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ACADEMY OF AVIATION AND AERONAUTICS SCIENCES

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OF AVIATION AND AEROSPACE SYSTEMS
processes, models, experiment

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- to mathematize the methods in solving of problems, generated by engineering practice;
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ACTUAL PROBLEMS OF AVIATION AND AEROSPACE SYSTEMS

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

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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.2(37), Vol.18, 2013*, is another special issue devoted to the greatest events of the history of Mankind associated with the beginning of Space exploration Era.

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

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

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

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

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

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

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

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

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

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

The papers published in this special issue describe the developments of the leading specialists in aerospace; they contain the historical analysis of the way that led to the positive results of the beginning of Space Era. Scientific research, analytical reviews on these events and relevant problems, analytical and information articles, polemical ideas and prospects of further development of Astronautics in Russia and in the World, reflections on the meaning of space scientific and engineering heritage for the whole world society and results in the sphere of aviation and aerospace systems are presented.
The special issue was prepared with support from our Partners, among them: Cosmonautics Federation of Russia, Central Scientific Research Institute for Machine Building, Federal Space Agency, K.E.Tsiolkovsky Russian Academy of Cosmonautics, Academy of Aviation and Aeronautics Sciences, A.A.Maksimov Scientific and Research Institute of Space Systems, N.E.Bauman Moscow State Technical University, Moscow Aviation Institute (National Research University), International Academy of Astronautics, Institute of Control Sciences of RAS, Concern CSRI Elektropribor, Kazan Federal University (KFU), …

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

N.G.Panichkin, M.N.Kovbich, N.Y.Dorozhkin (TsNIIMash, Russia), experts in the field of space-rocket activity, – with the brief scientific-technical survey of Academician Vladimir Fyodorovich Utkin activity and life, one of Directors TsNIIMash (1990-2000); it is devoted to 90-th Anniversary of General Designer of «Voevoda» - «Satan» rocket, V.F.Utkin.
E.Spedicato (University of Bergamo, Italy), the expert in the field of operations research, – with scientific research and discussion in framework of proposed coherent scenario for the evolution of Earth and Solar system since about 12,000 BC; in work it is presented novel aspects of evolution that is based on script of evolution connected with planet Nibiru which is mentioned in the most ancient sumerian myphologies.
Yu.A.Krashanitsa (National space University of N.E.Zhukovskiy name "KhAI", Ukraine), the expert in the field of the theory of the generalized potentials and the boundary-integral equations, – with results of numerical realization in the perspective integrated computer technology based on ideology of a method of the boundary-integral equations.
C.Maccone (SETI Permanent Study Group, International Academy of Astronautics, Italy), specialist in area of mathematical physics and space problems, – with presentation of novel author's mathematical model of Evolution in whole: on Darwin and in problem of search for extraterrestrial intelligence (SETI), using theory of Geometric Brownian Motion.
L.B.Shilov (TsSKB-Progress, Russia), the expert in the field of designing space vehicles of Earth observation, – with the algorithmic approach to a choice of installation sites of antenna devices on low-orbit space vehicle.
Zheng Guanghua, Chen Yong (Northwest polytechnic University, Xi'an, China), experts in the field of researches of flows and heat exchange in aviation engines, – with results of numerical research of technological system of the cooling combining convection and film cooling and having good efficiency.
G.Bertoni, P.Castaldi, M.E.Penati (University of Bologna, Italy), experts in the field of automatic control, including, active failure-safe control, – with discussion of methodological prospects and problems of training on engineering specialty during realization of the project (project-based education).

A.K.Medvedeva, A.M.Peslyak (S.A.Vavilov Institute for History of Natural Sciences and Engineering of RAS, Russia), specialists in area of space flight mechanics, history of Astronautics and Engineering, – with analytical, scientific-information survey on actual problems of Cosmonautics within XXXVII Academic Conference on Cosmonautics.

Academician V.F.Utkin and the TSNIIMash
(to 90-th Anniversary of General Designer of «Voevoda» - «Satan» rocket)

N.G.Panichkin, M.N.Kovbich, N.Y.Dorozhkin
TSNIIMash, Korolyev, M.R., Russia

Vladimir Fyodorovich Utkin (17.10.1923–15.02.2000) graduated from Leningrad Mechanical Institute (1952); main fields of scientific activity – development of optimal structural layout of products, research of construction materials subject to long-term contacts with deleterious gas/liquid media, development of methods for improvement of complex mechanical systems reliability. Academician of USSR AS (since 1984), twice Hero of Socialist Labor (1969, 1976), Lenin Prize laureate (1964), USSR National Prize laureate (1981), S.P.Korolev Gold Medal.

Rocket and Space Community

Academician Vladimir Fyodorovich Utkin

Vladimir Fyodorovich Utkin had worked in Dnepropetrovsk as a head of the Yuzhnoe Design Office/NPO Yuzhnoe for already 20 years when he began his closely collaboration with the Institute. It is this enterprise where four new-generation strategic missile systems assuring the parity of the Soviet nuclear forces were developed and put into service under the guidance of V.F.Utkin. As Academician N.A.Anfimov recalls at that same time the Yuzhnoe NPO developed several types of space launch vehicles and spacecraft. Each of these items was designed on the basis of new concepts/original technical solutions of the invention level, utilization of the latest achievements in various scientific fields.

Cooperation of Yuzhnoe and TSNIIMash was maintained in the form of preliminary design studies and search for opportunities of achieving the customized qualitatively new enhanced technical characteristics and design computations as well as experimental maturing and testing of the developed systems. Particularly close cooperation with the Yuzhnoe colleagues was experienced by our specialists in aerodynamics, structure integrity, dynamics and thermal control. All their developments were verified by computations and experiments conducted by departments and laboratories. Many original technical solutions adopted by the Yuzhnoe Design Office under V.F.Utkin's guidance have practically no world analogs. The specialists didn't overdesign the items to improve their technical characteristics and efficiency that demanded precise computations and obligatory validation first by ground and then by flight tests. TSNIIMash researchers and specialists directly participated in all these operations. Many of them became accustomed to the Moscow-Dnepropetrovsk round trip.

In 1969 the Soviet Union's top leadership proclaimed the doctrine of no-first use of nuclear weapons. It meant that the intercontinental ballistic missiles (ICBMs) under development had to be designed for the use of retaliatory strike only, in other words after a nuclear strike against their deployment areas. At that very time theYuzhnoe Design Office together with TSNIIMash put forward a number of technical solutions focused on the operational effectiveness enhancement of the new-generation Intercontinental Ballistic Missile retaliatory strikes including construction of hardened silos, mobile strategic missile systems and many other things.

Way back in Dnepropetrovsk V.F.Utkin had always been open for contacts with TSNIIMash scientists and specialists. As Academician N.A.Anfimov recalls, professor Alexander Vasilievich Karmishin, the Structure Integrity Department Chief and the "Leading Structural Engineer" was the man who enjoyed the particular Vladimir Fyodorovich's confidence. One of the clearly evident results of their creative collaboration is construction of the unique full-scale vibration load simulator in the Yuzhnoe Design Office for simulating the vibration loads on the first in the world railroad mobile missile complex which had to remain on the railroad tracks for all its service life moving along RASdomly selected routes preventing potential strikes against it by a would-be aggressor.

Vladimir Fyodorovich recalled that time as follows, "I remember the time when we in the Yuzhnoe Design Office were developing unusual battle railroad complexes, the so called missile trains for making ourselves safe from American Pershing pinpoint strikes. And the TSNIIMash Structure Integrity Department (headed by professor Alexander Vasilievich Karmishin, well known in the space industry) took part in solving of the most complex problems occurred during the development testing of these unique complexes. TSNIIMash was assigned the task of solving rather complex and critical problems of assuring the railroad complex survivability under long-term vibration loading conditions. Naturally, it required simulated operational tests. To avoid construction of a very expensive special railroad track it was proposed to design a vibration test facility supporting a railroad car together with the missile (by the way, their total mass was over 200 tons).

For that purpose a laboratory room was needed as well as some test equipment including imported equipment, the latter to be paid in foreign currency. Then we had to ask Oleg Vladimirovich Baklanov, the Minister of General-Purpose Mechanical Engineering to get the required financing by the State Planning Department (GOSPLAN). Using the unique vibration test facility developed within the shortest time the necessary complex structural strength was achieved which was soon entered the service. In 1987 the first serial train (altogether 12 trains were built) became operational leaving the Pavlograd mechanical engineering factory's special assembly and integration base. So the most critical problem of increasing the country's capability of containing the adversary was solved. And in 1984 A.V.Karmishin and we (the team of authors) got the inventor's certificate" [1, 6].

V.F.Utkin – TSNIIMash Director

Vladimir Fyodorovich Utkin, Academician of the Academies of Sciences of the USSR and the Ukrainian Soviet Socialist Republic, Twice Hero of Socialist Labor, Laureate of the Lenin and State Prizes, Chevalier of many high government awards took the position of the Director of TSNIIMash in 1990. He began to familiarize himself with the Institute's life, regularly visit its units, and have talks with people. It was found that the new Director highly appreciated the Institute and its previous activity results and he spoke about it with his partners more than once. Attitude of V.F.Utkin to what was accumulated by the Institute, i.e. themes of its activity, structure, employees, to the Director's deputies and the Director himself, i.e. Yury Alexandrovich Mozzhorin who continued to work in the Institute as the Chief Scientific Adviser was favorable. As a matter of experience Vladimir Fyodorovich paid special attention to the Institute's unique experimental facilities more than once stressing their determining significance for ground testing of newly developed rocket and space systems It is interesting to underline that when Utkin was holding the office of the TSNIIMash Director the supersonic/hypersonic aerodynamic tunnel U-306-3 largest in Europe was put into operation though previously it was designed mainly to be used for solving the problems of the Yuzhnoe Design Office.

Being an experienced designer and manufacturer he paid special attention to the experimental production shop understanding its value and significance for the leading institute of the Space Industry. He often visited the shop floors, spoke with locksmiths and machine operators, making impression on the workers by his knowledge of machine inventory, production technology of parts and equipment assemblies. Besides that Vladimir Fyodorovich started to daily supervise the social needs of the employees.

But V.F.Utkin didn't limit his efforts by preservation of everything time-worn and traditional. As Academician N.A.Anfimov wrote there were drastic innovations made. First of all Vladimir Fyodorovich removed the Control Group from the R&D Coordination Division, converted it in a Sector and made it accountable to him. At the same time exactingness of the control of realizing oral and written instructions was enhanced with analysis of their realization at weekly operative sessions of the enterprise leadership board. The second innovation was of principal nature. Being convinced that the Institute alongside with R&D activity should become responsible for leading certain experimental and development works Vladimir Fyodorovich having the General Designer's rich experience launched the R&D activity in the Institute in support of developing experimental special-purpose flying vehicles based on critical technologies and new-generation technologies. As a result TSNIIMash won the competition with one of the most authoritative and honorable Design Offices in this technology field and was awarded a government order thus busying a number of the Institute's units and cooperating organizations.

V.F.Utkin came to the Institute on the eve of the most difficult period of disintegration and crumbling of our economy and, particularly, the defense and industry complex. Destructive processes in the country's economy and sharp reduction of the government financing of the rocket and space industry development which started in 1990-1991 inflicted a painful blow to the Institute. The Institute was facing experienced workers outflow and reduction of the personnel number as well as permanent shortage of operational resources and just inability to maintain the manufacture buildings and unique test facilities. Vladimir Fyodorovich headed the struggle for surviving and preserving the TSNIIMash as a leading research center of the Rocket and Space BRASch.

Particularly great efforts were taken by Vladimir Fyodorovich to preserve the TSNIIMash integrity. At that time of troubles when the "reformers" promulgated the privatization of the public property, flotation of the public enterprises and their parts Vladimir Fyodorovich called the Institute workers for refusing to follow the trends of separating some large units from the Institute. He thought that the TSNIIMash strength is its integrity. The leading Institute of the Rocket and Space BRASch should fully satisfy the customers' demands and be ready to fulfill works on validation of the main lines of technology development, elaborate programmatic and conceptual documents, examine the projects, issue findings and recommendations, directly participate in product testing using the intellectual potential gathered for decades, and country-built experimental facilities. He convincingly proved that TSNIIMash would be a unique structure in the national and world practice only being a single entity and was firmly convinced that this heritage should not be lost [1, 5].

V.F.Utkin and the Russian Federal Space Program

Following the formation of the Russian Space Agency in 1992 Vladimir Fyodorovich headed the works of TSNIIMash on forming the Federal Space Program of Russia for the period of

up to 2000. The paper was endorsed by the Russian Space Agency, the Interagency Space Commission, and thereafter was approved by the RF Government's regulation. Vladimir Fyodorovich started its realization right after its approval. Life confirmed the exclusive importance of the State Program for preserving Russia's space activity in the phase of tRASsition from the planned to the market economy in the worst sense of the word. It is the availability of the Federal Space Program of Russia and ability of attracting foreign means within international cooperation framework that enabled the national Rocket and Space Industry to survive under conditions of economic collapse of the nineties.
As an Acting Member of the USSR Academy of Sciences, later the Russian Academy of Sciences and from 1988 to 1992 a Member of the Academy Presidium V.F.Utkin concentrated his efforts on maturing the largest scientific projects associated with development of Spektr heavy-mass space astrophysical observatory and an unmanned Mars exploration complex. The two projects were implemented behind the schedule due to financing shortages. At the same time to realize the projects scientific equipment costing over 450 million dollars was imported under the international agreements. Vladimir Fyodorovich headed an ad hoc joint commission of Roscosmos and the Russian Academy of Sciences for coordinating the efforts of the project members trying under the existing conditions to complete the space complex development. The Mars exploration complex was completed in 1996 and Vladimir Fyodorovich did his best in this business, but the Mars-96 unmanned interplanetary station launch was abortive due to failure of the second firing of the booster engine at orbit insertion leg in November 16, 1996. It was Utkin who was put in charge of heading the Interagency Commission for clarifying the abortive launch cause. The same kind of unpleasant work was fulfilled by V.F.Utkin in late 1999 after the Proton SLV failure when orbit-inserting the Express-A new-generation communication satellite [1].

V.F.Utkin and the Conversion Projects of the Institute

V.F.Utkin paid much attention to the conversion activity. Considering this kind of activity exclusively critical for the Institute's survival under the existing conditions he controlled all advanced developments associated with conversion and rendered all kinds of support. Showing deep interest in the gist of a new conversion work he applying his rich experience predicted the probability of success (and, as a rule, was not mistaken), gave concrete constructive advice.
N.G.Panichkin (Chief of the Applied Research Center) recalls some of the conversion works. "Our Institute received a letter from the USSR Office of the Prosecutor General which was sent by the corresponding authorities of the then Ukrainian Soviet Socialist Republic with the request to investigate the equipment damage case at the South-Ukrainian atomic power station located in the Nikolaev Region just after 11 months upon its commissioning. One should note, that this case was not a single one concerning an atomic power station of this design: with the guaRASteed service life of 30 years main cracks formed in 2-3 years from the time of putting the blocks in operation. In this case all previous records were hit".
It is a case with a rather new design version of a steam generator for the atomic power station blocks with 1000 MW boiling water reactors. Two core headers of the steam generator serving for heat-tRASsfer agent supply and discharge in the first heating loop are structurally represented by thick-wall cylinders. They are interconnected with 11,000 pipes forming a heat exchange surface for heating the second loop medium from which the steam is exhaled. To embed the heat exchange pipes in the core header its side surface is perforated chequerwise. During the operation cracks appeared in the strips between the holes. Some cracks form through main cracks presenting a serious danger of the steam generator failure-free operation in general. The causes of the cracks origination were to be identified".

Having received the order of V.F.Utkin to launch the studies of the case A.V.Karmishin, Chief of the Structure Integrity Department formed and headed an Expert Team of the Institute. Due to an extreme complexity of the processes in the steam generator the Team was staffed with the leading specialists of the enterprise including heat tRASsfer and hydrodynamic specialists. Because of a certain identity of the tasks under consideration the first role in solving the structure integrity problem on the whole was assigned to the specialists of the liquid propulsion rocket engine (LPRE) Structure Integrity Test Laboratory at that time headed by the author of the present article. The works started with studies of structure loading conditions: the following specifications given by the leading contractor of the atomic power station ("Hydropress" Special Design Office of Podolsk) – working pressures and their pulsations, thermal environment, internal forces in various elements of the steam generator were specified. It was found that the level of structure stress condition greatly depended on the residual technological stresses occurring during insertion of heat exchange pipes in the core header. We issued reports and formulated findings. The Contractor completely agreed with the TSNIIMash findings. Vladimir Fyodorovich was permanently informed of the work progress.
Having won the respect and esteem of the Podolsk specialists and management (they involved the leading institutions of the USSR Academy of Sciences, Institutes of other industries having lost 2-3 years for solving the given problem, but to no avail), the TSNIIMash structural community fulfilled a set of investigations at request of the "Hydropress" Special Design Office itself in support of updating the steam generator structure. The methods of embedding the pipe bunch were developed and put into service minimizing the residual technological stresses. Measures for extending the service life of active core headers produced applying the explosion technology were developed and realized by means of reducing the operational loads originating due to exemption of certain rigid loads. The positive effect of these solutions was proved by the results of monitoring all blocks of the atomic power station of the given design.
Another critical direction of the Institute conversion activity concerning the structure integrity is associated with assuring the safety of Russian hydraulic installations. But when the structural community of TSNIIMash was involved in the works concerning the atomic power station equipment due to circumstances of pure external nature the activity to study the lockage objects structure integrity was realized according to another scenario. After the Ministry of General-Purpose Mechanical Engineering disintegrated it became clear that it would be necessary to find conversion works outside the rocket and space bRASch framework. … We were lucky enough, – recalls N.G.Panichkin, – that at the very beginning of this pathway we met Vadim Alexeevich Vinogradov, a highly qualified specialist, man of vision and generally a good man, the leader of the Volga-Don Main Basin Administration. It was V.A.Vinogradov who sat first objectives and promoted investment in technical state examination of balance gate metal constructions on the Volga-Don Canal and their remaining structural strength determination as well as providing recommendations on repair operations. A.I.Likhoded and V.S.Sinelnikov stood at the origins of the pointed operations from our side. Those were extremely responsible operations as balance gate constructions are the main unit, providing security of hydraulic structures, restraining colossal water capacity. The results of man-made impact, connected with break of waterfront and water flood of enormous territories are comparable to the aftereffects of Chernobyl disaster. Not once and even twice we discussed with Vladimir Fyodorovich the question of the responsibility of the Institute in that activity. Who, if not we, having the unique experimental base, the most perfect analysis techniques, the most experienced specialists in the field of strength development of RST structures can facilitate cornered "MintRASs" of Russia. The main part of the operative

hydraulic works was put into operation more than 60 years ago. GuaRASteed lifetime of the balance gate metal constructions made void a long time ago. At the moment the country doesn't have neither technical nor financial possibilities to realize the required substitution of all balance gates. To help "MintRASs"of Russia in this problem solving we suggested our service. But only having analyzed the results of the Strength center work for several first years V.F.Utkin made a conclusion that the Institute could manage to do it.
For the period of collaborative work a data base about the majority operative balance gates was composed. Also the technical state of the gates was examined and the order of replacement was made. The ways of repair were offered as well as the prolongation of the constructions lifetime. For the purpose analysis methods of the metal constructions stress-strain behavior and the assessment methodology of their remaining structural strength were designed. For the first time in the world practice with the help of double-leaf gate fall-scale structure their stress condition experimental research was executed and the remaining lifetime was defined. Together with the project organizations and enterprises in charge of the gate exploitation relevant normative cross-reference was developed. Besides, a mobile diagnostic laboratory fitted with required equipment and computing technology for carrying-out of an express-analysis of the metal constructions technical state was created.
Together with the organization "Lenhydrostal" some projects were developed and more than 50 new generation balance gates with 100 years guaRASteed lifetime were put into operation. A RASge of possible failures with unpredictable disastrous effects was prevented. The connection geography was extended: in line with Volgo-Don Main Basin Administration of waterways and navigation works are also being realized with Moscow Canal, Samarsky, Gorodetsky, Balakovsky, Novosibirsky, Belomoro-Onezhsky and other hydraulic structure areas. All this provided "MintRASs"of Russia an oppotunity to give TSNIIMash the main role in its department in the field of providing strength and forcing metal constructions of Russian hydraulic works. The complex of the above mentioned researches awarded the Prize of the Government of Russia for the year of 2000. The leader of the putting forward work was going to be V.F.Utkin (but unfortunately, posthumously). However, in connection with the need of his participation that very year in the other project on missile munitions, the title of laureate he got being within the last group. Vladimir Fyodorovich enjoyed the respect of the specialists of "MintRASs"of Russia. In 1996 he was awarded the "300th anniversary of Russian fleet" medal. He was regularly invited to the famous jubilees in Kolomensky Hall of House of Unions. V.F.Utkin delivered a congratulatory speech on the occasion of the 200th anniversary of Russia's waterways".
As another case in point N.G.Panichkin mentions high-temperature dangerous waste destruction method development on the basis of missile technologies and its practice in Ryazanskaya area with the aim of pesticide cancellation and other poisonous agro industrial waste [1, 2].

