The author of *"How to improve the quality of images from EMS satellites"* discussed how to reduce the gridding error of satellite images. Georeferencing error without using reference points is determined by the parameters of the orbit, shooting conditions, knowledge of the relief height error values and SC accuracy parameters. The most important for the accuracy of satellite images binding is the errors in knowledge of the reticle coordinate system (RCS) orientation of spacecraft target payload, namely:

1) AX – error in knowledge of spacecraft orientation relative to the line of sight of the telescope X-axis RCS;
2) AY – error in knowledge of spacecraft orientation with respect to the Y-axis RCS;
3) AZ – error in knowledge of spacecraft orientation with respect to the Z-axis RCS.

Parameter 1) influences the images binding error weaker than options 2) and 3). The report suggests several ways to decrease the values of precision parameters 1), 2) and 3):

- joint flight calibration of orientation sensors and payload;
- the use of measuring devices during normal operation of the spacecraft;
- the use of images of stars in the frames of the target information.

The author has also presented a comparative effect of using each of the described methods.

The report *"The geometry of the interferometric radar terrestrial relief with a pair of spacecrafts"* considered the geometry of absolute and relative motion of two spacecrafts during interferometric survey circulating on low non-Kepler orbits and experiencing perturbations typical for such orbits. This mode allows making digital maps of surface relief. One of the key issues that determines the possibility of implementing the specified characteristics of digital maps is a correct and complete description of the geometric characteristics of the base in the geocentric absolute and target-centric relative coordinates. The authors give estimates of the obtained scatter of database parameters (distance between the spacecraft that carried out the shooting) for various schemes of interferometric observations with existing management capabilities of spacecraft on low orbits.

The report *"United method for testing the performance of spatial resolution synthetic aperture radar and its components during ground and flight tests"*, provided an overview of existing methods of validating parameters of synthetic aperture radar (SAR) and their components that affect the spatial resolution parameter, and justified the necessity of using a single methodology. The author proposed to inspect all components of the radar path by the response to an equivalent point target using a special radar tester. Response parameters allow one to estimate the actual capabilities of the test object and provide the given value of spatial resolution within the framework of the radar.
The article presented radar tester schemes, schemes of components radar tests (probing signals shaper, radio frequency converters, analog-to-digital receivers, transceiver modules AFAR, sub carriers and antenna locator assembly), the radar as a whole during ground tests, and radar flight test schemes.

The report *"Some issues of application of small spacecrafts"*, presented by A.Klishin turned out to be controversial. The report addressed a problem of short lifetime of a small spacecraft (SSC), which has now got a huge spread. Low cost of such spacecrafts due to inexpensive components, their low weight, as well as the possibility of in-group launch make it possible to create such SC by universities, small businesses and groups of enthusiasts in different countries. Due to the components with low resistance to environmental conditions of outer space, SSC have short life. Moreover, in practice it often appears that the smaller SC has shorter life. Faulty SSC become dangerous to other operating and re-output SC. With this in mind, the proportion of failed SSC in the total number of cataloged objects will constantly increase, if we do not take appropriate preventive measures. The paper presents concrete proposals to solve this problem such as the introduction of the minimum "mandatory" active SSC lifetime.

Several reports were devoted to improvement of spacecraft design. In *"Dynamics of a multistage continuous deployment of remote elements of spacecraft"* the design of multithrow arms was discussed. These arms are used to organize sensors of scientific equipment in order to minimize influence of service systems on the quality of scientific information and have a length of several meters up to fifteen meters.
Usually multithrow arms are tested with sequential lap opening. Such disclosure does not account for the effects of previous steps that lead to an increase in the amplitude and the inertial loading of additional elements. The authors developed a software package performing the selection of springs under specified technical requirements and parameters of phased deployment. The proposed algorithm provides a high convergence of the calculation results with the data of the experimental testing of a phased disclosure, on the basis of which it is proposed to use it to analyze continuous deployment. Following the procedure, a comparative

analysis of the results in a phased and continuous deployment of the payload sideshift arm was performed. It was found that the effect of "overlay" is manifested at the late stages of deployment. This technique allows obtaining information about the dynamics of the system for the preliminary design phase, selecting an acceptable power circuit based on continuous disclosure.