V.F.Utkin and TsUP of TSNIIMash

The Centre of Spacecraft Control and Modeling of TSNIIMash (TsUP-M) according to the general guidelines and its problems solving is much different from the similar organizations in Russia and abroad. This is critically explained by its origin specificity and following development. TsUP -M started up and grew in the frame of TSNIIMash – the heading Institute of Russia on rocket-and-space technology. This predicted the main specific character of TsUP -M activity consisting in that together with the spacecraft control the staff members realized and realize the great scientific and research work on the most different applied and fundamental directions of the rocket and space technology, taking in lots of ways the leading place not only in the country but also in the world.

The applied and scientific activities are closely intertwined. They add and enrich each other. In some cases this allows to get just unique results which in other cases probably wouldn't be possible to get (just let's recollect the unique comet rendezvous mission Galley when TSUP-M was the heading structure not only on the comet ephemerides detection program but also on guidance on the comet of European spacecraft "Jotto"). It should be pointed out that the main task of TsUP -M was and is the aim of providing spacecraft control. Mistakes in this work are in principle impossible. Nomenclature and work capacity here are enormous.
By V.F.Utkin's arrival TsUP -M had already been a powerful specialized foundation with developed infrastructure, high scientific and technical potential, having great experience in different space vehicles control. From outside it seemed that everything was excellent and the only task was to back the achieved things up, and of course improve that was achieved for a lot of years. However the objective factors, new directions of space technology development, the absence of advanced national technology, that TsUP required, led to the need of the present circumstances detailed evaluation and making cardinal decisions on the choice of the further ways of development. And the technical inquiry TsUP-M with suggestions on organization of Russian spacecraft operative control with maximum using of present technical and organizational structures and space development perspectives was put on V.F.Utkin's desk.
The main point of those suggestions was that considering that at the end of the 1980s there was an evident main spacecraft designers' tendency to create their own TsUPs at the enterprises, as well as the vast financial reduction of the space-and-rocket field, it made sense to examine the question of the extension of TsUP-M of TSNIIMash functions, having given all manned systems control, all outer space objects control, the scientific and social and economic objects control ("Meteor", "Prognoz", "Astron", "AUOS", "Okean" and others), the upper stages work control, the information processing operation and its reduction to users (ecological monitoring, space emergencies, etc.) to it.
After the detailed examination of TsUP administration's suggestions V.F.Utkin agreed with the given reasons and admitted their correctness and timing, as well as made magnificent efforts to realize them. It wasn't so easy, at least, because of two reasons. Firstly, there was serious opposition of some organizations (their interests and the suggestions didn't coincide). Secondly, technical re-equipping, procurement and implementation of the general license software and social software development without subcontracting needed great financial investments.
V.F.Utkin's prominent service consisted in that he could convince the administration of Roskosmos in the need of realization of these arRASgements. The technical re-equipping concept of TsUP was realized on the basis of the principle of providing spacecraft control effectiveness. That needed the task performance during all the stages of preparation and realization of spacecraft control with minimum expenses and guaRASteed reliability. One very important achievement is worth mentioning, it was the creation of a quite new special spacecraft control sector of a scientific and social and economic assignment. The first object which was controlled from the sector was a Russian-Ukrainian spacecraft "Okean-O", which had been designed and created by the end of the 1980s in the Yuzhnoe Design Office. The spacecraft was launched by "Zenith" carrier vehicle, also designed under V.F.Utkin's command.
For the solving of the spacecraft "Okean-O" control problems some new methods and combined spacecraft control algorithms were designed that allowed to provide the movement orientation of the spacecraft, its positive power balance, and the most important thing - the performance of claims of target information take-off. The work with the spacecraft "Okean-O" was successfully led for 3 split years (almost 3 times more than the guaRASteed period). It is interesting to note, that a week after the launch of the spacecraft "Okean-O" the press

announced about the spacecraft switchover. At the same time the spacecraft control centre was realizing the control preparation of the spacecraft “Meteor 3M” with some American facilities on board. It was put successfully into orbit.

It shouldn’t go unmentioned that one more new important activity direction of TsUP is the program “Sea Start” preparation and its putting into action with the use of the mentioned “Zenith” launch vehicle. The successful program work organization and performance widely extends the possibilities of TsUP and stands the latter on a principally new level of development. The past completely confirmed the correctness of the ideas and principles of TsUP-M realignment. TsUP-M not only completely rearmed but began realizing new works, taking up positions of the brunch spacecraft control centre [4].

Coordination Scientific and Technical Board (CSTB) and International Space Collaboration

V.F.Utkin paid a lot of attention to the International space collaboration. Under his guidance the scientific and research safety assessment of the international space flights on board “Mir” and ISS (International Space Station) was organized in the framework of Russian-American Utkin-Stafford commission. The moments of the commission co-chairmen’s (V.F.Utkin and general Stafford) work are especially memorable after the impact of “Progress M-34” cargo spacecraft with “Mir” on June, 25, 1997. That incident became a reason of the campaign in American press, placing in question the reliability of Russian space technology and American astronauts’ safety using it. The results of Utkin-Stafford commission study case (that was on the basis of the inspection of TSNIIMash) reported to the commission of US Congress by Stafford prevented the risk of the USA withdrawal from the collaborative space program. As a leader of Coordination Scientific and Technical Board (CSTB) of Rosaviacosmos and RAS (Russian Academy of Sciences) on providing research experiments on board “Mir” and Russia’s segment of ISS, Utkin was in charge of examination and choosing Russian scientists’ suggestions on scientific and applied researches and experiments on board orbital stations.

The confirmed Provision about CSTB provided the organization of choosing the suggestions on the pursuance of the research, project examination of scientific and applied researches and experiments, development and creation of specific facilities for the needs of ISS and manned complexes and their financing suggestions, as well as defining of the main priorities of scientific and applied program realization, defining of the collaborative direction and Russia’s participation in international manned mission programs, the results reviewing of program final stages on manned complexes, realizing of the results of the scientific work inspection, and giving recommendations on their further putting into activity on a competitive basis.

According to V.F.Utkin’s idea CSTB had to be a collegiate scientific and technical expert body with the purpose of development, formation of long-term research programs and experiments on manned space complexes (on a competitive basis) created in the framework of Russian Federal Space Program, Interstate Space Program and programs of international collaboration, their scientific and technical accompaniment, providing their evolutionary development and perfection. CSTB got the role in realizing of strategic planning and in some cases - in the solving of the most difficult and responsible problem of tactic planning and control of realization researches on manned space complexes with working out of some specific recommendations for the leadership of the programs.

Originally CSTB consisted of 10 sections – structural and thematic branches. Within the sections of CSTB were leaders and scientific specialists, designers, highly qualified specialists of enterprises and organizations of the rocket-and-space branch, as well as some representatives of RAS and other departments, altogether in such cooperation there were 80 organizations. Among them were: Institute for Solid State Physics of RAS, the Institute of

Terrestrial Magnitism and Radio Wave Propagation, Institute of Biomedical Problems, Institute of Radiotechnics Electronics of RAS, Space Research Institute of RAS, RAO “Biopreparation”, “Energy” (technical researches and experiments), TSNIIMash, M.V.Keldysh Research Centre, RI of Nuclear Physics of Moscow State University. CSTB has almost the same structure at the present time. The leaders of the sections were heading Russian scientists and specialists on specific research direction. Lots of the leaders were at the same time the directors of the heading scientific organizations or their large units.

Under the aegis of CSTB the great work capacity on formation and realization of research programs was performed with some international partners’ participation. Despite the great strain in work during specific problem solving and the enormous cooperation of outside scientists all the works were performed with great enthusiasm and creative delivery from subprofesionals to the leadership. V.F.Utkin could set a task and organize work that everyone was interested.

Before the important meetings and making responsible decisions Utkin called extra CSTB meetings, where the key problems were discussed and conceptual ways of problem solving were worked out. V.F.Utkin always provided representatives of all sections a possibility for the public speaking.

V.F.Utkin thought first of all as a designer, got the main point of problems at once. He always listened to the speakers up to the end and then with one capacious phrase drew up the discussion results. Utkin’s decisions were always thought over.

From 1994 to 2000 CSTB in cooperation with the heading specialists in the field of science and technology executed a great piece of work. It was a difficult period but by that time in accordance with the interstate agreements the program of scientific and technical collaboration between Russia and the USA in the field of manned space missions had been realizing.

As the main designer of the military rocket called “Voevoda” (in the USA it was called “Satan”) Utkin earned a great reputation among the international partners.

In arduous discussions with the international partners Utkin often made examples fron the history of Russian rocket-and-space technology, the unique Russian experience of long-lasting manned space flight. That was the best way to convince the opponents.

World space agencies invited V.F.Utkin to take part in different conferences and work groups. His reports were always vivid and bright. At meetings he marked the discussion of any technical problems.

Under V.F.Utkins guidance for the short period of time a great deal of pioneer work was done. The main of them: the integrated plan of researches was formed and its realization on the the program “Science-NASA” (Rosaviakosmos-NASA contract, US$20 millions, 1994-1998). The program of scientific and applied researches on the orbital complex “Mir” (1997-1999), as well as the other long-lasting scientific and applied researches and experiments program on Russian segment of ISS (1999) were developed [1, 3].

V.F.Utkin’s work style

Utkin’s creative process can be divided into 4 stages: the idea development, its conceptual construction, the working out of scientific and practical image of the idea, public discussion of the suggesting decision and the urgent realization with positive results.

The main task of V.F.Utkin’s activity was to force and develop Russia’s rocket-and-space industry, preserving its leading role in space. The Director had authority with the leadership of Rosaviakosmos: General Director Yu.N.Koptev, his assistant V.V.Alaverdov, the Head of Department B.V.Bodin and other people.

Everybody who worked with V.F. Utkin in TSNIIMash marked his uncommon commitment, the precision in work and deep knowledge and huge interest not only to the fields of science and technology he dealt with but also to other ones. He was a very well-educated person.
V.F.Utkin examined any question with punctuality and seriousness, that helped him make very precise conclusions and faultless decisions about the ways of further activity.
His work in TSNIIMash was marked with high State Russian Awards. In 1996 V.F.Utkin was awarded the Order “For Merits before Fatherland”, III degree in 1996 and in 1998 he was awarded the Order “For Merits before Fatherland”, II degree [1, 5].

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Nikolay Georgievich Panichkin, a scientist, specializes in rocketry strength; supervisor of ground tryout of rocket and space systems, including the systems of scientific, social and economic purposes.
Graduated from Moscow Institute of Physics and Technology (1968), finished full-time postgraduate study of MIPT (1971), Candidate of Physical and Mathematical Sciences (1975), senior researcher (1984), Associate Professor (1997).
Full member (1994), Academician-Secretary of K.E.Tsiolkovskiy Russian Academy of Cosmonautics.
Since 1971 in TsNIIMash – Head of the Center for Strength Research (1992), Deputy Director for scientific work in the field of aerothermomechanics and strength – Head of the Center for Applied Research (2000).
Since 2009 – first Deputy General Director for applied research, reliability, standardization, certification and experimental facilities.
The first Deputy General Director for applied research, testing, experimental facilities and international activity (March 2012 – February 2013).
From 2013 – General Director of Federal State Unitary Enterprise TsNIIMash.
Deputy Director of Space Vehicles department (the main MIPT department).
Published more than 6 monographs and over 100 papers.
Laureate of USSR National Prize (1989) and the Prize of the Government of the Russian Federation in the field of science (2000, 2001, 2012), honored mechanical engineer of the Russian Federation (1995). Awarded with the medals “300 years of the Russian Navy” (1996) and “In Commemoration of the 850th Anniversary of Moscow” (1997); department-level awards.

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During the period of 1984-2011 did his military service starting from the position of company execution officer and up to the Associate Professor of the military academy department, retiree colonel.
Since 2011 – Head of TsNIIMash division responsible, among all, for retrospective research of establishment and development of Russian space industry.
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At present he is studying history and propagating the achievements of Russian astronautics.
Awarded with the Order of the Badge of Honor (1969) and a number of honorary awards of public organizations.

From Nibiru to Tiamat, an astronomic scenario for earliest Sumerian cosmology

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In this paper we consider the Sumerian tradition of a planet, called Nibiru, claimed to approach Earth every 3600 years. We argue that the real period was 20 years and that a close passage of that body near Earth around 9500 BC ended the last Ice Age and the Atlantis civilization. Moreover a satellite of Nibiru became our Moon, in addition to the previous satellite, that was Mars. We discuss ancient statements that Moon originally looked bigger and brighter than now and that the period of about 2400 years when there were two satellites explains the myth of Isis and Osiris. We argue that Nibiru around 6900 BC disappeared in a giant impact on Jupiter. Between 9500 and 6900 BC Nibiru probably came about 120 times near Earth, several times quite close, the close passages possibly related to the reincarnations of the Indian supreme goddess Shakti. We discuss some consequences of the impact on Jupiter, using also results of Ackerman and of Li, among them: the formation of Venus-Athena, the formation of the asteroid belt, the generation of short period comets, the battle of Jupiter against Giants and Titans, the removal of Mars from a weak tie with Earth (Osiris killed by Seth), and the displacement of Jupiter from its previous orbit, where the asteroid belt is now located, to the present orbit more distant from Sun. We notice that the impact was almost certainly a frontal one, maximizing the effects [1-29].

1. The origin of Moon, an introduction

Till not many years ago the origin of the Moon was generally related to the origin of Earth. Both bodies were considered as originated from the condensation of primordial material, several theories proposing different details of the process. When Moon's rocks were collected via space expeditions, it appeared that the standard scenario was not correct, because the rock composition of Moon was too different from Earth's. Moreover many rocks had a different isotopic composition, a fact unexplainable in terms of known physical and chemical processes. Therefore other approaches were considered:

- Capture of the Moon as a body originating in other parts of the solar systems or of the galaxy. Three body capture is known to be impossible in a pure gravitational framework, but would be possible e.g. for a body that is braked by an extensive planetary atmosphere, beyond the only ten km of today's Earth. Analysis under braking conditions was performed by Japanese astronomers; see e.g. Nakazawa et al (1983), who found that capture in such a case is possible. Surprisingly they found that the orbit of the body would become circular in less than twenty years. This is an example of unexpected fast processes that show up in astronomy. See in particular Meyer et al (2002), who established that a giant gas planet may form from a torus of gas and dust not in the previously estimated ten million years, but just in… about a century! The problem with this scenario is that there is no evidence of Earth possessing such an extensive atmosphere even in remote past
- The second theory, which has become the standard one, is that, some billions years ago; Earth was tangentially impacted by a body of mass about the mass of Mars, i.e. about ten percent of our planet mass. The impact would have vaporized part of our planet together with the impacting body. Some of the vaporized material would have remained in orbit around Earth. Then it would coalesce forming our satellite, who's mass is about ten percent of the mass of Mars. These theories, see Palme (2004), hinges on sophisticated modeling under several assumptions, and cannot be considered as firmly established.

Another theory is capture of the Moon in 4 or 5 body frameworks, where it is dynamically possible. There are presently two such theories. One is due to the geologists Ticleanu et al (2011), and was presented at the Santorini Atlantis conference of 2011. They assume capture about 40.000 BC, when there is evidence of a large perturbation of the precession movement of Earth. My theory was also presented in a preliminary way at that conference, and both communications were voted as the two most interesting. Here I recall the main features of my theory. Then I refine it using astronomic information obtained later and I extend it to a new explanation of the mysterious Sumerian cosmologic story of Tiamat. In this frame I also give a natural explanation of the myth of Isis, Osiris, Seth and Horus. As a bonus we get a new theory for the formation of the asteroid belt and the short period comets of the Jovian family, new information on Mars, a confirmation of the mythological story of the birth of Venus from Jupiter, and why Jupiter was the king of the planetary gods. A number of important non trivial research problems to be addressed by mathematical modeling follows from our approach.

2. Capture of Moon from planet Pachamacac-Nibiru-Metis and later events

Our approach has as main features:

- It assumes capture of the Moon within human memory, actually around 9450 BC; notice that there are many arguments about human memory reaching to that time or even beyond, for instance the first yuga starts in our approach at 27.000 BC, the time when Homo Neanderthalensis disappeared, letting our planet in the hands of Homo Sapiens
- At that time Earth had another satellite, orbiting at about one million km distance, that we identify with Mars; it was inside Hill's sphere, where Earth gravity dominates over Sun's, a sphere having a radius of about 1.5 millions km
- The Moon was captured within a four (or five) body event, from a large body P passing sufficiently close (but outside Earth's Roche limit, which is a sphere of about 15.000 km diameter); the body we identify with the gods Pachacamac of Chimu and Incas, Nibiru of Sumerians, Metis of Greeks, possibly Shakti of Hinduism
- The Moon was initially probably closer to Earth than now, so that Sun's disk looked only two thirds large as Moon's
- Moon's capture may have moved Mars to a more far away orbit, while still having it bound gravitationally to Earth, hence within Hill's sphere
- The body P had an orbital period of 20 years. After Moon's loss it probably approached Earth's about 120 times, sometimes quite close, but not as close as when it lost a satellite; such close passages were probably ten and may relate to the ten reincarnations of the Hindu goddess Shakti as terrible goddesses (Kali, Durga…)
- The period when Earth had two satellites, two Moons, left a special memory in several symbols and allows to explain mythical stories as the one of Isis, Osiris, Seth, Horus…
- The body intersected Jupiter orbit of that time, closer to Sun than now, until about 6900 BC it impacted Jupiter itself, providing the most stupendous celestial event in human memory
- The impact reduced substantially the core mass of Jupiter. Several important astronomic events followed, that now can only be discussed qualitatively, most important the birth of Venus (Athena), the removal of Mars from its weak tie with Earth, the formation of the asteroid belt and of the short period Jovian family comets
- Jupiter was removed to the present orbit, losing the special qualities that made it the king of the planets, say of gods. From a body well visible as a small disk, it became the present point-like star
- Mars for a period of about 5400 years, hence from about 6850 BC till about 1450 BC, moved on an elliptic orbit passing periodically near Earth, as required by celestial mechanics. Such passages took place every 54 years, or every 108 years either by night or by day, and numbered probably 100. They correspond to the 99 known names of God in Koran, the hundredth name secret except to people of knowledge. It corresponds to the last passage when a special planetary interaction rounded the orbit of Mars.

In the next section we discuss the capture of Moon. In the following section the period when Earth had two satellites is considered. Then we consider the impact on Jupiter that ended planet Nibiru. Finally a brief discussion of the 100 passages of Mars near Earth, with hints how they can explain the Noachian Flood and rituals as circumcision, escission, veneration of lingam and so on.

3. The capture of the Moon from body P

Our proposal is that Moon's origin lies in the capture by Earth of a satellite from a body P passing nearby. The body may have come from the Kuiper or Oort regions, from the space between the two said regions, rich of bodies of size between Earth and Jupiter according to Dogon and Fargion (1998), or from outside the solar system, where similar bodies are known to exist in the form of brown or red dwarfs, or… The satellite entered Earth's Hill sphere, where Earth gravity dominates over solar gravity, and was captured by our planet. The event took place most probably about 9450 BC, the time when Ice Age ended abruptly and the Atlantis civilization was terminated, see Spedicato (2007a,b; 2010). The end of Ice Age was probably due to the close passage of P, whose gravitational tidal effects deformed Earth, giving it for a brief time an ovoid form. The oceanic crust fractured along thousands of km of fault lines and large amount of magma poured out. This event produced warm rains that melted much of the world ices and increased the world temperature; see Spedicato (2010). In terms of celestial mechanics the capture can be considered in a four body frame (Sun, Earth, P, captured satellite; a five body frame if we do not disregard the probably small effects due to Mars as a previous Earth satellite). In this case capture is possible in a pure gravitational context, contrary to the case of the three body event. My thanks to the late great astronomer Tom Van Flandern, who first considered as a four body event the probable capture of Charon by Pluto from Neptune. Capture requires fine modeling of the parameters relating to the closest distance of P to Earth and to the position of the satellite at the moment of the closest passage of P. A problem that can be modeled by suitable choice of the initial parameters of P and its satellite on their approach to Earth. The mathematical modeling should use accurate ODE solvers (best would be the Brugnano-Trigiante solvers…) and nonlinear optimization.
In qualitative terms, we conjecture that capture took place when, on the closest approach of P, one of the satellites of P was located so that Earth was between that satellite and P. Thus Earth was closer to the satellite and became gravitationally dominating. Then P moved away having lost that satellite. The initial orbit of what had become our Moon was certainly not circular, but from the quoted Japanese results we can guess that circularization was fast, taking perhaps less than a century. The initial orbit of the Moon was probably also closer to Earth than now, moving to the present distance only after the Biblical Flood (to be dated at 3161 BC on arguments to be given elsewhere). Indeed in Velikovsky unpublished work In the beginning, see references, it is recalled that according to a Sumerian astronomical tablet the Moon, called Nannar by Sumerians, loomed in the sky greater than Sun, whose apparent size was only two thirds of Moon's. Since now Moon and Sun have almost the same angular size, and certainly Sun's size was not different at Sumerian times, than it follows that Moon's distance to Earth was 2/3 of todays. Now today Moon's distance varies between 356.000 and 406.700 km, with average value of 384.400 km. Two thirds of this value is about 256.000 km. Presently Moon has a period of about 27.3 days, or 29.5 from the point of view of an observer from our moving planet. Kepler third law states that, at first order, the ratio of the square of the major orbital semi axis (the radius of the orbit if it is circular) to the cube of the period is constant. This law implies that closer bodies move faster. Applying such a law to a Moon at two thirds the present distance we get a lunar period slightly less than 21 days, against the present 27.3. This value implies a number of months of about 16…. And it is worth to recall

the special value of 16 in Hindu traditions, 16 being the optimal age for youth and beauty of humans, and the age at which Hindu god statues are represented, see Daniélou (2002). The transition of a year with 16 months to the present one is requires serious investigation, being most probably related to the catastrophic events that affected our planet even after the end of Ice Age. The two main such events are probably the 6900 BC multiple impact on Earth of masses coming from Jupiter, see later on, and the event known as the Biblical Flood, whose complex explanation will be given elsewhere. We recall anyway a discovery by archaeologist Giuseppe Brunod, private communication. He noticed that Val Camonica petroglyphs show that in the fourth millennium BC the year had not 12, but 13 months, each month being represented by a dagger. This change may relate again to the events of the Biblical Flood. Notice the likely relation with the following statement in Plutarch: Hermes took away one seventieth of the light of the Moon and gave it to Earth, whose year passed from 360 to 365 days… So, before the Flood, Moon was closer and gave more light, and the year had 360 days…

Another consequence of a Moon looming so larger than Sun would be that if there were solar eclipses, they might have led to such a complete coverage of the sun's disk that full darkness would cover Earth, while now a solar eclipse does not fully eliminate visibility. Thus solar eclipses in that time would have been a magnificent but possibly terrifying event, to be seen at the origin of the terror that they inspired even at later times.

A possible objection to our theory of Moon's capture is that Moon revolves around Earth showing always the same face. However, as just few years would be enough to round the Moon's orbit as shown by the quoted Japanese researchers, it is not impossible that having the same lunar hemisphere facing our planet would be realized within few years. I thank Prof. Gaspani of Brera's observatory in Milano for suggesting a short time, especially in view of the proposed shorter initial distance of the Moon to Earth.

The Moon's capture appears to have been memorized in several traditions found among the Greek scholars, in India, in Southern America, in tribal people and so on. For a partial list see Spedicato (2011b) and Velikovsky's book "In the beginning", available in the Jan Sammer website dedicated to him. Here we recall five traditions:

- The Chimu of coastal Peru claimed that the Moon had a father, Pachacamac
- The Uru are a tribe living in floating islands in the Titicaca Lake, now divided between Peru and Bolivia. They claim to be living on such islands already before the Moon existed. If this statement is correct, then they were probably active at the time of Atlantis, whose capital we have located in the island of Quisqueya, say Hispaniola, and may have had contacts with that civilization, or be part of their empire
- For the Hindu the Moon appeared after the sea boiled
- For the Malekula of Melanesia the atmosphere filled with vapor, so that nothing could be seen. When vapors disappeared, much land had been covered by the sea and in the sky there was a new body, the Moon
- In the Hawaiian epic Kumulipo, see Notarangelo (2000), it is said that when Earth became hot, when the sky went rotating to and from, when the sunlight was darkened, in order that the Moon come to give her light. Such verses are clearly related to the Malekula legend and are easily explained in our scenario where the close passage of a body ruptures the oceanic crust, letting magma come out followed by vapors and rains, the satellite lost by the body appearing as the consequence of the physical events described.

We notice here how well the Malekula tradition describes the expected effects of the passage of P: the breaking of the ocean crust due to its gravitational tide, the following emission of magma, the pouring of immense warm rains, clouds covering much of the Earth (with increase of temperature and rapid melting of the ices). When clouds dissolved, Moon appeared in the sky.

An important point is that before the capture of the Moon our planet had to have another satellite. One reason is the existence of certain sedimentary structures, found especially along the eastern coasts of Australia, that are called varves and that form at each cycle of the Moon. They existed, it seems, before the end of Ice Age, hence Earth had to have another satellite. Other arguments also support the presence of an Earth satellite before capture of the Moon, including paintings in the caves of France and Spain, and elsewhere, made in full Paleolithic. In particular we recall the cave Lascaux, where paintings are dated at the period 13.000 to 15.000 BC, with depictions apparently of Moon and Sun, see Gaspani (2012).
The candidate for the previous satellite, which most probably remained as an Earth satellite after the capture of the Moon, is Mars. If we are correct that Mars was an original satellite of Earth, then Mars was in the habitable zone, with water and most probably life. Support to this hypothesis comes from its similar rock composition, rate of rotation and angle over the ecliptic plane, the last two facts pointing to a long relation with Earth, resulting in resonance phenomena. That Mars had water till not long ago follows from recent explorations; see Piccaluga (2006) or Ginenthal (2002). Mars water was lost to much extent in one or more catastrophic events, the most important one, not to be discussed here, being related to the Biblical Flood. For the idea of Mars having been an Earth satellite I am indebted to scholar Matteo Fagone, a contributor to PianetaMarte.net.
For long time I wondered about the distance of Mars from Earth before capture of the Moon. The solution came from Censorinus book “De die natali”, where this Roman scholar of the third century AD writes: the Arcadians claim, but I do not believe that before the Moon existed the year had not twelve but three months. Notice that the Arcadians, living in an elevated and rugged region of Peloponnesus protected on the north by the Erymanthus range, reaching about 2400 m, were considered to be the people living in Greece since the oldest times, hence the repositories of the oldest traditions. Now we can interpret Censorinus information as about a previous satellite of Earth, performing not twelve but three cycles per year. Hence it was moving slower, being on a more distant orbit; from Kepler’s third law we can estimate such a distance at about one million km, with respect to the present average distance of about 380.000 km of the Moon, hence well inside the Hill sphere. If this satellite was indeed Mars, then at that distance it would look somewhat smaller and less luminous than Moon. But if Moon originally was closer to Earth, implying a number of months greater than twelve, then the superiority of the new satellite would have been quite great in terms of apparent size and luminosity.

4. An Earth with two Moons

Mars now is not attached gravitationally to Earth, so some event in our scenario must have removed it from the Earth tie. It could have been removed by the gravitational pull of body P. However if, at its closest passage, P was facing the side of Earth opposite to Mars, it could have remained in the original orbit, or be moved by the gravitational pull of P to a more remote orbit, but still tied to Earth, till the event that we propose broke its gravitational tie with Earth. We think Earth had indeed two Moons for a period of about 2400 years, on the basis of three arguments:

- Traditions that Earth for a time had two satellites, not to say of astronomic theories for two satellites in early times of Earth
- The Turkish symbol showing a large half Moon which has inside a five pointed small star; five points symbolize Mars, as the fifth celestial body from Earth (Moon, Sun, Mercury, Venus, Mars); a six pointed star refers to Jupiter, the king of planets
- The symbol of a white half Moon with at center a red globe that was noticed around 1845 by the Jesuit Huc, on his arrival in Lhasa. The symbol was painted on the doors of the

homes in the section of Lhasa inhabited by the people called Prebun, coming from Bhutan, see Huc (1850)

- The need to explain arrival of salty water on Earth following the Tiamat explosion, that will be considered in next section.

If our scenario is correct, then Moon was captured about 9450 BC, and Earth had two satellites till about 6900 BC, hence for a period of about 2550 years. In the sky there were two Moons, one large and one small!

One should also notice that Aphrodites was originally the name for Moon and not for Venus, according to Macrobius, Saturnalia VVV-1,3. The same conclusion is also reached by De Grazia (2009), via analysis of the Mars love affair with Aphrodites in Homer. We can additionally observe that Aphrodites is not a Greek name, but an oriental one. It could be a hybrid name, composed of the Akkadian word afar, meaning dust, foam, and di, meaning blue in zhang zhung, the lingua franca for millennia north of India, and te-ta, meaning great in Chinese. Hybrid names are quite common in Asia. If our interpretation is correct, then the name would recall the time when Moon appeared in the sky after the vapor, the foam, of the oceans dissipated, at the end of the Ice Age, as the Malekula legend recalls so well. The people who survived the heat following the warm rains has to stay on mountains, or on caves with a stable temperature. Venus birth is associated with Erice, a mountain in western Sicily about 800 m high, in our interpretation a place where people survived the heat from the warm rains and were amazed when the new Moon appeared in the sky.

During that period, body P, say Nibiru, every 20 years came close to both Earth and Jupiter. During that time there were no Mars and no Venus orbiting on their present orbits. From the orbital period and Kepler’s third law, the major semiaxis of Nibiru can be estimated at 7.4 AU, or 1.110 billion km, hence less than the major semiaxis of Saturn, which is 1.426 billion km. Hence Nibiru did not cross Saturn’s orbit. The calculation of the minor semiaxis, equivalent to the eccentricity, is yet to be done. If we assume that Nibiru passed close to Earth so that it lost a satellite, eccentricity had to be quite significant, implying stability problems, hence a life expected to be not long (thanks to astronomer Adriano Gaspani of Brera observatory for this observation).

When Nibiru crossed Earth orbit, usually nothing happened, Earth being quite far away at that moment. But some of the about 120 crossings that took place must have taken Nibiru quite close to Earth, with destructive effects, albeit not as dramatic as when Moon was captured. Such passages were certainly terrifying to human people, then existing in very small numbers after the great catastrophe of the end of Ice Age. Here we hypothesize that they may explain the reincarnations of Shakti, the top goddess in the Hindu pantheon, see Alexandra David Néel, who was introduced to the most secret rituals of Hinduism; she asked who was the God of the Gods, and Shakti was the answer she got.

Shakti is a goddess with many properties. She is associated to the greatest energy; she is, with Parvati, one of the main wives of the great god Shiva. In her reincarnations she appears as a terrifying goddess, with a garland of skulls as Kali, or as Durga, who is headless, keeping her head by gripping its hair with her hand…. Goddesses as Kali, Durga, Saraswati, Lakshmi, …. A memory of the terrifying passage of Nibiru? Was Shakti the Hindu equivalent of Nibiru, Metis, Pachacamac?

We should also note a recent discovery about Catal Huyuk, one of the oldest cities, possibly existing in the tenth millennium and contemporary to Atlantis. It has been found that the walls of that city were painted with white chalk 120 times. Notice that 120 by 20 gives 2400, which is about the time estimated by us for Earth with two moons. We notice that Moon usually appears white, this being probably the reason why white is the color of the clothes of most priests in the world now and in the past, and maybe that was also the color of Nibiru. So we conjecture that

painting white the walls every 20 years for 120 times was a recall of the passage of Nibiru and of the escape of Earth to a possible new dramatic event as the one that terminated Ice Age.
We close this section with a natural explanation of the myth of Isis and Osiris, that goes back at least to the Pyramids Texts, of the Ancient Kingdom. The association of Isis with Moon is well known, and we notice that Isis priests, who were common in Rome in imperial times, had clothes of white linen, see e.g. the Metamorphoses of Apuleius. In the sky, under our scenario of two moons, man could see the new Moon, larger, brighter and more beautiful, and the old Moon, Mars. The new Moon was moving faster and reaching and overcoming the old Moon several times in the year. The moment when the two bodies overlapped could be thought as a moment of making love. The two satellites appeared to act as a couple in love, more erotic charge possibly associated with the new Moon, and being later reflected in the quite high erotic dimension that characterized the rites of Isis.
To describe the death of Osiris and the birth of Horus after Isis collected in Egypt 13 pieces of Osiris (penis not found) requires astronomic information given in the next section. Briefly we have that about 6900 BC Nibiru-Metis impacts Jupiter. Enormous amount of mass from Jupiter core is expelled into space. There is evidence that seven pieces hit our planet. While probably Moon was not hit, it is likely that Mars was subject to a huge impact, which left a great depression on one of its hemispheres, and a similarly huge bulge on the opposite hemisphere. The impact had enough momentum and energy to remove Mars from Earth's Hill sphere, so that it started moving on its own orbit, of elliptical type, which will characterize it for some 5400 years. Its removal as an earth satellite is interpreted as its death, due to the impacting mass, that is the evil Seth. The impact sends Mars material into space, a significant amount reaching Earth, on the hemisphere facing Mars, and the pieces collected in Egypt may be considered as part of Mars-Osiris expelled material.
The birth of Horus is a more complex and possibly unique event in the galaxy, which has been proposed and analyzed (without the reference to Horus) by Ackerman (1999a,b). Leaving to a later paper a more in depth analysis, proposing also the origin of rituals as circumcision, escission, lingam veneration et alia, we just say that Horus is the core of Mars, emerging from the fracture on Mars crust called Valles Marineris, and finally becoming… planet Mercury. Thus the eye of Horus is the core of Mars slowly showing up, and similar interpretation holds for the mysterious omphalos. Without giving our arguments, we state that the core completely exited on the fourteenth day of month Nissan, about beginning of April, year 3161 BC. It brought down the last waters of the Martian oceans, so that Earth got a deluge from the fountains of the high and the fountains of the low. It was the beginning of the Noachian Flood, i.e. of the second great catastrophe in Plato. It was the day when the man now called Oetzi, probably on a mission from Val Camonica to Bavaria, knew that the flood had arrived, lied down on a flat stone, was covered by dozen meters of snow, to be rediscovered a few years ago…

5. End of Nibiru, explosion of Tiamat, birth of Venus, Mars leaving Earth

People interested in Nibiru have not realized that the 3600 years given for Nibiru's period in Sumerian texts are not correct, coming from a multiplication by 180 quite common in Asian chronologies, see Spedicato (2013). Some people are still waiting for a new passage of Nibiru and often identify Nibiru with the so called Planet X. This body was introduced by astronomers to explain certain perturbations of bodies in the solar system, but has never been found. In our scenario, Nibiru not only had no period of 3600 years, so great that no human could associate its arrival to a previous passage, but it has disappeared. Indeed Nibiru, the Metis of Greek mythology, ended its life as beautifully described by e.g. Hesiodus 890,

Apollodorus 7,3 and Hyginus: Metis, pregnant of Athena, entered the body of Jupiter and Athena was expelled from Jupiter's head.
An interesting detail of the Metis myth is that when she entered Jupiter body she was five months pregnant by Jupiter, of whom she was a wife, which may be explained by a previous passage close to Jupiter that deformed Metis. We also note that Athena and Venus are the same body, since the identification of the star of the morning with the star of the evening took place by Greek astronomers late in the first millennium BC. Below we analyze Metis entering Jupiter at the light of very recent and quite unexpected astronomic findings.
In the Sumerian cosmology the event that in our opinion corresponds to the Metis story, albeit being richer of details, is the story of the planet-god Tiamat. Here we give only some basic features of the story. Our scenario has a very recent origin. It follows from information in a book by Scranton (2012) and suddenly appeared to this author's mind when reading the book by Leick (2006) on lost cities of Mesopotamia.
We cite the following events related to the giant goddess Tiamat, not being the complete story:

- it opened as a shell
- it spread its entrails into space
- it left a trail of luminous pearls, sometimes associated to a milky way
- it splashed Earth with salty water

The above dramatic and apparently pure phantasy events can be explained by the following scenario, involving our body P, i.e. the considered god-planets Pachacamac, Nibiru, Metis:

- P impacted Jupiter at high speed, high energy, having itself a large mass, and a speed several dozen km per second, see below; the impact, as from Ackerman private communication, might even have triggered nuclear fusion explosions, due to the presence of lithium and deuterium in Jovian atmosphere
- It entered the body of Jupiter, see below for Ackerman theory on the composition of Jupiter; the impact point was where the red spot now lies, pointing to a huge and deep crater, possibly thousands of km deep; hot gases are still gushing out
- A very large amount of Jupiter mass was expelled due to the impact, of order the mass of the impacting body, say several times the Earth mass
- Some of the impacting material orbited Jupiter, seen from Earth as the Giants and Titans fighting against Jupiter; some of it later may have coalesced forming new satellites of Jupiter. We have lost Ovid's Gigantomachia, but a passage in Ovid's Tristia gives the interesting information that the giants had a snake-form, suggesting a comet type tail, produced by gases lost while revolving around Jupiter
- Some of the material, less than lunar mass (no more than 2% of Earth mass), remained in Jupiter original orbit, forming the present asteroid belt; the material was initially very hot, thereby appearing as chain of luminous pearls
- Some material formed the short period comets, mostly belonging to the so called Jovian family, since they orbit inside Jupiter present orbit; their motion is prograde, as is the case for all planets, while the motion of long period comets is about half prograde, half retrograde. The fact that the Jovian family comets are prograde indicates that the impact of Metis on Jupiter was essentially a frontal one, i.e. an impact that maximized the exchange of energy and momentum, and the slowing down of Jupiter
- Chunks of different size were expelled to long distances in the solar system, presumably within a certain cone of emission. Most of them probably ended in the Sun. Part of them reached Earth, and may be identified with the seven large objects that at the same time, about 7000 BC, hit Earth, both on continents and on oceans, as claimed by Tollman A. & E. (1993). Notice that the Koefels crater in the Alps is dated at that time, see Combes (2007). If Mars was still an Earth satellite, but revolving quite far away and hence weakly

gravitationally tied to Earth, then having a surface about one fourth of Earth, it may have been hit by two, or more, or less, masses similar to those that hit Earth. We conjecture, as stated in the previous section, that Mars was hit by a rather big chunk that left a huge depression and a bulge on its opposite side, a well known and unexplained feature of Mars. The impact most probably removed Mars from its gravitational tie with Earth. Moreover if Mars still had oceans, part of their water was projected into space and might have reached Earth, explaining the Tiamat story of arrival of salty waters. Such waters were noticed of course when they reached the interior of continents, especially of deserts, where they may have formed some of the many salty lakes found there. According to Sumerian sources such salty waters in particular mixed with the sweet waters of Apsu. Apsu can be identified with the present deserts of Takla Makan and Lop Nor, that some thousand years ago were covered by sweet water. This water originated from the melting of the ices in the Tibetan plateau, and the Tienshan, Nanshan… ranges, around 9450 BC, as established by geomorphologist Eröl Orguz. There are arguments that the Sumerian pre-Flood cities, like Eridu, were built in this region, the Sumerian moving to Mesopotamia after the Flood, see Spedicato (2012). Also some material from the large impact on Mars might have reached Moon, displacing it to a more distant orbit, corresponding to a number of months less than the initial sixteen.
The above scenario implies that Jupiter orbit was where is now the asteroid belt, between present orbits of Mars and Jupiter. So Jupiter was, under such a scenario, at a closest distance from Earth of 1.3 AU, i.e. about 200 million km, since the asteroid belt has an elliptic structure, whose minimum distance to Sun is 2.3 AU. Presently Jupiter is at 5.2 AU from Sun, hence at closest 4.2 AU from Earth, i.e. about 630 million km. Venus now is at 0.7 AU from Sun, hence 0.3 AU from Earth at closest distance, i.e. 45 million km. Now Venus is the most brilliant planet in the sky and at closest distant appears as a small disk, as I saw at naked eyes when the sky was very clear at the South Balkan Observatory in Bulgaria. Jupiter when in the orbit associated to the asteroid belt, if our data are correct also for that time, would therefore have appeared about four times smaller due to distance with respect to Venus, but about 12 times larger for its diameter is about 144.000 km (possibly it was larger before the impact!) against about 12.000 for Venus. So Jupiter appeared 3 times greater than Venus at their closest approach. Thus it looked in the sky not as a point, but as a disk, of angular size about one tenth of present lunar size.
When Jupiter was impacted, the heat from the impact must have expanded its atmosphere greatly, probably giving it an apparent size in the sky greater than the size of the Moon. The heat was slowly lost, while Jupiter moved till the present position, where it is quite difficult to recognize it as the king of the planets. While Jupiter was so expanded, certainly giant lighting phenomena took place, also visible from Earth. The famous lightings of Jupiter??!!
The fight of the Giants and the Titans can be interpreted in terms of the very hot material expelled that orbited Jupiter. Snake-like lights were seen exiting from Jupiter and then reentering it. It is not clear how to explain the help that Jupiter got from Athena, as shown in the Panathenaic festival in Athens, see Celsus, Contra Christianos. Maybe she was expelled not immediately, but after the minor chunks which orbited Jupiter, and its expulsion partly dispersed them. Notice that analysis of the evolution of Venus-Athena down to the present state has been done in two major monographs by physicist Ackerman (1999a,b), who made great use of Vedic texts, to be dated at least at the fourth millennium BC, according to Subhash Kak, a scientist from the royal Kashmiri family. About the Giants, the Theogony of Hesiod, verse 636, states that their war with Jupiter lasted ten years. This may mean that after such a time the bodies associated with the Giants became invisible, both due to their cooling and to the increased distance of Jupiter moving to another orbit.