The authors of *"Improving the durability, rigidity, precision and electrical resistance of spacecraft units using micro-arc oxidation"* noted the results of the application of micro-arc oxidation (MAO) in projects of Lavochkin Association. For such coatings produced using aluminum alloys the following characteristics are obtained: thickness up to 400 microns, microhardness – up to 2500 kg/mm^2, the breakdown voltage up to 6000V, heat – up to 2500°C, the wear resistance – at carbide level, porosity – from 2 to 50 %.

As a result of applying MAO:

- the weight of standard disclosure units is reduced;
- the reliability of the rolling units is increased;
- the schemes and conditions of MAO coating were chosen;
- the analysis of effect of coatings on the stiffness and strength of aluminum alloy pipes was made; it is noted that a coating of thin-walled tubes with a ratio of coating area to cross-sectional area more than 50% is the most appropriate;
- there was a reduction coefficient of linear thermal expansion of the aluminum parts by MAO coating, which is important for high-precision design.

The reported cases are only a few examples of application of this technology. Coatings based on MAO significantly increase the performance of metallic materials and expand the scope of their use.

In *"Engineering solution of reducing shock loads at separating stages of SC"* the author discussed the ways to reduce shock loads when pyrotechnic locks are triggered and analyzed test results. Perception of impact by hardware depends on the power of the shock pulse and on what frequency structural oscillations respond to such loading. Tests have shown that the propagation of the shock wave through the spacecraft hardware decreases shock load, which depends on the damping characteristics of the structure of the object and existing constructional joints. In the course of "Spectrum-UV" SC testing it was found that at the distance of 0.9 m (every other constructive joint) from the pyrotechnic lock - pusher the peak value decreases by an order-down to 300; when the distance from the impact plane reaches 1.5 m (two joints), the peak load is reduced by an order – 30, etc. Successful solution to reduce the dynamic effects on the unit when pyrotechnic and detonation devices are activated is the introduction of the damping devices in pyrolock-pushers and application of new high-energy materials (HEM), such as EVV-22, EVV-75, "Tranelit" and their modifications. HEM allow manufacturing monolithic "mini" charges of complex configuration, working with high reliability and precision, development of absolutely new designs of execution and transfer devices on their basis, reduction of the weight and dimensions of the components and devices, and as a result, reduction of their dynamic effects on spacecraft. As the tests showed, these activities significantly reduced the dynamic impact on the spacecraft design when pyrotechnic and detonation devices were activated.

The report *"On the history of development of self-propelled chassis of planetary expedition to Mars in the 70s of the twentieth century"* gave kinematic schemes and rovers' designs (developed under the national program of Mars exploration), their composition and technical specifications, as well as the results of ground tests were presented. The work was performed by Yu.Khakhanov, who participates in the rover development.

The first system of travelling on Mars surface was called PrOP – M-71 (Mikromarsokhod). The instrument was developed to determine the soil properties of the Martian surface and verify the new original skiing-striding mover. The control systems performed synchronization of motion of mover ski and implemented algorithms for bypassing obstacles (in the case of contact with them by rover bumpers). Rover was powered from the rover's landing unit by the block cable that passed also the telemetry data to the Earth through the orbital spacecraft. The rover was able to move from the landing unit to the distance of 15 meters. This rover was mounted on "Mars-3" space probe, whose lifetime on Mars surface was unfortunately very short.

Work on the development of self-propelled chassis (SPC) for the new rovers continued in the framework of "M-75". Special attention was paid to the development of a new control system with high autonomy – the rover should be able to move autonomously for more than 10 minutes. Much work was carried out to find the options of information system for collecting and processing data on the environment, to create self-propelled chassis for transportation of astronauts, to develop options and walking wheeled chassis.

The report gave an overview of the tests of the original circuit design propulsion rovers and options structures. Despite the considerable amount of time that elapsed since the mentioned developments, this technological advance on the specified school is of great interest to specialists, and it will undoubtedly be used in the future for the implementation of planetary exploration.