The above scenario is supported by the discovery from probe measurements of the interior masses of Jupiter and Saturn. It has been found that Jupiter core mass is remarkably smaller than Saturn's, by a factor two possibly, a finding that cannot be reconciled with existing theory, unless some mass of Jupiter was lost in a giant impact. See Scranton (2012), who quotes an article in New Scientist by D. Shiga (2010), and the subsequent analysis by Chinese astrophysicist Li Shulin, of Peking University, who estimated the mass of the impacting body in ten Earth masses. See also the more recent paper by New Scientist editor Maggie Mc Kee, December 2011, who as an alternative presents more exoteric theories as the slow dissolving of the Jupiter core. Of course it will take time to the standard astronomy world to accept that such dramatic events took place in solar system at human memory, to be preserved by mythology, traditions and religions.
Now, the important question of the dating of the event. In the Tollmans book a date of about 7000 BC is given for their considered simultaneous impacts of seven large objects on Earth. It is also known that verves, special marine sediments, indicate a breaking of the arctic ice cover around that period, see Bibby (1960). A little known statement in Ixtilochitl, a historian of Spanish father and Aztec mother, given in Gilbert and Cotterell (2006), reports from a lost Toltec code that Venus was born 1.366.560 days from the beginning of the Mayan chronology, considered to be year 3114 BC (the year implying that the long computation should end in December 2012, so that someone claimed that day to correspond to the end of the world…). Assuming duration of the year of 360 days, back counting from 3114 would then give for the birth of Venus a date of about 6900 BC, well in agreement with Tollmans' geologic and paleontological dating. It is quite surprising that this precise Toltec statement has apparently escaped the attention of scholars, including in particular the people that accepted a real birth of Venus from Jupiter on the arguments given by Velikovsky. Let us here just notice that the period between end of Ice Age and 6900 BC was a dark period for mankind. People had to be very scared of the celestial events and may for this reason have built the subterranean cities found e.g. in Anatolia. Then mankind slowly recovered, and the great period of Neolithic development started…
Something yet to be studied is the effect of the impact on the orbit of Jupiter. The impact was probably frontal in view of the resulted effects, especially of the fact that the short term Jovian family comets move in prograde sense. Reasons of momentum conservation plus the jet effects of the impact and the loss of part of Jupiter mass would certainly decrease of orbital speed of Jupiter. Therefore on the basis of Kepler's third law Jupiter moved to a more distant orbit, ending in the present one… a problem whose analysis is very complex, since mechanics effects have to be coupled with thermodynamic effects, not to say of possible electromagnetic effects.
Finally, an intriguing question. When Jupiter reached its present orbit, was it empty? We have in mind Titus-Bode law, a consequence of the macro quantization studied by, inter alia, Vladimir Damgov (2004). Was Saturn there? Did Jupiter interact with Saturn?

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Development of hydrodynamic potentials theory and the method of boundary-integral equations in hydrodynamics problems

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Results of generalizations of the original vector and tensor analysis and its applications in terms of the method of boundary integral equations are presented and numerical implementation of the method for solving nonlinear boundary value problems of hydrodynamics. In this work, a new generalized approach to obtain analytical and numerical solutions for a wide class of nonlinear problems in continuum mechanics is presented. New approach and required formal apparatus for the formulation of the boundary integral equations, equivalent to the initial-boundary problems for the main mathematical models in mechanics of fluid and gas, are developed.

Introduction

Due to multiparametricity and nonlinearity of the main problems of mechanics of fluid and gas, alongside with physical experiment, the computational experiment is widely applicable. Significant achievements should be noted in the computational analysis, especially in numerical implementation of particular mathematical models in mechanics. In gas mechanics, significant progress is achieved in computational fluid mechanics that takes into account physics-chemical processes, which allows determination of aerodynamic characteristics of in the transonic flight regimes, create real-time computational models. In dynamics of viscous incompressible fluids, most attention is paid to the qualitative methods of characterization of initial-boundary value problems that in turn, raise new questions and reveal new solutions, lead to the new mathematical models of the problems of viscid fluid flow at low and medium Reynolds numbers. Such problems occupy at the leading place in the areas of natural science and ecology. In the aerodynamics of complex lift-generating surfaces, systematic use of the method of boundary-integral equations and variants of its numerical implementation, the distributed and integral aerodynamic characteristics are obtained for two- and three-dimensional load-bearing forms; processes that cause flow separation, creation and stability of vortexes structures, are studied. This allows conduction of extensive theoretical and experimental research for efficient sources of energy such as self-starting air- and hydro-turbines for various power requirements.

1. The ideology of the method and the integral representation of solutions

The most reliable and proven mathematical model of a viscous fluid flow is the initial-boundary value problem for systems of differential equations in partial derivatives known as the Navier-Stokes equations. This system was formulated in 1826 and so far a general method for investigating and solving this nonlinear system has not been found. Rather, particular solutions of the system are known, often found as a by-product. Exact particular solutions are valuable for the study of viscous liquids, because they can help in figure out the error nous results under certain assumptions. Methodological value of such solutions is also invaluable.

Exact analytical solutions of the complete Navier-Stokes equations exist for only a few very specialized cases. Instead, the equations are frequently simplified by making appropriate approximations about the flow. Currently, exact solutions of the complete Navier-Stokes equations for many practical problems can be obtained numerically, using various techniques of computational fluid dynamics.

Solving Navier-Stokes initial-boundary value problems for systems of differential equations in partial derivatives is an important and challenging task in applied mathematics and mechanics, and their solution will significantly change the way of the hydro- and aerodynamic calculations are conducted, improve the quality of these calculations and increase the reliability of the results that may also bear real economic value.

The boundary integral approach has obvious advantages over finite difference and finite element methods. This is why nowadays this method is being successfully applied for solving complex engineering problems – on surface and in space, stationary and time-dependent.

The stationary problem [1] for the flow of the incompressible viscous fluid around a body is shown in fig. 1. The most efficient method for solving a wide spectrum of boundary value problems of continuum mechanics is the method of boundary integral equations [2]. In the absence of internal moments and temperature effects, a mathematical model of the dynamics of an incompressible fluid flow is described using a well-known system of conservation laws:

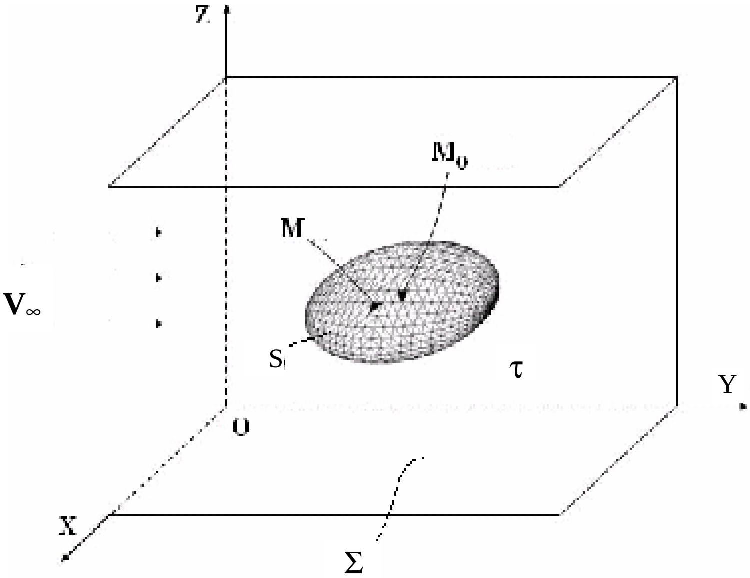

Fig.1. Fixed body S in a steady flow of a viscous incompressible fluid inside the control volume Σ.

of Mass: $$(\nabla,\mathbf{V})=0 \tag{1}$$

of Momentum: $$(\nabla,(\mathbf{V}*\mathbf{V}))=\left(\nabla,\left(-\mathbf{I}\frac{p}{r}+n\left(\nabla\mathbf{V}+\nabla^*\mathbf{V}\right)\right)\right) \tag{2}$$

where **V** is velocity of fluid flow; $\nabla^*\mathbf{V}$ is the dual tensor $\nabla\mathbf{V}$, and r is density of the medium, p is pressure, n is kinematical viscosity and **I** is an identity tensor.

In addition, it is advisable to investigate the conservation of vortices W = [∇**V**]:

$$\left[\nabla,[\boldsymbol{\Omega},\mathbf{V}]\right]+n\left[\nabla,[\nabla,\boldsymbol{\Omega}]\right]=0 \tag{3}$$

as a critical kinematics characteristics of the interaction of viscous flow with a streamlined body.

Solution of the system of differential equations of the conservation laws (1 - 3) is subject to the natural boundary condition

$$\mathbf{V}\big|_{S+\Sigma}=\mathbf{U}^{S+\Sigma}(s,t)\ \ p\big|_{\Sigma}=p_\infty,\quad \boldsymbol{\Omega}_n\big|_S=0,\quad \boldsymbol{\Omega}\big|_\Sigma=0 \tag{4}$$

where $\mathbf{V}\big|_S$ is the velocity of points on the fluid surface of the body and is a boundary condition that may depend on the surface coordinates (s, t) in some particular cases.

The main objective of the vector analysis is the determination of the vector field **V** on the set of divergence

$$(\nabla,\mathbf{V})=q \tag{5}$$

and vorticity $$[\nabla,\mathbf{V}]=\boldsymbol{\Omega} \tag{6}$$

where the intensity function of the density of mass flow q - known as the vortices vector $\mathbf{\Omega}$ - near-contains the definition.
Thus, in accordance with the theorems of vector analysis [3] and with the theory of boundary value problems of mathematical physics [4], solutions must be consistent with the natural boundary conditions of the mathematical model (1-4). Therefore, it is necessary to solve the boundary value problem (1-4), for example, in R^3.
Then equations (5-6) can be constructed using the differential operators of a second order:

$$\nabla(\nabla,\mathbf{V}) = \nabla q, \quad \nabla(\nabla,\mathbf{\Omega}) = 0 \tag{7}$$

It is not difficult to prove [4-5] that the tensor

$$\mathbf{\Gamma} = \mathbf{I}j - [\mathbf{I},\mathbf{G}] \tag{8}$$

where $j(|\mathbf{x}-\mathbf{y}|) = \dfrac{1}{4p\,|\mathbf{x}-\mathbf{y}|}$ is the fundamental solution of Laplace's equation in R^3, and the vector $\mathbf{G} \in C^2(E)$ defined by the conservative condition

$$(\nabla,\mathbf{\Gamma}) = 0 \Leftrightarrow \nabla j = [\nabla,\mathbf{G}] \tag{9}$$

is the fundamental solution of differential operators in (7), i.e.

$$\nabla(\nabla,\mathbf{\Gamma}) = \mathbf{I}d(|\mathbf{x}-\mathbf{y}|) \tag{10}$$

where $d(|\mathbf{x}-\mathbf{y}|)$ is the Dirac delta function, which depends on two points in space. In spherical coordinates ($q \in [0; \pi]$; $w \in [0; 2\pi]$) the vector $\mathbf{G}$ used in one of the following:

$$\mathbf{G}_1 = -\frac{w}{4p}\nabla(\cos q), \quad \mathbf{G}_2 = \frac{\cos q}{4p}\nabla w \tag{11}$$

Conservative nature of the law of conservation of the momentum (2) allows us to write the generalized D.Bernoulli integral:

$$\mathbf{V} * \mathbf{V} + \mathbf{I}\frac{p}{r} + n\left(\nabla^*\mathbf{V} - \nabla\mathbf{V}\right) = \nabla^*\mathbf{\Psi} \tag{12}$$

where the choice of the vector potential Y, by virtue of conservatism of the left side of expression (2) will be governed by the condition

$$\left(\nabla,\left(\nabla^*\mathbf{\Psi}\right)\right) \equiv \nabla(\nabla,\mathbf{\Psi}) = 0 \tag{13}$$

i.e. vector Y belongs to the class of solutions of equations (7).
Similarly, the law of conservation of vortices $\mathbf{\Omega}$ (see (3)) has an integral representation

$$\left[\mathbf{I},[\mathbf{\Omega},\mathbf{V}]\right] + n\left(\nabla^*\mathbf{\Omega} - \nabla\mathbf{\Omega}\right) = \nabla^*\mathbf{\Phi} \tag{14}$$

which is a vector potential and it is a solution of equation (13)

$$\left(\nabla,\left(\nabla^*\mathbf{\Phi}\right)\right) \equiv \nabla(\nabla,\mathbf{\Phi}) = 0 \tag{15}$$

For further development of the theory of boundary integral equations prove the following generalized vector-operations of tensor analysis [3, 4]:

$$\left(\nabla,\left(\mathbf{I}j\right)\right)=\nabla j \tag{16}$$

$$\left(\nabla,\left[\mathbf{I},\mathbf{a}\right]\right)=\left[\nabla,\mathbf{a}\right] \tag{17}$$

$$\left[\nabla,\mathbf{I}j\right]=\left[\mathbf{I},\nabla j\right] \tag{18}$$

$$\left[\nabla,\left[\mathbf{I},\mathbf{a}\right]\right]=\nabla^{*}\mathbf{a}-\mathbf{I}\left(\nabla,\mathbf{a}\right) \tag{19}$$

$$\left[\mathbf{I},\left[\nabla,\mathbf{a}\right]\right]=\nabla^{*}\mathbf{a}-\nabla\mathbf{a} \tag{20}$$

$$\nabla\left(\nabla,\mathbf{a}\right)=\left(\nabla,\nabla^{*}\mathbf{a}\right) \tag{21}$$

where the vector function **a** has continuous derivatives up to second order in the study area and the tensor of dyads type [3]:

$\nabla^{*}\mathbf{a}=\mathbf{i}\nabla a_{x}+\mathbf{j}\nabla a_{y}+\mathbf{k}\nabla a_{z}$ is the dual tensor $\nabla\mathbf{a}=\mathbf{i}\dfrac{\partial\mathbf{a}}{\partial x}+\mathbf{j}\dfrac{\partial\mathbf{a}}{\partial y}+\mathbf{k}\dfrac{\partial\mathbf{a}}{\partial z}$, and **I** - identity tensor

$\mathbf{I}=\mathbf{ii}+\mathbf{jj}+\mathbf{kk}$,

For vector-valued functions **a**, **b** $\in W^{2}{}_{2}(t)$, and $\nabla j \in L_{2}(t)$, $S \equiv \partial t$; $L \equiv \partial S$ due to the fundamental equations (16-21), we have the vector-tensor generalization of the integral theorems of analysis, such as: generalized Stoke's theorem

$$\iint\limits_{(S)}\left(\mathbf{n},\left[\nabla,\left[\mathbf{I},\mathbf{a}\right]\right]\right)dS=\int\limits_{(\partial S)}\left[d\mathbf{r},\mathbf{a}\right] \tag{22}$$

since, from (20) we have $\iint\limits_{(S)}\left(\mathbf{n},\left[\nabla,\left[\mathbf{I},\mathbf{a}\right]\right]\right)dS=\iint\limits_{(S)}\left(\mathbf{n},\left(\nabla^{*}\mathbf{a}-\mathbf{I}\left(\nabla,\mathbf{a}\right)\right)\right)dS=\int\limits_{(\partial S)}\left[d\mathbf{r},\mathbf{a}\right]$

and the generalized theorem of Ostrogradsky - Gauss

$$\iiint\limits_{(t)}\left\{\left(\nabla\left(\nabla,\mathbf{a}\right),\mathbf{b}\right)-\left(\mathbf{a},\nabla\left(\nabla,\mathbf{b}\right)\right)\right\}dt=\iint\limits_{(S)}\left(\left\{\frac{\P\,\mathbf{a}}{\P\,\mathrm{n}}+\left[\mathbf{n},\left[\nabla,\mathbf{a}\right]\right]-\mathbf{n}\left(\nabla,\mathbf{a}\right)\right\},\mathbf{b}\right)dS=$$

$$=\int\limits_{(\partial S)}\left(d\mathbf{r},\left[\mathbf{a},\mathbf{b}\right]\right)+\iint\limits_{(S)}\left(\mathbf{a},\left\{\frac{\P\,\mathbf{b}}{\P\,\mathrm{n}}+\left[\mathbf{n},\left[\nabla,\mathbf{b}\right]\right]-\mathbf{n}\left(\nabla,\mathbf{b}\right)\right\}\right)dS \tag{23}$$

Then for the operators in (9-10) constructed generalized Green's formula:

$$\iiint\limits_{(t)}\left\{\left(\nabla\left(\nabla,\mathbf{a}\right),\mathbf{\Gamma}\left(\left|\mathbf{x}-\mathbf{y}\right|\right)\right)-\left(\mathbf{a},\nabla\left(\nabla,\mathbf{\Gamma}\left(\left|\mathbf{x}-\mathbf{y}\right|\right)\right)\right)\right\}dt=$$

$$=\iint\limits_{(S)}\left\{\left(\left(\left(\frac{\P\,\mathbf{a}}{\P\,n}+\left[\mathbf{n},\left[\nabla,\mathbf{a}\right]\right]\right),\mathbf{\Gamma}\right)-\left[\mathbf{n},\mathbf{\Gamma}\right]\left(\nabla,\mathbf{a}\right)\right)-\left(\mathbf{a},\left(\frac{\P\mathrm{G}}{\P n}+\left[\mathbf{n},\left[\nabla,\mathrm{G}\right]\right]\right)\right)\right\}dS \tag{24}$$

Integrating in space (τ) a combination of differential operators (9, 7, 10, 13, 15) (for an arbitrary vector **a**), taking the standard limit, and also taking into account the properties of the double-layer potential [5], the fundamental solution of Laplace's equation in R^{3}, we have an integral representation solutions

$$\mathbf{a}=\iint\limits_{(S+\Sigma)}\left\{\left(\left(\frac{\P\,\mathbf{a}}{\P\,n}+\left[\mathbf{n},\left[\nabla,\mathbf{a}\right]\right]\right),\mathbf{\Gamma}\right)-\left(\mathbf{a},\left(\frac{\P\,\mathbf{\Gamma}}{\P\,n}+\left[\mathbf{n},\left[\nabla,\mathbf{\Gamma}\right]\right]\right)\right)\right\}dS \tag{25}$$

This expression is the source of the integral representations of solutions of the definition of basic kinematics and dynamic characteristics of the interaction of a moving viscous fluid and a solid. And here all the differential operations are linear combinations of the characteristics of the problem and potentials Y and F:

$$\mathbf{V} = \iint\limits_{(S+\Sigma)} \left\{ \left(\left(\frac{\partial \mathbf{V}}{\partial n} + [\mathbf{n}, \mathbf{\Omega}] \right), \mathbf{\Gamma} \right) - \left(\mathbf{V}, \left(\frac{\partial \mathbf{\Gamma}}{\partial n} + [\mathbf{n}, [\nabla, \mathbf{\Gamma}]] \right) \right) \right\} dS \tag{26}$$

$$\mathbf{\Omega} = \iint\limits_{(S+\Sigma)} \left\{ \left(\left(\frac{\partial \mathbf{\Omega}}{\partial n} + [\mathbf{n}, [\nabla, \mathbf{\Omega}]] \right), \mathbf{\Gamma} \right) - \left(\mathbf{\Omega}, \left(\frac{\partial \mathbf{\Gamma}}{\partial n} + [\mathbf{n}, [\nabla, \mathbf{\Gamma}]] \right) \right) \right\} dS \tag{27}$$

$$\mathbf{\Psi} = \iint\limits_{(S+\Sigma)} \left\{ \left(\left(\frac{\partial^* \mathbf{\Psi}}{\partial n}, \mathbf{\Gamma} \right) - [\mathbf{n}, \mathbf{\Gamma}](\nabla, \mathbf{\Psi}) \right) - \left(\mathbf{\Psi}, \left(\frac{\partial \mathbf{\Gamma}}{\partial n} + [\mathbf{n}, [\nabla, \mathbf{\Gamma}]] \right) \right) \right\} dS \tag{28}$$

$$\mathbf{\Phi} = \iint\limits_{(S+\Sigma)} \left\{ \left(\left(\frac{\partial^* \mathbf{\Phi}}{\partial n}, \mathbf{\Gamma} \right) - [\mathbf{n}, \mathbf{\Gamma}](\nabla, \mathbf{\Phi}) \right) - \left(\mathbf{\Phi}, \left(\frac{\partial \mathbf{\Gamma}}{\partial n} + [\mathbf{n}, [\nabla, \mathbf{\Gamma}]] \right) \right) \right\} dS \tag{29}$$

Numerical solution of linear systems of boundary integral equations type (26-29) for kinematics and dynamic characteristics can be obtained using the classical quadrature integration on each element of the triangulated surface (fig. 2).