The next report by Yu.Khakhanov *"The analysis of emergency situations aroused from the operation of self-propelled chassis Lunokhod-1 and Lunokhod-2. Causes, methods of overcoming, consequences"* dismantled most serious emergencies arising from the performance of Lunokhod missions. Dramatic minutes of Lunokhod control in emergency situations were discussed. Based on this experience, the author provides recommendations for future developers of planetary rovers in terms of necessity of ground tests, redundancy of key systems and algorithms of coping with emergencies.

Alexander Evgenyevich Shakhanov, senior engineer of Lavochkin Association (Moscow, Russia). Graduated from the Moscow Aviation Institute in 2009 with a specialization “Flight dynamics and aircraft motion control”. The author of 15 reports. Scientific interests – general problems of SC design, communication systems.

Ekaterina Vitalyevna Zamkovaya, senior engineer of Lavochkin Association (Moscow, Russia). Graduated from the Moscow Aviation Institute in 2009 with a specialization “Spacecraft and booster design”. Scientific interests – target payload design, data quality maintenance.

Oleg Nikolaevich Favorskiy

Oleg Nikolaevich Favorskiy, Member of the International Editorial Committee of Russian-American scientific journal “APAAS” turned 85 on 27 January 2014. Favorskiy Oleg Nikolaevich is an Academician of USSR AS and RAS (since 1990; corresponding member – since 1981), Deputy Academician-Secretary of the Division of Power Engineering, Mechanics, Mechanical Engineering and Control Problems of RAS, Chairman of RAS Scientific Council on Russian Power Engineering Development, Chairman of the Council on Thermophysics and Thermal Technology of RAS, Vice-President of the International Academy of Power Engineering and the Academy of Aviation and Aeronautics, Academician of Electrical Engineering Academy.

The major part of Oleg Nikolaevich Favorskiy’s career has been associated with P.I.Baranov Central Institute of Aviation Motors (CIAM). He started working there just after his graduation from MAI (1951), became a scientist, defended his Candidate (PhD) thesis on the development of basic theory for a two-shaft turbojet engine and Doctoral thesis on space nuclear power plants and heat transfer in space. Possessing brilliant intuition, he has always chosen to work at the most crucial problems of aviation and power engineering industries. In particular, Oleg Nikolaevich showed himself to be an excellent organizer of science, managing and coordinating the work of a large CIAM Division on Research of nuclear rocket engines and nuclear power plants with direct thermal-electrical energy conversion. His organizing skills and creativity were highly appreciated in aviation industry, and he was appointed to the position of First Deputy Director of CIAM in 1971. From 1973 to 1988 he held the position of Executive Manager and Chief Designer of Moscow Scientific Production Association Soyuz.

During this period, Oleg Nikolaevich directed works on several original (for its time) aircraft engines. E.g. he directed final stages of development of R27V-300 engine intended for vertical take-off and landing airplane Yak-38 and R15BF2-300 engine for the best airplane of its time MiG-25. In 1978, Soyuz developed the first ever gas dynamic laser with the power exceeding 100 kW, which ran on air extracted from the engine, on the basis of R27V-300. A “small” by-pass turbojet R95-300 for a winged missile developed under the supervision of O.N.Favorskiy is the most famous one. It was an absolutely new engine designed in less than eight months and mastered by the industry in a year. A unique engine R79-300 was created in 1977-1980 for a supersonic vertical take-off and landing fighter Yak-141. At the end of 1980's, Oleg Nikolaevich returned to CIAM and held the position of Deputy Director General. He is managing the works on stationary power engineering and ecology and is performing major scientific work.

For his services in development of engines and power plants, O.N.Favorskiy was awarded with the Badge of Honor, Order for Merit to the Fatherland and a number of medals. O.N.Favorskiy is an Honored Engineer of Russia (2002), Honored Aeronautical Engineer (2003), Laureate of N.K.Baibakov Prize. He was awarded with Academician S.T.Kishkin, Academician N.A.Dollezhal, Academician V.P.Glushko, aeronautical engineer M.M.Bondaryuk medals. Favorskiy's works were awarded with Lenin (1983) and National (2000) Prizes. Oleg Nikolaevich Favorskiy is an author of 6 books, more than 250 articles and 60 inventions.