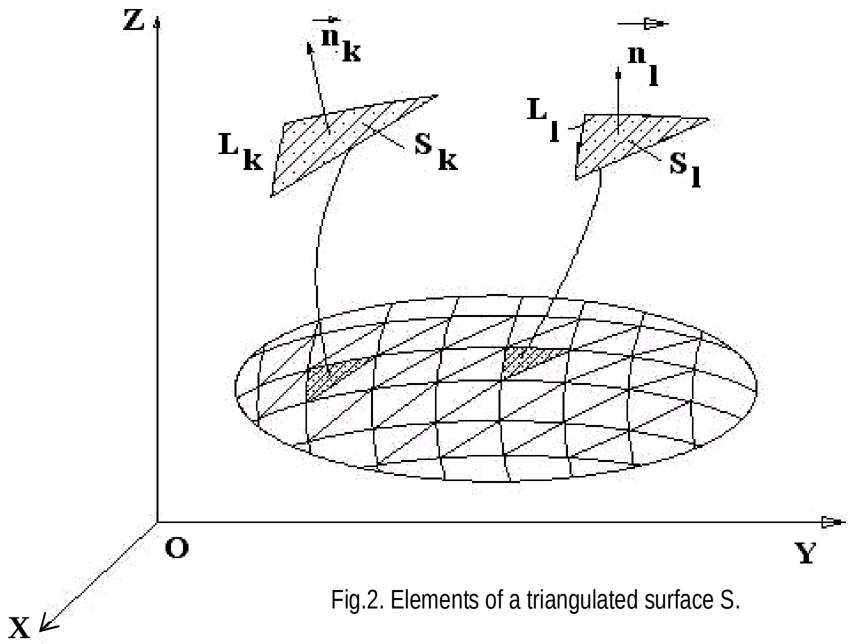

Fig.2. Elements of a triangulated surface S.

In an example problem, a simple algorithm for triangulation of the family of surfaces of second order and, in particular, the ellipsoidal shape was used. Local coordinate system was defined on each element and its shape and other parameters are expressed in terms local frame.
The study conducted for the limit values of improper integrals of the potentials of single and double layers, singular integrals and integrals of regular vector-valued functions, allowed us to develop a range of quadrature formulas for the approximate calculation of these integrals on the elements of a triangulated surface of the three-dimensional body.
On this basis, the algorithm and numerical implementation of boundary integral equation method for solving boundary value problems of viscous incompressible fluid flow around a body based on the full Navier-Stokes equations were developed.
Some results of calculations for the distribution and total hydrodynamic characteristics, as well as the convergence of the computational method are shown in figs. 3-7 [6].

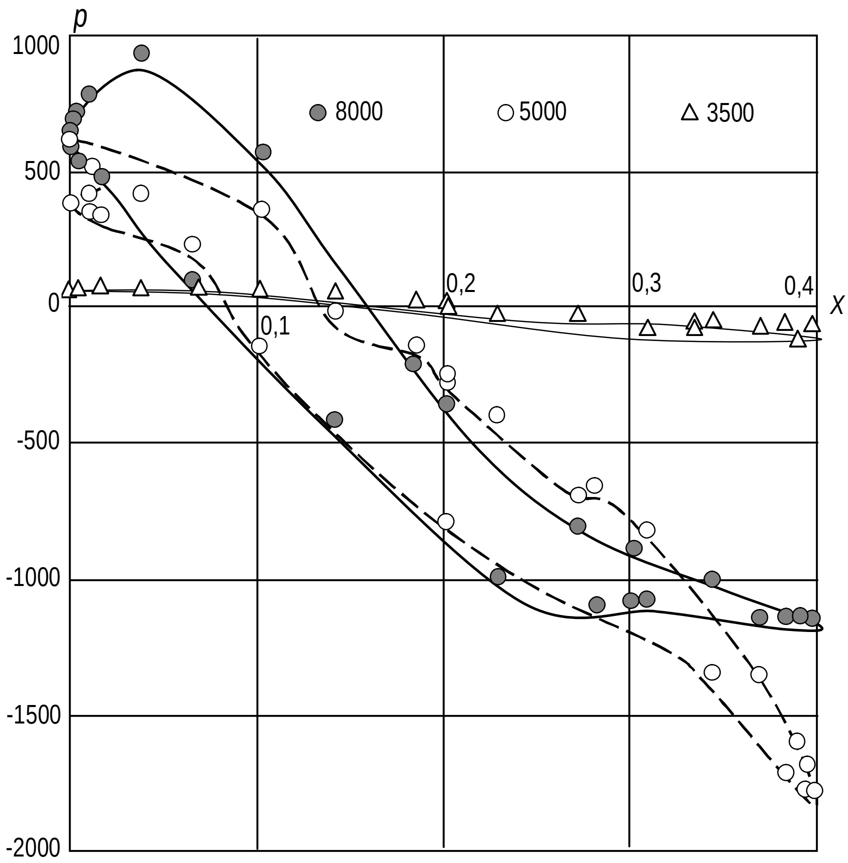

Fig. 3. Influence of the number of cells of the triangulation surface of the ellipsoid (1.0, 1.0, 0.3) on the quality of the calculation at α = 5°.

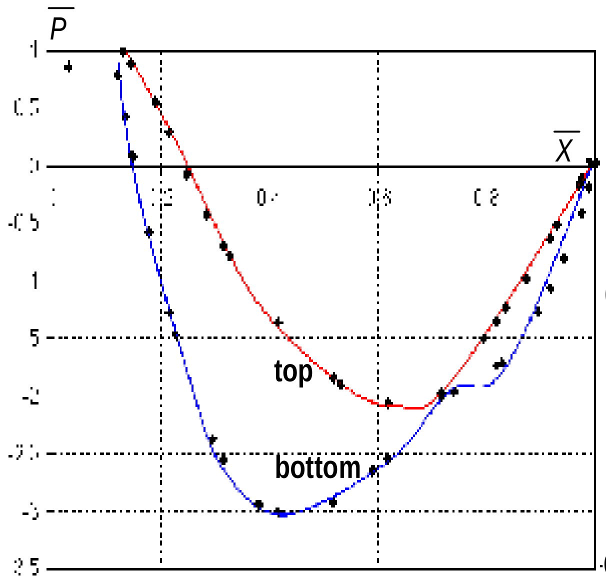

Fig.4. The pressure distribution on the top and bottom limits of longitudinal section of an ellipsoid $\overline{p} = f\left(\overline{x}\right)$ with α = 10°.

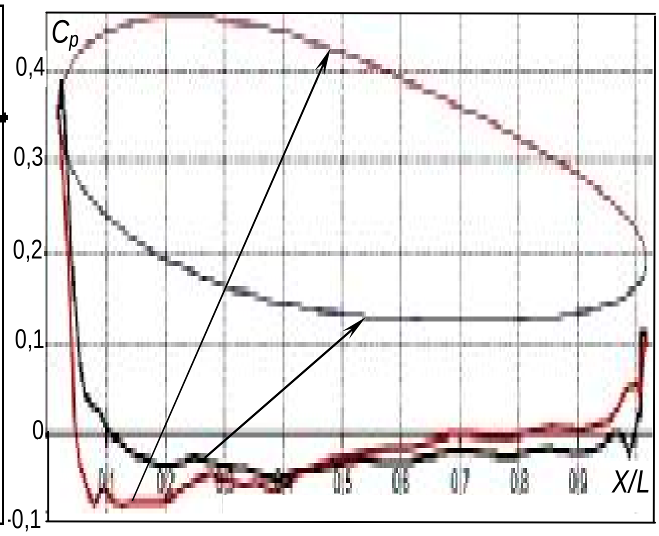

Fig.5. Distribution of pressure on the surface of an ellipsoid with elongation λ = 5,33 at Re = 10^4 and angle of attack α = 5°.

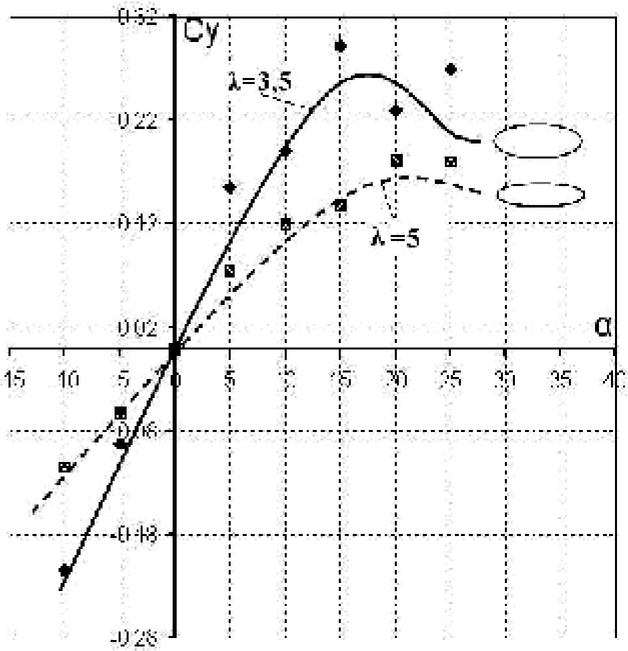

Fig.6. The dependence of the lift coefficient C_y on a angle of attack for an ellipsoid with different elongation.

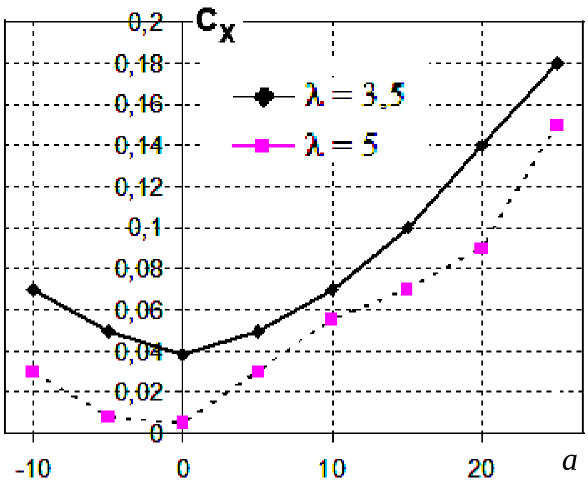

Fig.7. The dependence of the drag coefficient C_x on the angle of attack (a) ellipsoid at different elongation and Re = 4.9×10^4.

2. Results and discussions

This approach has the absolute advantage over finite difference methods and finite element method. That is why at the present time this method has been successfully applied to solve complex engineering problems - flat and spatial, stationary and time dependent. Shown in Fig. 3-5 results illustrate the wide range of capabilities of the developed method in terms of computing as distributed and total hydrodynamic characteristics of flow around bodies of arbitrary space configuration and external effects.

3. Conclusions

In this paper, a new generalized approach to obtain analytical and numerical solutions for a wide class of nonlinear problems in continuum mechanics is presented. New approach and required formal apparatus for the formulation of the boundary integral equations, equivalent to the initial-boundary problems of the basic mathematical models in mechanics of fluid and gas, are developed.

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A mathematical model for asteroidal impact casualties

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In a series of recent papers and in books there are different discussions and statements [1-24] on interesting models. Among them there is author's a mathematical model that may be applied to the analysis of Mass Extinctions as a stochastic process of the time. His work is based on lognormal probability distributions, b-lognormals (i.e. lognormals starting at a time b>0 higher than zero) and the stochastic process called Geometric Brownian Motion (GBM). The key feature of GBM is that its mean value increases exponentially in time. Thus, GBM may be applied to represent the number of living species on Earth at a certain time during the last 3.5 billion years, with a total increase from 1 (i.e. the first living being appeared on Earth 3.5 billion years ago (i.e. RNA)) to 50 million (the estimated current number of living species on Earth). In this mathematical scenario, Mass Extinctions are just times in the past where the GBM value did go down a lot from its own mean exponential curve and, a certain time after the impact that caused the Mass Extinction, did go up again to regain its previous high values or even higher values still. For example, Figure 1 hereafter is taken from the author's 2011 paper, and shows the two b-lognormal distributions corresponding to the two Mass Extinctions P/T and K/T that plagued the Earth 250 and 64 million years ago, respectively, thus putting an end to the Paleozoic and Mesozoic Eras, respectively.
In this paper we apply our mathematical theory to estimate how many casualties there might be if an asteroid or a comet was to strike the Earth nowadays. This may be evaluated either:
1) In the numbers of Humans only, or
2) In the number of some other Species only, to be selected at will.
For instance, the K/T impact 64 million years ago clearly killed all dinosaurs, but it also paved the way to mammals, and so the relevant two b-lognormals of the dinosaurs and the mammals behaved quite differently at the K/T impact time.

1. SETI and Darwinian evolution merged mathematically

1. 1. Introduction: the Drake equation (1961) as the foundation of SETI

In 1961 the American astronomer Frank D. Drake tried to estimate the number *N* of communicating civilizations in the Milky Way galaxy by virtue of a simple equation now called the Drake equation. *N* was written as the product of seven factors, each a kind of filter, every one of which must be sizable for there to be a large number of civilizations:

- *Ns* the number of stars in the Milky Way Galaxy;
- *fp* the fraction of stars that have planetary systems;
- *ne* the number of planets in a given system that are ecologically suitable for life;
- *fl* the fraction of otherwise suitable planets on which life actually arises;
- *fi* the fraction of inhabited planets on which an intelligent form of life evolves (as in Human History);
- *fc* the fraction of planets inhabited by intelligent beings on which a communicative technical civilization develops (as we have it today); and
- *fL* the fraction of planetary lifetime graced by a technical civilization (a totally unknown factor).

Written out, the equation reads

$$N = Ns \cdot fp \cdot ne \cdot fl \cdot fi \cdot fc \cdot fL \qquad (1)$$

All of the *f*'s are fractions, having values between 0 and 1; they will pare down the large value of *Ns*. To derive *N* we must estimate each of these quantities. We know a fair amount about the early factors in the equation, the number of stars and planetary systems. We know very little about the later factors, concerning the evolution of life, the evolution of intelligence or the lifetime of technical societies. In these cases our estimates will be little better than guesses.
It has to be said that the original formulation of (1) by Frank Drake in 1961 was slightly different, namely

$$N = R^{*} \cdot fp \cdot ne \cdot fl \cdot fi \cdot fc \cdot L \tag{2}$$

In (2) R^{*} is the average rate of star formation per year in the Galaxy and L is the length of time for which civilizations in the Galaxy release detectable signals into space. However, the number of stars in the Galaxy, N_S, is related to the star formation rate R^{*} by

$$Ns = \int_{0}^{T_{Galaxy}} R^{*}(t)\, dt \tag{3}$$

where T_{Galaxy} is the age of the Galaxy. Assuming for simplicity that R^{*} is constant in time, then (2) yields

$$Ns = R^{*} \cdot T_{Galaxy} \quad \text{i.e.} \quad R^{*} = \frac{Ns}{T_{Galaxy}} \tag{4}$$

that, inserted into (2), changes it into

$$N = Ns \cdot fp \cdot ne \cdot fl \cdot fi \cdot fc \cdot \frac{L}{T_{Galaxy}} \tag{5}$$

Then (5) becomes just (1) if one identifies

$$fL = \frac{L}{T_{Galaxy}} \tag{6}$$

as the fraction of planetary lifetime (as a part of the whole Galaxy existence T_{Galaxy}) graced by a technical civilization.

In the fifty years elapsed since Drake proposed his equation, a number of scientists and writers tried either to improve it or criticize it in many ways. For instance, in 1980 C.Walters, R.A.Hoover and R.K.Kotra (Walters, Hoover&Kotra, 1980) suggested to insert a new parameter in the equation taking interstellar colonization into account. In 1981 S.G.Wallenhorst (Wallenhorst, 1981) tried to prove that there should be an upper limit of about 100 to the number N. In 2004 L.V.Ksanfomality (Ksanfomality, 2004) again asked for more new factors to be inserted into the Drake equation, this time in order to make it compatible with the peculiarities of planets of Sun-like stars. Also the temporal aspect of the Drake equation was stressed by Ćirković (2004). But while these authors were concerned with improving the Drake equation, other simply did not consider it useful and preferred to forget about it, like Burchell (2006).

Also, it has been correctly pointed out that the habitable part of the Galaxy is probably much smaller than the entire volume of the Galaxy itself (The important relevant references are Gonzalez, Brownlee&Ward (2001); Lineweaver, Fenner&Gibson (2004); and Gonzalez (2005)). For instance, it might be a sort of a torus centered around the so called “corotation circle”, i.e. a circle around the Galactic Bulge such that stars orbiting around the Bulge and within such a torus never fall inside the dangerous spiral arms of the Galaxy, where supernova explosions would probably fry any living organism before it could develop to the human level or beyond. Fortunately for Humans, the orbit of the Sun around the Bulge is just a circle staying within this torus for 5 billion years or more (Marochnik&Mukhin, 1988, Balazs, 1988).

In all cases the final result about N has always been a sheer number, i.e., a positive integer number ranging from 1 to thousands or millions. This “integer or real number” aspect of all variables making up the Drake equation is what this author regarded as “too simplistic”. He extended the Drake equation so as to embrace Statistics in his 2008 paper (Maccone (2008)). This paper was later published in Acta Astronautica (Maccone, (2010a)), and more mathematical consequences were derived in Maccone (2010b) and Maccone (2011a).

1.2. Statistical Drake equation (2008)

Consider Ns, the number of stars in the Milky Way Galaxy, i.e. the first independent variable in the Drake equation (1). Astronomers tell us that *approximately* there should be about 350 billion stars in the Galaxy. Of course, nobody has counted *all* stars in the Galaxy! There are too many practical difficulties preventing us from doing so: just to name one, the dust clouds that don’t allow us to see even the Galactic Bulge (central region of the Galaxy) in visible light, although we may “see it” at radio frequencies like the famous neutral hydrogen line at 1420 MHz. So, it doesn’t really make much sense to say that $Ns = 350\times10^9$, or similar fanciful exact integer numbers. More scientific is saying that the number of stars in the Galaxy is 350 billion plus or minus, say, 50 billions (or whatever values the astronomers may regard as more appropriate).

It makes thus sense to REPLACE each of the seven independent variables in the Drake equation (1) by a MEAN VALUE (350 billions, in the above example) PLUS OR MINUS A CERTAIN STANDARD DEVIATION (50 billions, in the above example).

By doing so, we made a step ahead: we have abandoned the too-simplistic equation (1) and replaced it by something more sophisticated and scientifically serious: the STATISTICAL Drake equation. In other words, we have transformed the simplistic classical Drake equation (1) into a statistical tool capable of investigating of a host of facts hardly known to us in detail. In other words still:

1) We replace each independent variable in (1) by a RANDOM VARIABLE, labelled D_i (from Drake);

2) We assume the MEAN VALUE of each D_i to be the same numerical value previously attributed to the corresponding input variable in (1);

3) But now we also ADD A STANDARD DEVIATION s_{Di} on each side of this mean value, as provided by the knowledge obtained by scientists in the discipline covered by each D_i.

Having so done, we wonder: how can we find out the PROBABILITY DISTRIBUTION for each D_i? For instance, shall that be a Gaussian, or what? This is a difficult question, for nobody knows, for instance, the probability distribution of the number of stars in the Galaxy, not to mention the probability distribution of the other six variables in the Drake equation (1). In 2008, however, this author found a way to get around this difficulty, as explained in the next section.

1.3. The statistical distribution of N is lognormal

The solution to the problem of finding the analytical expression for the probability density function of the positive random variable N is as follows:

1) Take the natural logs of both sides of the statistical Drake equation (1). This changes the product into a sum.

2) The mean values and standard deviations of the logs of the random variables D_i may all be expressed analytically in terms of the mean values and standard deviations of the D_i (Maccone, 2008).

3) The Central Limit Theorem (CLT) of statistics, states that (loosely speaking) if you have a SUM of independent random variables, each of which is ARBITRARILY DISTRIBUTED (hence, also including uniformly distributed), then, when the number of terms in the sum

increases indefinitely (i.e. for a sum of random variables infinitely long)… the SUM RANDOM VARIABLE APPROACHES A GAUSSIAN.

4) Thus, the ln(N) approaches a Gaussian.

5) Namely, N approaches the LOGNORMAL DISTRIBUTION (as discovered back in the 1870s by Sir Francis Galton). Table 1 shows the most important statistical properties of a lognormal.

6) The mean value and standard deviations of this lognormal distribution of N may be expressed analytically in terms of the mean values and standard deviations of the logs of the D_i already found previously, as shown in Table 1.

For all the relevant mathematical proofs, more mathematical details and a few numerical examples of how the Statistical Drake Equation works, please see Maccone (2010a).

Table 1. Summary of the properties of the lognormal distribution that applies to the random variable N = number of ET communicating civilizations in the Galaxy.

Random variable	N is number of communicating ET civilizations in Galaxy
Probability distribution	Lognormal
Probability density function	$f_N(n) = \frac{1}{n} \cdot \frac{1}{\sqrt{2p}\, s} e^{-\frac{(\ln(n)-m)^2}{2s^2}} \quad (n \geq 0)$
Mean value	$\langle N \rangle = e^m\, e^{\frac{s^2}{2}}$
Variance	$s_N^2 = e^{2m}\, e^{s^2}\left(e^{s^2} - 1\right)$
Standard deviation	$s_N = e^m\, e^{\frac{s^2}{2}} \sqrt{e^{s^2} - 1}$
All the moments, i.e. k-th moment	$\langle N^k \rangle = e^{km}\, e^{k^2 \cdot \frac{s^2}{2}}$
Mode (= abscissa of the lognormal peak)	$n_{\text{mode}} \equiv n_{\text{peak}} = e^m\, e^{-s^2}$
Value of the Mode Peak	$f_N(n_{\text{mode}}) = \frac{1}{\sqrt{2p}\, s} \cdot e^{-m} \cdot e^{\frac{s^2}{2}}$
Median (= fifty-fifty probability value for N)	$\text{median} = m = e^m$
Skewness	$\frac{K_3}{(K_2)^{\frac{3}{2}}} = \left(e^{s^2} + 2\right)\sqrt{e^{s^2} - 1}$
Kurtosis	$\frac{K_4}{(K_2)^2} = e^{4s^2} + 2\, e^{3s^2} + 3\, e^{2s^2} - 6$
Expression of m in terms of the lower (a_i) and upper (b_i) limits of the Drake **uniform** input random variables D_i	$m = \sum_{i=1}^{7} \langle Y_i \rangle = \sum_{i=1}^{7} \frac{b_i[\ln(b_i)-1] - a_i[\ln(a_i)-1]}{b_i - a_i}$
Expression of s^2 in terms of the lower (a_i) and upper (b_i) limits of the Drake **uniform** input random variables D_i	$s^2 = \sum_{i=1}^{7} s_{Y_i}^2 = \sum_{i=1}^{7} \left(1 - \frac{a_i b_i \left[\ln(b_i) - \ln(a_i)\right]^2}{(b_i - a_i)^2}\right)$

1.4. Darwinian evolution as the exponential increase of the number of living species

Consider now Darwinian Evolution. To assume that the number of species increased exponentially over the 3.5 billion years of evolutionary time span is certainly a gross oversimplification of the real situation, as proven, for instance, by Rohde&Muller (2005). However, we will assume this exponential increase of the number of living species in time just in order to cast the theory into a mathematically simple and fruitful form. Later we will do better, we hope.

In other words, we assume that 3.5 billion years ago there was on Earth only one living species, whereas now there may be (say) 50 million living species or more. Note that the actual number of species currently living on earth does not really matter as a number for us: we just want to stress the ***exponential*** character of the growth of species. Thus, we shall assume that the number of living species on Earth increases in time as $E(t)$ (standing for "exponential in time"):

$$E(t) = A\, e^{Bt} \tag{7}$$

where A and B are two positive constants that we will soon determine numerically. This assumption of ours is obviously in agreement with the classical Malthusian theory of population growth. But it also is in line with the more recent "Big History" viewpoint about the whole evolution of the Universe, from the Big Bang up to now, requesting that progress in evolution occurs faster and faster, so that only an exponential growth is compatible with the requirements that (7) approaches infinity for $t\to\infty$ and all its time derivatives are exponentials too, apart from constant multiplicative factors.

Let us now adopt the convention that the current epoch corresponds to the origin of the time axis, i.e. to the instant $t = 0$ his means that all the past epochs of Darwinian Evolution correspond to negative times, whereas the future ahead of us (including finding ETs) corresponds to positive times. Setting $t = 0$ in (7), we immediately find

$$E(0)=A \tag{8}$$

proving that the constant A equals the number of living species on earth right now. We shall assume

$$A = 50 \text{ millions species} = 5\cdot 10^7 \text{ species} \tag{9}$$

To also determine the constant B numerically, consider the two values of the exponential (7) at two different instants t_1 and t_2, with $t_1 < t_2$, that is

$$\begin{cases} E(t_1) = A\, e^{B t_1} \\ E(t_2) = A\, e^{B t_2} \end{cases} \tag{10}$$

Dividing the lower equation by the upper one, A disappears and we are left with an equation in B only:

$$\frac{E(t_2)}{E(t_1)} = e^{B(t_2 - t_1)} \tag{11}$$

Solving this for B yields

$$B = \frac{\ln\left(E(t_2)\right) - \ln\left(E(t_1)\right)}{t_2 - t_1} \tag{12}$$

We may now impose the initial condition stating that 3.5 billion year ago there was just one species on Earth, the first one (whether this was RNA is unimportant in the present simple mathematical formulation):

$$\begin{cases} t_1 = -3.5 \cdot 10^9 \text{ years} \\ E(t_1) = 1 \quad \text{whence} \quad \ln\left(E(t_1)\right) = \ln(1) = 0 \end{cases} \tag{13}$$

The final condition is of course that today (t_2=0) the number of species equals A given by (9). Upon replacing both (9) and (13) into (12), the latter becomes:

$$B = \frac{\ln\left(E(t_2)\right)}{-t_1} = \frac{\ln\left(5 \cdot 10^7\right)}{-\left(-3.5 \cdot 10^9 \text{ year}\right)} = \frac{1.605 \cdot 10^{-16}}{\text{sec}} \tag{14}$$

Having thus determined the numerical values of both A and B, the exponential in (7) is thus fully specified. This curve is plot in fig.1 just over the last billion years, rather than over the full range between -3.5 billion years and now.

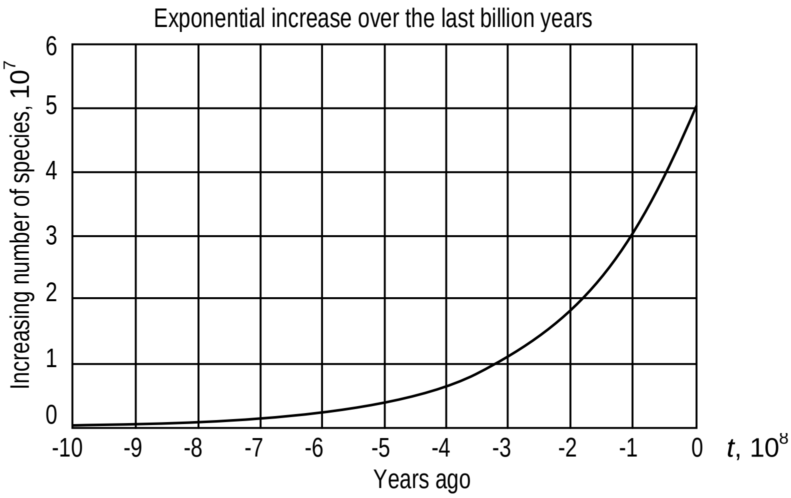

Fig.1. Exponential curve representing the growing number of species on Earth up to now, without taking the well-known Mass Extinctions into any consideration at all.

1.5. Introducing the "Darwin" (d) unit, measuring the amount of evolution that a given species reached

In all sciences "to measure is to understand".

In physics and chemistry this is done by virtue of units such as the meter, second, kilogram, coulomb, etcetera. So, it appears useful to introduce a new unit measuring the degree of evolution that a certain species has reached at a certain time t of Darwinian Evolution, and the obvious name for such a new unit is the "Darwin", denoted by a lower case "d". For instance, if we adopt the exponential evolution curve described in the previous section, we might say that the dominant species on Earth right now (Humans) have reached an evolution level of 50 million darwins.

How many darwins may have an alien civilization already reached? Certainly more than 50 millions, i.e. more than 50 Md, but we will not check out until SETI scientists will possibly detect the first extraterrestrial civilization.

We are not going to discuss further this notion of measuring the "amount of evolution" since we are aware that endless discussions might come out of it. But it is clear to us that such a new measuring unit (and ways to measure it for different species) will sooner or later have to be introduced to make Evolution a fully quantitative science.

1.6. Darwinian evolution is just a particular realization of Geometric Brownian Motion in the number of living species

Consider again the exponential curve described in the previous section. The most frequent question that non-mathematically minded persons ask this author is: "then you do not take the mass extinctions into account". The answer to this objection is that our exponential curve is just THE MEAN VALUE of a certain stochastic process that may run above and below that exponential in a totally unpredictable way. Such a stochastic process is called Geometric Brownian Motion (abbreviated GBM) and is described, for instance, at the web site: http://en.wikipedia.org/wiki/Geometric_Brownian_motion, from which figure 2 is taken.

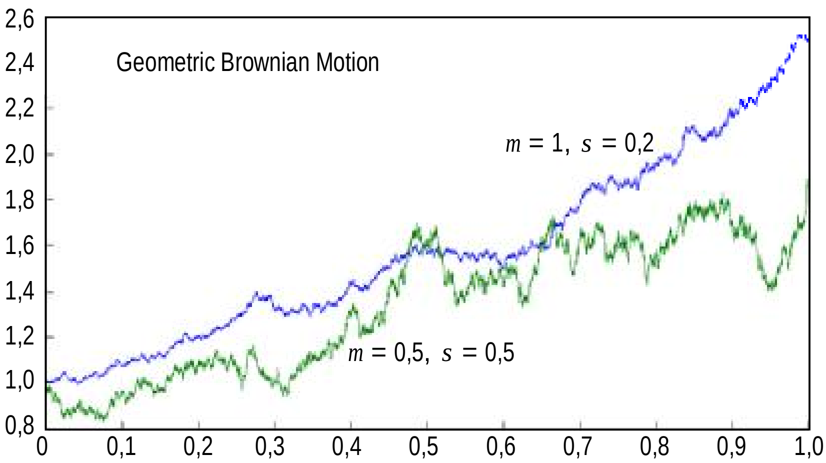

Fig.2. Geometric Brownian Motion. Two particular realizations of the stochastic process called Geometric Brownian Motion (GBM) taken from the Wikipedia site http://en.wikipedia.org/wiki/Geometric_Brownian_motion
Their mean values are the exponential (7) with different values of *A* and *B* for each shown stochastic process.

In other words, mass extinctions that occurred in the past are indeed taken into account as unpredictable fluctuations in the number of living species that occurred in the PARTICULAR REALIZATION of the GBM between -3.5 billion years and now. So, extinctions are "unpredictable vertical downfalls" in that GBM plot that may indeed happen from time to time. Also notice that:

1. The particular realization of GBM occurred over the last 3.5 billion years is very much unknown to us in its numeric details, but...
2. We won't care either, inasmuch as the theory of stochastic processes only cares about such statistical quantities like the mean value and the standard deviation curves that are deterministic curves in time with known equations.

2. Geometric Brownian Motion (GBM) as the key to stochastic evolution of all kinds

2.1. The $N(t)$ GBM as stochastic evolution

On January 8th, 2012, this author come to realize that his Statistical Drake Equation, previously described in Sections 2.2 and 2.3, is the special ***static case*** (i.e. "the picture", so as to say) of a more general Time-Dependent Statistical Drake Equation (i.e. "the movie", so as to say) that we study in this section. In other words, this result is a powerful generalization in time of all results described in Sections 1 and 2. This section is thus an introduction to a new, exciting mathematical model that one may call "Exponential Evolution in Time of the Statistical Drake Equation".

To be precise, the number N in the Statistical Drake Equation (1), yielding the number of extraterrestrial civilizations now existing and communicating in the Galaxy, is replaced in this section by a ***stochastic process*** $N(t)$, jumping up and down in time like the number e raised to a Brownian motion, but actually in such a way that ***its mean value keeps increasing exponentially in time as***

$$\langle N(t) \rangle = N_0 \, e^{mt} \tag{15}$$

In (15), N_0 and m are two constants with respect to the time variable t. Their meaning is, respectively:

1) N_0 is the number of ET communicating civilizations at the time $t = 0$, namely "now", if one decides to regard the positive times ($t > 0$) as the future history of the Galaxy ahead of us, and the negative times ($t < 0$)as the past history of the Galaxy.

2) m is a positive (if the number of ET civilizations increases in time) or negative (if the number of ET civilizations decreases in time) parameter that we may call "the drift". To fix the ideas, and to be optimistic, we shall suppose $m > 0$.

This evolution in time of $N(t)$ is just what we expect to happen in the Galaxy, where the overall number $N(t)$ of ET civilizations does probably ***increase*** (rather than decrease) in time because of the obvious technological evolution of each civilization. But this $N(t)$ scenario is a stochastic one, rather than a deterministic one, and certainly does not exclude temporary setbacks, like the end of civilizations due to causes as diverse as:

a) asteroid and comet impacts,

b) rogue planets or stars, arriving from somewhere and disrupting the gravitational stability of the planetary system,

c) supernova explosions that would "fry" entire nearby ET civilizations (think of AGN, the Active Nucleus Galaxies and ask: how many ET civilizations are dying in those galaxies right now?),

d) ET nuclear wars,

e) and possibly more causes of civilization end that we don't know about yet.

Mathematically, we came to define the probability density function (pdf) of this exponentially-increasing stochastic process $N(t)$ as the lognormal

$$N(t)\_\text{pdf}(n, N_0, m, s, t) = \frac{1}{\sqrt{2p}\, s\, \sqrt{t}\, n} e^{-\frac{\left[\ln(n) - \left(\ln N_0 + m\,t - \frac{s^2 t}{2}\right)\right]^2}{2 s^2 t}} \qquad \text{for} \qquad 0 \le n \le \infty \tag{16}$$

It is easy to prove that this lognormal pdf obviously fulfills the normalization condition

$$\int_0^\infty N(t)\_\text{pdf}(n, N_0, m, s, t)\, dn = \int_0^\infty \frac{1}{\sqrt{2p}\, s\, \sqrt{t}\, n} e^{-\frac{\left[\ln(n) - \left(\ln N_0 + m\,t - \frac{s^2 t}{2}\right)\right]^2}{2 s^2 t}} dn = 1 \tag{17}$$

Also, the mean value of (16) yields indeed the exponential curve (15)

$$\int_0^\infty n \cdot N(t)\_\text{pdf}(n, N_0, m, s, t)\, dn = \int_0^\infty n \frac{1}{\sqrt{2p}\, s\, \sqrt{t}\, n} e^{-\frac{\left[\ln(n) - \left(\ln N_0 + m\,t - \frac{s^2 t}{2}\right)\right]^2}{2 s^2 t}} dn = N_0\, e^{m\,t} \tag{18}$$

The proof of (17) and (18) is given in Appendix 11.A as the Maxima file "GBM_as_N_of_t_v33" of Maccone (2012).

In Table 2 Summary of the properties of the lognormal distribution that applies to the stochastic process $N(t)$= exponentially increasing number of ET communicating civilizations in the Galaxy, as well as the number of living species on earth over the last 3.5 billion years. Clearly, these two different GBM stochastic processes have different numerical values of N_0, m and s, but the equations are the same for both processes.

Table 2. summarizes the main properties of GBM, namely of this *N*(*t*) stochastic process.

Stochastic Process	$N(t)=\begin{cases}\text{1) Number of ET Civilizations (in SETI)}\\ \text{2) Number of Living Species (in Evolution)}\end{cases}$
Probability distribution	Lognormal distribution of the Geometric Brownian Motion (GBM)
Probability density function	$N(t)\_pdf(n,N_0,m,s,t)=\frac{1}{\sqrt{2p}\;s\sqrt{t}\,n}\,e^{-\frac{\left[\ln(n)-\left(\ln N_0+mt-\frac{s^2t}{2}\right)\right]^2}{2s^2t}}$ for $n\geq 0$
Mean value	$\left\langle N(t)\right\rangle=N_0\,e^{mt}$
Variance	$s^2_{N(t)}=N_0^2\,e^{2mt}\left(e^{s^2t}-1\right)$
Standard deviation	$s_{N(t)}=N_0\,e^{mt}\sqrt{e^{s^2t}-1}$
All the moments, i.e. *k*-th moment	$\left\langle N^k(t)\right\rangle=N_0^k\,e^{kmt}\,e^{\left(k^2-k\right)\frac{s^2t}{2}}$
Mode (= abscissa of the lognormal peak)	$n_{\text{mode}}\equiv n_{\text{peak}}=N_0\,e^{mt}\,e^{-\frac{3s^2t}{2}}$
Value of the Mode Peak	$f_{N(t)}(n_{\text{mode}})=\frac{1}{N_0\sqrt{2p}\;s\sqrt{t}}\cdot e^{-mt}\cdot e^{s^2t}$
Median (= fifty-fifty probability value for *N*(*t*))	$\text{median}=m=N_0\,e^{mt}e^{-\frac{s^2t}{2}}$
Skew ness	$\frac{K_3}{(K_2)^{\frac{3}{2}}}=\left(e^{s^2t}+2\right)\sqrt{e^{s^2t}-1}$
Kurtosis	$\frac{K_4}{(K_2)^2}=e^{4s^2t}+2\,e^{3s^2t}+3\,e^{2s^2t}-6$

2.2. Our statistical Drake equation is the static special case of *N*(*t*)

In this section we prove the crucial fact that the lognormal pdf of our Statistical Drake Equation given in Table 1 is just “the picture” case of the more general exponentially growing stochastic process *N*(*t*) (“the movie”) having the lognormal pdf (16) as given inTable 2. To make things neat, let us denote by the subscript “GBM” both the m and s, appearing in (16). The latter thus takes the form:

$$N(t)\_\text{pdf}\left(n,N_0,m_{GBM},s_{GBM},t\right)=\frac{1}{\sqrt{2p}\;s_{GBM}\sqrt{t}\,n}\,e^{-\frac{\left[\ln(n)-\left(\ln N_0+m_{GBM}\,t-\frac{s^2_{GBM}\,t}{2}\right)\right]^2}{2s^2_{GBM}\,t}} \tag{19}$$

for 0≤*n*≤∞.