Today Oleg Nikolaevich's scientific interests are associated with the research of gas turbine power plants, power engineering ecology and the effect of jet aviation on atmospheric processes and environment. For his works in power engineering, he got one of the most prestigious international prizes "Global energy" in 2008. He is the Head of school "Physical and chemical processes of formation of environmentally dangerous compounds in power plants and jet engines", which has been winning grants of the President of Russian Federation (since 2003). The research conducted in this field received well-deserved recognition, and the results are widely used by different research institutes both in Russia and abroad.

Together with scientific works, Oleg Nikolaevich, Professor of MPhTI, has always paid much attention to training of young specialists. More than sixty postgraduate students defended their PhD theses under his supervision, five of them later became Doctors of Sciences. His monographs constitute the basis for multiple courses of lectures delivered at different higher schools of Russia and CIS. O.N.Favorskiy is a member of several academic councils, Editor-in-Chief and a member of editorial boards of different Russian scientific journals: "Energiya: Ekonomika, Tekhnika, Ecologiya" (Energy: Economics, Engineering, Ecology), "High Temperature", "Dvigatel" (Engine), "ELECTRO. Electrotekhnika, Electroenergetika, Elektrotekhnicheskaya Promyshlennost" (ELECTRO: Electrical Engineering, Electrical Power Engineering, Electrical Industry), "Gazoturbinniye Tekhnologii" (Gas Turbine Technologies), "Konversiya v Mashinostroenii" (Conversion in Mechanical Engineering), "Teploenergetika" (Heat Power Engineering).

We wish to dear Oleg Nikolaevich "stability on infinite time interval under all permanently acting perturbations"! Happiness, new success and energy in all activities!

INTERNATIONAL FEDERATION OF NONLINEAR ANALYSTS

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International Scientific Edition

IFNA-ANS-AAAS-RAATs - International Scientific Edition (ISE) is founded (1994) by *Kazan Chetayev School of stability and mechanics* ,under the aegis of International Federation of nonlinear analysts and Academy of nonlinear sciences.This interuniversity non-ordinary initiative raised by the intelligence of swiftly developing World brilliantly implements the objectives and goals laid in its foundations which had been formed by the following provisions:

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- "Unity in Diversity" (**V.Lakshmikantham**);
- **"If to be, it is necessary to be the First" (V.P.Chkalov);**
- "**Newtonian Mechanics** is an unequalled achievement of physics (natural philosophy), the whole history of human civilization. IT IS EVERLASTING. **Its powerful tree is sprouting more and more branches**. Among them there are the branches that have grown from scions grafted on this tree and cultivated in other natural sciences" (**G.G.Chyorny**);
- "Mathematics is an effective "transport" which is able to provide significant breakthrough in understanding of the essence of Environment, with deep penetration of its approaches into all the spheres including the unconventional ones".

The period of effective and successful activities resulted in establishment of ISE as a *bilingual* interdisciplinary Scientific Edition representing researches of nonlinear problems in all the diversity of basic and applied sciences. Structurally the Journal is organized as periodic Edition in two series (Journals), with preparing invited articles (as problematic character surveys) and also special topical issues on advanced scientific directions including natural sciences and the humanities (mathematics, mechanics, physics, chemistry, engineering sciences, including aviation and aerospace technologies; biological, medical, social and political sciences; ecology, cosmology, economics; nanoscience and nanotechnology, stability and sustainable development in economical, social and political systems; problems of risk and information protection, operational research, problems of higher engineering education, …).

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– **P.J.Werbos**. *Brain-Like Intelligent Control: From Neural Nets to True Brain-Like Intelligence*
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АКТУАЛЬНЫЕ ПРОБЛЕМЫ АВИАЦИОННЫХ И АЭРОКОСМИЧЕСКИХ СИСТЕМ

Казань Дайтона Бич

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