Similarly, the let us denote by the subscript “Drake” both the m and s appearing in the lognormal pdf given in the third line of Table 1 (this is also eq. (1.B.56) of Maccone (2012)), namely the pdf of our Statistical Drake Equation:

$$\text{lognormal\_pdf\_of\_Statistical\_Drake\_Eq}\left(n, m_{Drake}, s_{Drake}\right) = \frac{1}{\sqrt{2p}\; s_{Drake}\, n} e^{-\frac{\left[\ln(n) - m_{Drake}\right]^2}{2 s_{Drake}^2}} \quad (20)$$

for $0 \le n \le \infty$.

Now, a glance at (19) and (20) reveals that they can be made coincide if, and only if, the two simultaneous equations hold

$$\begin{cases} s_{GBM}^2\, t = s_{Drake}^2 \\ \ln N_0 + m_{GBM}\, t - \dfrac{s_{GBM}^2\, t}{2} = m_{Drake}. \end{cases} \quad (21)$$

On the other hand, when we pass (so as to say) “from the movie to the picture”, the two s must be the same thing, and so must be the two m, that is, one must have:

$$\begin{cases} s_{GBM} = s_{Drake} = s \\ m_{GBM} = m_{Drake} = m. \end{cases} \quad (22)$$

Checking thus the upper equation (22) against the upper equation (21), we are just left with

$$t = 1 \quad (23)$$

So, $t = 1$ is the correct numeric value of the time leading “from the movie to the picture”. Replacing this into the lower equation (21), and keeping in mind the upper equation (22), the lower equation (21) becomes

$$\ln N_0 + m_{GBM} - \frac{s^2}{2} = m_{Drake}. \quad (24)$$

Since the two m also must be the same because of the lower equation (22), then (24) further reduces to

$$\ln N_0 - \frac{s^2}{2} = 0 \quad (25)$$

that is

$$N_0 = e^{\frac{s^2}{2}} \quad (26)$$

and the problem of “passing from the movie to the picture” is completely solved.

In conclusion, we have proven the following ***“movie to picture” theorem***:

The stochastic process $N(t)$ reduces to the random variable N if, and only if, one inserts

$$\begin{cases} t = 1 \\ s_{GBM} = s_{Drake} = s \\ m_{GBM} = m_{Drake} = m \\ N_0 = e^{\frac{s^2}{2}} \end{cases} \quad (27)$$

into the lognormal probability density (16) of the stochastic process $N(t)$.

2.3. Geometric Brownian Motion as the key to mathematics of finance

But what is this $N(t)$ stochastic process reducing to the lognormal random variable N in the static case?

Well, $N(t)$ is no less than the famous Geometric Brownian Motion (abbreviated "GBM"), of paramount importance in the mathematics of finance. In fact, in the so-called Black-Sholes models, $N(t)$ is related to the log return of the stock price. Huge amounts of money all over the world are handled at Stock Exchanges according to the mathematics of the stochastic process $N(t)$, that is differently denoted S_t there ("S" from Stock). But we won't touch these topics here, since this paper is about Evolution and SETI, rather than about stocks.

We just content ourselves to have proven that the GBM used in the mathematics of finance is the same thing as the exponentially increasing process $N(t)$ yielding the number of communicating ET civilizations in the Galaxy!

3. Darwinian evolution re-defined as a GBM in the number of living species

3.1. A concise introduction to cladistics and cladograms

Cladistics is the science describing *when* new forms of life developed in the course of Evolution. Cladistics is thus the science of lineages, i.e. phylogenetic trees, like the one shown for instance in fig.3, and it is today strongly based on computer codes, in turn based on high-level mathematics.

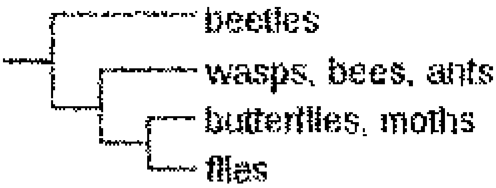

Fig.3. A horizontal cladogram, (taken from http://en.wikipedia.org/wiki/Cladogram) with the ancestor (not named) to the left.

Our innovative contribution to cladistics and cladograms like the one in Figure 3 is to put the horizontal axis of the time below them, and then realize that the cladograms branches are ***exponential functions of the time.*** In other words, these exponential arches are either increasing in time, or decreasing, or just staying constants (i.e. they are just horizontal lines, like the ones in fig.3), but the length of these exponential arches is as long as the species they represent survived during the course of Evolution.

This mathematical representation of the whole of Evolution is:

1. Easy, inasmuch as exponential functions like (7) are the easiest possible functions in mathematics.
2. Clear, inasmuch as we know pretty well when a new species appeared in the course of Evolution.
3. GBM-based, inasmuch as the exponential arches indeed are the mean values in time of the corresponding "unpredictable" GBMs yielding the number of members of that species living at a certain time in Evolution. At last, the study of the mathematical properties of GBMs is now open to scientists, rather than just to bankers and businessmen, as it happened in the last 40 years (1973-2013). Note that in 1997 the Nobel Prize in Economics was assigned Robert C. Merton and Myron Sholes (Fischer Black had already died in 1995) for their mathematical discoveries (Black-Sholes-Merton models) based on GBMs. Perhaps, new Nobel Prizes will be assigned for applying GBMs to Evolution and Astrobiology.

3.2. Cladistics for us: namely the GBM mean exponential as the locus of the peaks of *b*-lognormals representing each a different species started by evolution at the time $t=b>0$

How is it possible to "match" the GBM mean exponential curve with the lognormals appearing in the Statistical Drake Equation? Our answer to this question is "by letting the GBM mean exponential become the ENVELOPE of the b-lognormals representing the cladistics branches, i.e. the new species that were produced by Evolution at different times as long as Evolution unfolded. Let us now have a look at Figure 4 hereafter.

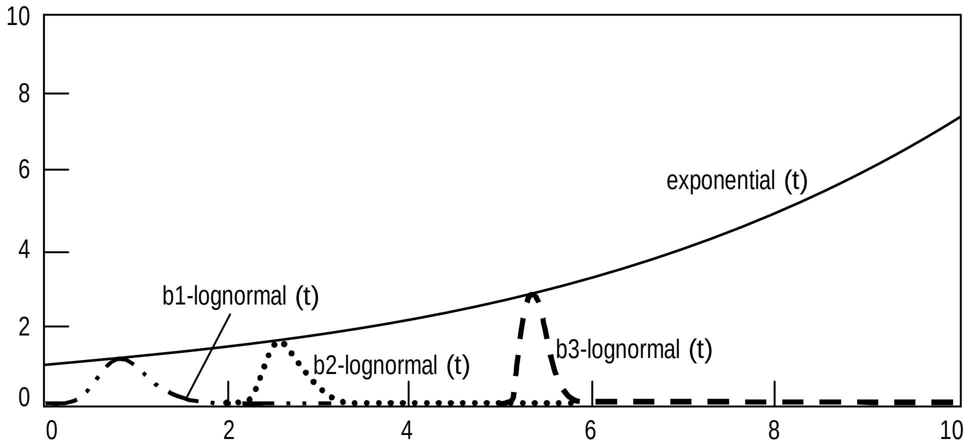

Fig.4. Darwinian Exponential as the ENVELOPE of b-lognormals. Each b-lognormal is a lognormal starting at a time (t = b = birth time) larger than zero and represents a different species “born” at time b of the Darwinian Evolution.

The envelope shown in fig.4 is NOT really an envelope in the strictly mathematical sense explained in calculus textbooks. However, it is “nearly the same thing in the practice” because it actually is the geometric LOCUS OF THE PEAKS of all b-lognormals. We shall now explain this in detail.

First of all, let us write down the equation of the b-lognormal, i.e. of the lognormal starting at any positive instant $t = b>0$ (while ordinary lognormals all start just at zero); in other words, $(t - b)$ replaces n in the first equation in Table 1:

$$\text{b\_lognormal}\left(t, m, s, b\right) = \frac{1}{\sqrt{2p}\, s \cdot \left(t-b\right)} e^{-\frac{\left(\ln(t-b)-m\right)^2}{2s^2}} \tag{28}$$

holding for $t > b$ and up to $t = \infty$.

Then, notice that its PEAK falls at the abscissa p and ordinate P given by, respectively (as given by the 8th and 9th line in Table 1):

$$\begin{cases} p = b + e^{m-s^2} = \text{b\_lognormal\_peak\_abscissa}, \\ P = \dfrac{e^{\frac{s^2}{2}-m}}{\sqrt{2p}\, s} = \text{b\_lognormal\_peak\_ordinate}. \end{cases} \tag{29}$$

Can we MATCH the second equation (29) with the Darwinian Exponential (7)? Yes, if we set at time $t = p$:

$$\begin{cases} A = \dfrac{1}{\sqrt{2p}\, s} \\ e^{B\,p} = e^{\frac{s^2}{2}-m} \end{cases} \quad \text{that is} \quad \begin{cases} A = \dfrac{1}{\sqrt{2p}\, s} \\ B\,p = \dfrac{s^2}{2} - m \end{cases} \tag{30}$$

The last system of two equations may now be inverted, i.e. exactly solved with respect to m and s:

$$\begin{cases} s = \dfrac{1}{\sqrt{2p}\,A} \\ m = -B\,p + \dfrac{1}{4p\,A^2} \end{cases} \tag{31}$$

showing that each b-lognormal in fig. 4 (i.e. its m and s) is perfectly determined by the Darwinian Exponential (namely by A and B) plus a precise value of the b-lognormal's peak time p. In other words, this is a one-parameter (the parameter is p) family of curves that are all constrained between the time axis and the Darwinian Exponential.

Clearly, as long as one moves to higher values of p, the peaks of these curves become narrower and narrower and higher and higher, since the area under each b-lognormal always equals 1 (normalization condition).

3.3. Cladogram branches are increasing, decreasing or stable (horizontal) exponential arches as functions of the time

It is now possible to understand how cladograms shape up in our mathematical theory of Evolution: they depart from the time axis at the birth time (b) of the new species and then either:

1) INCREASE if the b-lognormal of the i-th new species has (keeping in mind the convention $p_i < 0$ for past events, i.e. events prior to now):

$$\begin{cases} A_i = \dfrac{1}{\sqrt{2p}\,s_i} \\ B_i = \dfrac{\dfrac{s_i^2}{2} - m_i}{p_i} > 0 \ \text{ that is } \ m_i > \dfrac{s_i^2}{2} \end{cases} \tag{32}$$

2) DECREASE if the same b-lognormal has (keeping in mind the convention $p_i < 0$ for past events):

$$\begin{cases} A_i = \dfrac{1}{\sqrt{2p}\,s_i} \\ B_i = \dfrac{\dfrac{s_i^2}{2} - m_i}{p_i} < 0 \ \text{ that is } \ m_i < \dfrac{s_i^2}{2} \end{cases} \tag{33}$$

3) KEEP STAYING CONSTANT (i.e. rather than exponential arches we have horizontal segments) for all time values for which the i^{th}-b-lognormal is characterized by:

$$\begin{cases} A_i = \dfrac{1}{\sqrt{2p}\,s_i} \\ B_i = 0 \ \text{ that is } \ \dfrac{s_i^2}{2} = m_i \end{cases} \tag{34}$$

This last case really is the most "routine" one, inasmuch as the given species neither increases nor decreases in time, but rather, for generations and generations, "the parents are born, mate, babies are born, the parents die, the babies mate, and so on endlessly". This we call a STATIONARY species. And, mathematically, the surprise is that a STATIONARY species.

This last case really is the most “routine” one, inasmuch as the given species neither increases nor decreases in time, but rather, for generations and generations, “the parents are born, mate, babies are born, the parents die, the babies mate, and so on endlessly”. This we call a STATIONARY species. And, mathematically, the surprise is that a STATIONARY species no longer is described by b-lognormals, but rather by the new probability density found by replacing the last equation becomes the NEW STATIONARY pdf:

$$\text{stable\_pdf}\left(t, s\, , b\right) = \frac{1}{\sqrt{2p}\, s\, \sqrt{t-b}}\, e^{-\frac{\left(\ln(t-b)\right)^2}{2s^2}}\, e^{-\frac{s^2}{8}}\, . \tag{35}$$

In plain words, this is the pdf for species undergoing NO EVOLUTION at all, and this is NOT pdf of the lognormal type because of the square root $\sqrt{t-b}$ appearing in (35) instead of the (t – b) appearing in (28). Clearly, more words and examples would be needed to better clarify our theory, but we have no space for that here. Table 3 yields the key statistical properties of the stationary pdf (35) (see also Maccone (2011b)).

Table 3. Summary of the statistical properties of the new random variable NoEV given by eq. (35) and representing the STATIONARY LIFE of a new species born at time *b* and undergoing NO EVOLUTION thereafter.

Random variable	NoEv= NoEvolution probability=STATIONARY LIFE
Probability distribution	(no name yet)
Probability density function	$f_{\text{NoEv}}\left(t, s\, , b\right) = \frac{1}{\sqrt{2p}\, s\, \sqrt{t-b}}\, e^{-\frac{\left(\ln(t-b)\right)^2}{2s^2} - \frac{s^2}{8}} \qquad (t \ge b)$
Mean value	$\left\langle \text{NoEv} \right\rangle = b + e^{s^2}$
Variance	$s^2_{\text{NoEv}} = e^{2s^2}\left(e^{s^2} - 1\right)$
Standard deviation	$s_{\text{NoEv}} = e^{s^2}\sqrt{e^{s^2} - 1}$
Mode (= abscissa of the NoEv peak)	$t_{\text{mode}} \equiv t_{\text{peak}} = b + e^{-\frac{s^2}{2}}$
Value of the Mode Peak (= ordinate of the NoEv peak)	$f_{\text{NoEv}}(t_{\text{mode}}) = \frac{1}{\sqrt{2p}\, s}$
Median (= fifty-fifty probability value for NoEv)	$\text{median} = m = b + e^{\frac{s^2}{2}}$
Skewness	$\frac{K_3}{\left(K_2\right)^{\frac{3}{2}}} = \left(e^{s^2} + 2\right)\sqrt{e^{s^2} - 1}$
Kurtosis	$\frac{K_4}{\left(K_2\right)^2} = e^{4s^2} + 2\, e^{3s^2} + 3\, e^{2s^2} - 6$

3.4. KLT-filtering in the Hilbert space and Darwinian selection are “The same thing” in our theory …

As a glance to the future developments of our mathematical theory of Darwinian Evolution, let us now recall that the KLT is... a principal axes transformation in the Hilbert space spanned by the eigenfunctions of the autocorrelation of a noise plus a possible signal in it. Put this way, the KLT (standing for Karhunen-Loève transform) may look “hard to understand”

(Maccone (2010c), Szumski (2011)). But we wish to describe by easy words that it amounts to the well-known Darwinian Selection process. In fact, consider a Euclidean space with a large number N of dimensions. A point there means giving N coordinates. Each coordinate we assume to be "a function of the body that Humans have in common with other animals, but other animals may OR MAY NOT (because too primordial) have in common with Humans. Then, the axis representing Humans in this N-space has the largest variance of the set of points around it because Humans have ALL functions. Monkeys have NEARLY the same number of functions as Humans but in practice they have FEWER of them. Thus, the Monkey axis in the N-space has the SECOND LARGEST VARIANCE around it. In the mathematical jargon of the KLT this is re-phrased by saying that Humans are the DOMINANT = FIRST EIGENVALUE in the KLT of the N-space, whereas Monkeys are the SECOND EIGENVALUE, and so on for lower species, that are really almost "noise" (i.e. rubbish) when compared to Humans.

Now about filtering, i.e. extracting a tiny signal by virtue of the KLT from thick noise (this works so much better by virtue of the KLT than by virtue of the trivial FFT used by engineers all over the world, but that is another story, for which the reader may see Maccone (2010c). So, just as the Darwinian Evolution FILTERED HUMANS OUT OF A LOT OF "NOISE" (i.e. other lower-level living organisms), so the KLT applied to the above large N-dimensional space may DESCRIBE MATHEMATICALLY the SELECTION carried on by Darwinian evolution across 3.5 billion years. But that requires another paper at least, or, better, the new book entitled "Mathematical SETI" that this author is now writing.

3.5. Conclusion about our statistical model for evolution and cladistics

Evolution, as it occurred on Earth over the last 3.5 billion years, is just one chapter of the larger book encompassed by the Drake equation, which covers a time span of 10 billion years or so.

We sought to outline a unified and simple mathematical vision of both Evolution and SETI, as the title of this paper says.

Our vision is based on the lognormal probability distribution characterizing N in the Statistical Drake Equation.

We have shown that the envelope of such lognormal distributions "changing in time" (b-lognormals) may account for the exponential increase of the number of living species on Earth over 3.5 billion years.

4. Mass extinctions as exceptionally low values of the $N(t)$ GBM in the number of living species

4.1. Mass extinctions of the past in our mathematical model

A Mass Extinction is a widespread and rapid decrease in the amount of life on Earth (see, for instance, the Wikipedia site http://en.wikipedia.org/wiki/Extinction_event, from which the following figure 5 was taken).

In our mathematical representation of Darwinian Evolution, Mass Extinctions are neatly defined as exceptionally low values of the $N(t)$ GBM stochastic process yielding the number of living species on Earth at time t.

The natural question thus arises: given two positive numbers N_1 and N_2 (with $N_2 > N_1$), what is the probability that $N(t)$ has its value lying in between these two numbers N_1 and N_2 ? That is, what is $\Pr\{N_1 \le N(t) \le N_2\}$? The answer to this question is of course given by the integral of the GBM pdf (19) taken between N_1 and N_2, that is

$$\Pr\left\{N_1 \le N(t) \le N_2\right\} = \int_{N_1}^{N_2} N(t)\_\mathrm{pdf}\left(n, N_0, m_{GBM}, s_{GBM}, t\right) dn = \tag{36}$$

$$= \int_{N_1}^{N_2} \frac{1}{\sqrt{2p}\; s_{GBM} \sqrt{t}\, n} \exp\left\{-\frac{\left[\ln(n) - \left(\ln N_0 + m_{GBM}\, t - s_{GBM}^2\, t/2\right)\right]^2}{2\, s_{GBM}^2\, t}\right\} dn =$$

But the last integral may be re-written in terms of the well-known error function erf(x) (we omit the relevant steps), with the final result:

$$= \mathrm{erf}\left(\frac{\ln(N_2/N_0)}{\sqrt{2}\, s\sqrt{t}} + \frac{\sqrt{2}\left(s^2 - 2m\right)\sqrt{t}}{4s}\right) - \mathrm{erf}\left(\frac{\ln(N_1/N_0)}{\sqrt{2}\, s\sqrt{t}} + \frac{\sqrt{2}\left(s^2 - 2m\right)\sqrt{t}}{4s}\right)$$

where the error function erf(x) is given by

$$\mathrm{erf}(x) = \frac{2}{\sqrt{p}} \int_0^x e^{-z^2}\, dz \tag{37}$$

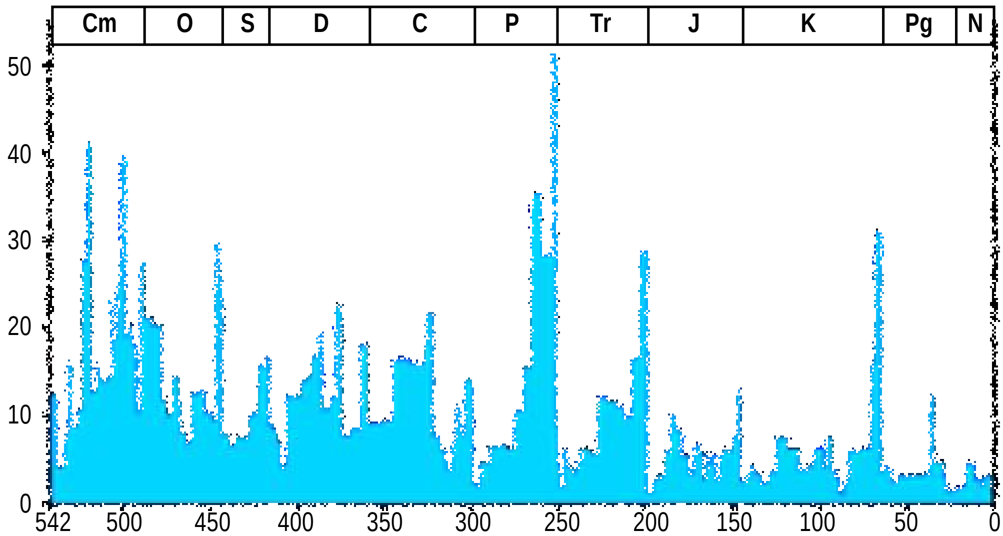

Fig.5. The grey graph shows the apparent *percentage* (not the absolute number) of marine animal genera becoming extinct during any given time interval. It does not represent all marine species, just those that are readily fossilized Taken from the Wikipedia site http://en.wikipedia.org/wiki/Extinction_event). On the horizontal axis are millions of years ago.

In conclusion, we have

$$\Pr\left\{N_1 \le N(t) \le N_2\right\} = \mathrm{erf}\left(\frac{\ln(N_2/N_0)}{\sqrt{2}\, s\sqrt{t}} + \frac{\sqrt{2}\left(s^2 - 2m\right)\sqrt{t}}{4s}\right) - \mathrm{erf}\left(\frac{\ln(N_1/N_0)}{\sqrt{2}\, s\sqrt{t}} + \frac{\sqrt{2}\left(s^2 - 2m\right)\sqrt{t}}{4s}\right) \tag{38}$$

Notice that, in the ***stationary*** case of the NoEv(t) stochastic process characterized by (34), then (38) dramatically reduces to the much easier equation

$$\Pr\left\{N_1 \le \mathrm{Stationary\_NoEv}(t) \le N_2\right\} = \mathrm{erf}\left(\frac{\ln(N_2/N_0)}{\sqrt{2}\, s\sqrt{t}}\right) - \mathrm{erf}\left(\frac{\ln(N_1/N_0)}{\sqrt{2}\, s\sqrt{t}}\right) \tag{39}$$

Equation (38) (and equation (39) in the stationary NoEv case) provide the mathematical key to describe Mass Extinctions in our mathematical model for Darwinian Evolution based on GBMs and b-lognormals. However, this author plainly admits that, at the moment, he was unable to make further progress beyond (38) and (39). The task is daunting, and would request a much longer paper than this one. Nevertheless, this author thought that transmitting his "Mathematical Evolution" model to the international Planetary Defense Community would have been worth something, especially looking forward to future numeric simulations of how many casualties and asteroidal or cometary impact did cause in the past (Mass Extinctions) and would cause in the future. This, unless the capability of deflecting an asteroid or a comet is quickly achieved by Humankind, something that seems unlikely as of 2013.

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Claudio Maccone, a mathematical physicist and a space scientist (Turin, Italy). SETI was his main interest over the last 30 years and he is Co-Chair of the SETI Permanent Study Group of the IAA. He proposed to replace the FFT by the KLT, suggested crater Daedalus (Moon Farside) as the best RFI-free observing site for radio astronomy, wrote a book about the FOCAL space missions to 550 AU to exploit the radio magnification provided by the Sun as a gravitational lens, and discovered the statistical extension of the Drake equation described in this paper.
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Problems of antenna devices installation on a space vehicle of Earth observation

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There have been developed some methods and algorithms to choose places to install antenna onboard spacecraft which transmits data to a satellite at the stage of near Earth spacecraft design development meant for Earth observation. Some special features of spacecraft operation and its design ate considered in the models and algorithms. Selection criterion for most preferable places to install antenna according to the target specification has been offered.

Introduction

One of the key factors to ensure effective application of high-informative space systems meant for the Earth observation is to downlink increasing level of received data. Transmission of such data to ground stations within radio visibility zone is not the solution to the problem. As a result, actual efficiency and online data delivery to customers are decreasing if compared with the values obtained by perspective Earth observation satellites.

It is possible to solve such problem if data will be transmitted by geostationary satellite retransmitter (SR) vie optical channel. Advantages of the optical channel application are the following:

- possibility of laser equipment development with large coverage range;
- total lack of interferences while any radio electronic equipment onboard spacecraft are on;
- insensibility to electromagnetic environment;
- enhanced specific energy and mass characteristics of the equipment (per unit channel capacity).

It is possible to transfer video data when transmitting and receiving antennas of satellites are in mutual visibility conditions and are not shadowed by the body of the spacecraft or by any device attached to the spacecraft (fig. 1). When the video data are transmitted by the SR, it is advisable not to interrupt observation.

In this connection at the stage of near-earth spacecraft designing, a problem of places selection to install antennas onboard spacecraft are actual. It will help to minimize the time when transmitting antennas are shadowed by elements of the spacecraft and at the same time to transmit video data to the SR.

When choosing a place to install antenna onboard spacecraft, the antenna devices have to be mutually associated with the other external devices and antenna coverage areas have to be ensured.

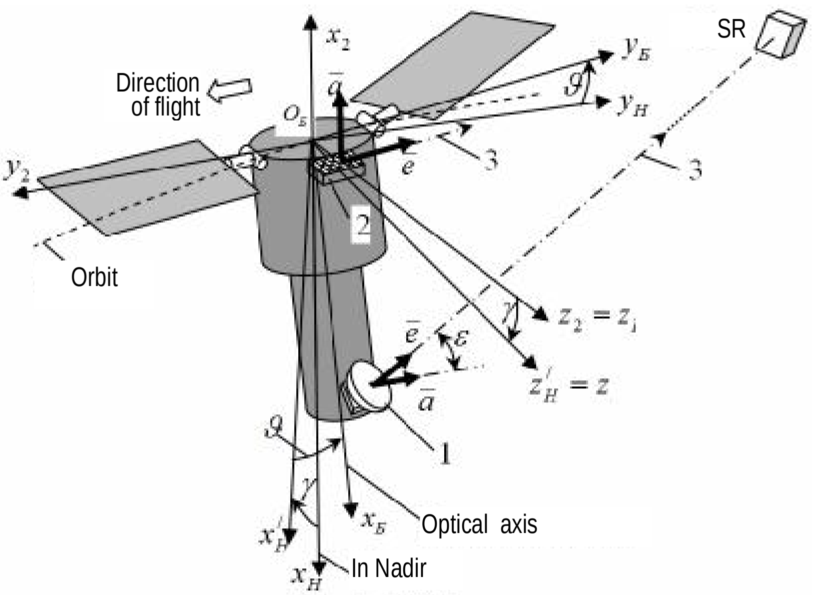


Fig. 1. Scheme of antenna pointed at ($\bar{e}$ vector) SR when visibility line is not shadowed by the spacecraft elements. 1, 2 – transmitting antennas of different types; 3 – visibility line between antenna and SR.

Moreover, it is necessary to consider a purpose of spacecraft application.

Special features are that spacecraft during its orbital flight performs triaxial rotation about center of mass to guide surveillance equipment on specified areas of the Earth surface located arbitrarily relative to a flight route of the spacecraft to survey areas, routes with variable azimuth as well as to perform stereo survey and convergent survey. Location of areas under survey is also arbitrarily.

At the time of antenna installation it is necessary to consider design of elements integrated inside spacecraft which can be of different shapes.

As a selection criterion for most preferable places to install antenna it is offered to use mutual visibility time t_{PB} of antenna devices and SR.

In assessment of such criterion, full and simplified statement of the problem is possible. When there is a full statement of the problem, shadowing of transmitting antennas by spacecraft elements, when these antennas are pointed at the SR, is considered. In this work we deal with a simplified statement of the problem, half-space around observation spacecraft, where the specified transmitting antenna is installed, is marked out and SR location in any half-space is estimated.

Such problem is not possible to solve applying analytic dependence because the number of factors which influence on the solution is great. There are some mathematical models to estimate spacecraft mutual visibility [1], however, there are transcendental equations and their solutions make simulation algorithms more complicated. To solve such problem it is advisable to use in this work a simulation method for orbital flight of the Earth observation satellite and SR, taking into account any software-based turn of the satellite when the satellite has a specific operational purpose.

The core of the modeling

In base coordinate system a unit vector $\bar{a}$ is drawn to a plane of the half-space where antennas are not shadowed by spacecraft elements (Fig. 1). In every time point of simulated orbital flight, mutual visibility conditions (lack of shadowing created by the Earth) of spacecraft and SR without consideration of antennas shadowing by spacecraft elements are being checked. When such conditions are met, coordinates of spacecraft and SR are defined in geocentric coordinate system and coordinates of a unit vector $\bar{e}$, beam direction from spacecraft to SR, are calculated. Then, there is a cycle translating from one coordinate into another (more detailed in algorithm) to define coordinates of vector $\bar{e}$ in spacecraft base coordinate system. After it, an angle between $\bar{a}$ and $\bar{e}$ vectors is calculated. If this angle is less than 90º (cosine of this angle is positive), SR is within the half-space where directive antenna is installed, so shadowing of transmitting antennas created by spacecraft body is missing. Increment of time simulation is performed and accumulated time when antennas attached to spacecraft are visible from SR.

Basic assumptions

- The Earth shape is spherical but to calculate orbit parameters it is necessary to use elliptic motion equations when estimated values of ascending node longitude (orbit precession) and ascending node-perigee angle during long term flight are periodically corrected because of nonsphericalness of the Earth (secular perturbation induced by the second zonal harmonic in geopotential decomposition is considered).
- To calculate evolution of ascending node longitude (orbit precession) and evolution of ascending node-perigee angle during long term flight, nonsphericalness of the Earth is considered (first-order secular perturbation is taken into account).

– Influence of upper layers of the atmosphere on orbits which are under research is neglected.

Initial data, the algorithm and mathematical models used for task solutions are given below.

Initial data meant for calculation

Longitude of SR stationary point l_{CP} should be given (latitude j_{CP} =0). All the other initial data are intermediate data calculated during implementation of older software [2] meant for estimation of spacecraft efficiency index, i.e. radius-vector modulus of the spacecraft $r_{KA}(t)$, longitude $l_{KA}(t)$ and latitude $j_{KA}(t)$ of subsatellite point on the Earth surface in every time point of simulation modeling. But to start such program it is necessary to use the following initial data: w_3 – angular velocity of the Earth rotation relative to its axis, i – orbit plane inclination, Ω – longitude of ascending node, w – ascending node-perigee angle, $r_П$ and r_A – satellite perigee and apogee altitude.

Maximal angle of spacecraft rotation $r_{\max}$ is changing with the band width $L_{обз}$, which meets requirements to image quality at the edge of the band or requirements to observation periodicity.

Step of time calculation Δt (seconds, minutes) and duration calculation (days, months, year, operation life) are given.

Geometrical model of the spacecraft is created, type of integration and probable places of antennas installation are defined.

Coordinates of the vector which determines antennas positioning in basic coordinate system are given.

Algorithm and mathematical models

In every time point of simulated flight, area of spacecraft and SR mutual invisibility is built like a movable cone with a vertex in the center of the Earth and with generatrix lines directed to a mutual visibility boundary of the spacecraft (Fig.1).

Estimation of a fact when the spacecraft gets into a zone where the satellite-retranslator is shadowed by the Earth is equal to a determination of the spacecraft location in every time point of simulated flight inside the cone where one-half angle is equal to a central angle of the Earth a.

If the spacecraft is outside this cone, then spacecraft mutual visibility conditions are met.

Mutual visibility analysis algorithm of the spacecraft is given below.

1. A counter of accumulated time t_{PB}, when directed antennas of the spacecraft and SR are under mutual visibility, is adjusted to zero.

2. Motion of the spacecraft in a fixed geocentric coordinate system is simulated. The spacecraft coordinates are believed to be already known (determined) at every time point of the simulation. The models and the algorithm of the spacecraft motion is described in paper [2].

3. Conditions when a low-orbiting spacecraft gets into an area limited with an angle α, are also represented in paper [1] and are given by the following equation:

$$\left|\arccos\left[\sin(j_B)\sin(j_{KA}) + \cos(j_B)\cos(j_{KA})\cos(l_{KA} - l_B)\right]\right| < a$$

In this formula a coordinate j_B is equal to zero because the spacecraft is geostationary but coordinate l_B corresponds to the point of the Earth opposite to subsatellite point of the geostationary spacecraft, i.e.: $l_B = p - l_A$, if l_A – east longitude (positive) and $l_B = p + l_A$, if l_A – west longitude (negative).

In order to define conditions when the spacecraft are within shadowed area of the Earth created by the SR, some elements of spherical trigonometry were used (fig.2).

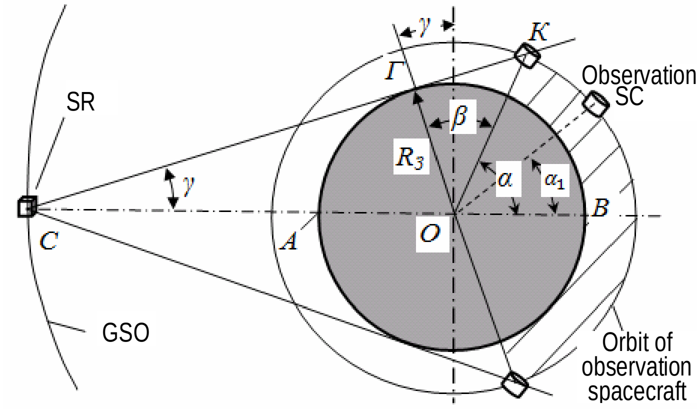


Fig. 2. Scheme for modeling of spacecraft mutual visibility

Such models implementation simplifies simulation algorithms because subsatellite point of the SR is fixed relatively to the Earth surface and is not required simulation of the SR orbital motion.

When a line of SC and SR mutual visibility is shadowed by the Earth data transmission is not possible and calculation goes to the point 15 of the algorithm.

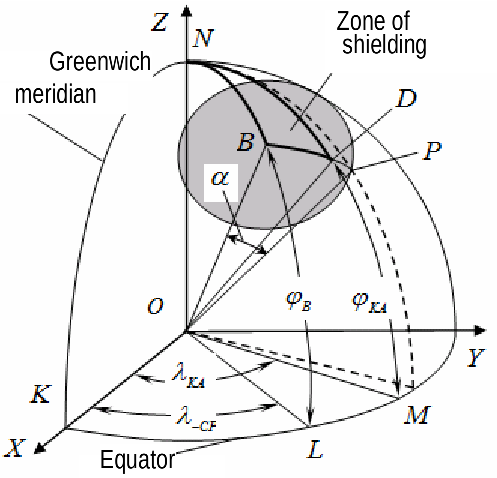


Fig. 3. Scheme for conditions determination when spacecraft gets into the Earth area shadowed by the SR

When shadowing is missing the following condition is verified: is the SR within the half-space of the SC base coordinate system, where the directed antenna is installed, or not? To check this 4-14 points of the algorithm are fulfilled.

4. Coordinates of SR and SC in geocentric Greenwich coordinate system for every time point of simulated flight are determined.

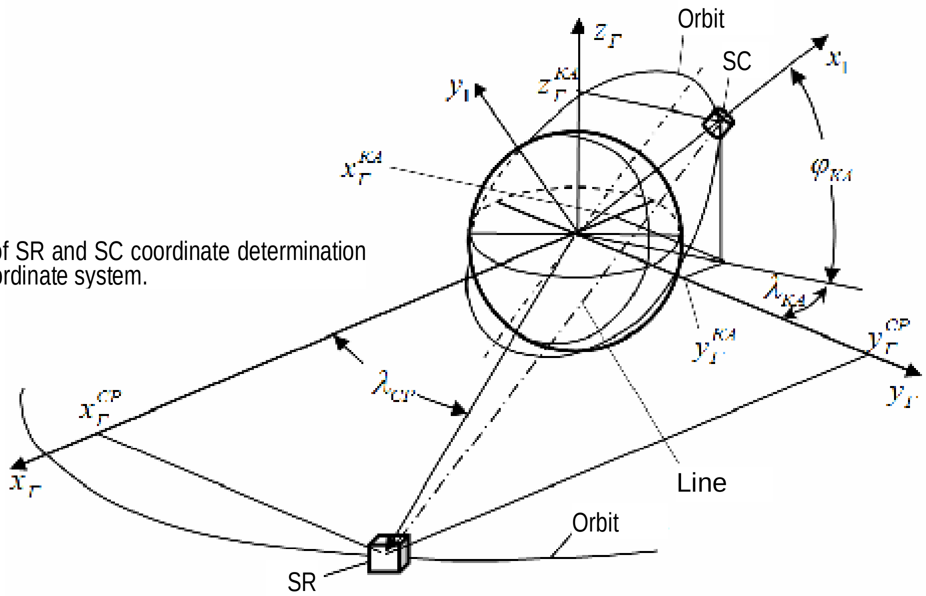
$$x_{\Gamma}^{KA} = r_{KA} \cos j_{KA} \cos l_{KA};$$

$$y_{\Gamma}^{KA} = r_{KA} \cos j_{KA} \sin l_{KA};$$

$$z_{\Gamma}^{KA} = r_{KA} \sin j_{KA}.$$

Scheme of the coordinate determination in this point as well as in 4 and 5 points of this algorithm is given in figure 4.

Fig. 4. Scheme of SR and SC coordinate determination in Greenwich coordinate system.



5. Coordinates of the SR are being calculated in Greenwich coordinate system.

$$x_{\Gamma}^{CP} = r_{CP}\, cos\, l_{KA};\; x_{\Gamma}^{CP} = r_{CP}\, sin\, l_{KA};\; z_{\Gamma}^{CP} = 0 .$$

6. Coordinates of a unit vector (vector $\bar{e}$) directed from SC at SR are being calculated in geocentric Greenwich coordinate system

$$x_{\Gamma}^{e} = \frac{r_{CP}\cos l_{KA} - r_{KA}\cos j_{KA}\cos l_{KA}}{\sqrt{(x_{CP}-x_{KA})^2+(y_{CP}-y_{KA})^2+(z_{CP}-z_{KA})^2}}$$

$$y_{\Gamma}^{e} = \frac{r_{CP}\sin l_{KA} - r_{KA}\cos j_{KA}\sin l_{KA}}{\sqrt{(x_{CP}-x_{KA})^2+(y_{CP}-y_{KA})^2+(z_{CP}-z_{KA})^2}}$$

$$z_{\Gamma}^{e} = \frac{-r_{KA}\sin j_{KA}}{\sqrt{(x_{CP}-x_{KA})^2+(y_{CP}-y_{KA})^2+(z_{CP}-z_{KA})^2}}$$

7. Translation of the vector $\bar{e}$ coordinates from geocentric Greenwich coordinate system into fixed geocentric coordinate system is performed

$$\begin{Vmatrix} x^e \\ y^e \\ z^e \end{Vmatrix} = A^T \cdot \begin{Vmatrix} x_{\Gamma}^e \\ y_{\Gamma}^e \\ z_{\Gamma}^e \end{Vmatrix}, \text{ where } A = \begin{Vmatrix} \cos(w_3 t) & \sin(w_3 t) & 0 \\ -\sin(w_3 t) & \cos(w_3 t) & 0 \\ 0 & 0 & 1 \end{Vmatrix}.$$

8. Translation of the vector $\bar{e}$ coordinates from fixed geocentric coordinate system ($Oxyz$) into geocentric orbital coordinate system ($O_1x_1y_1z_1$) connected with a pericentre of the orbit (fig. 5) [3, 4] is performed; here m_{ij}:

$$\begin{Vmatrix} e_{x1} \\ e_{y1} \\ e_{z1} \end{Vmatrix} = \begin{Vmatrix} m_{11} & m_{12} & m_{13} \\ m_{21} & m_{22} & m_{23} \\ m_{31} & m_{32} & m_{33} \end{Vmatrix} \cdot \begin{Vmatrix} e_x \\ e_y \\ e_z \end{Vmatrix}$$

$m_{11} = \cos w \cdot \cos W - \sin w \cdot \cos i \cdot \sin W$ $\quad m_{21} = -\sin w \cdot \cos W - \cos w \cdot \cos i \cdot \sin W$ $\quad m_{31} = \sin i \cdot \sin W$

$m_{12} = \cos w \cdot \sin W + \sin w \cdot \cos i \cdot \cos W$ $\quad m_{22} = -\sin w \cdot \sin W - \cos w \cdot \cos i \cdot \cos W$ $\quad m_{32} = -\sin i \cdot \cos W$

$m_{13} = \sin w \cdot \sin i$ $\quad m_{23} = \cos w \cdot \sin i$ $\quad m_{33} = \cos i$

9. Translation of the vector $\bar{e}$ coordinates from geocentric orbital coordinate system ($O_1x_1y_1z_1$) connected with a pericentre of the orbit into barycentric coordinate system ($O_2x_2y_2z_2$) is performed (fig. 6) [3, 4].

$$\begin{Vmatrix} e_{x2} \\ e_{y2} \\ e_{z2} \end{Vmatrix} = \begin{Vmatrix} \cos J & \sin J & 0 \\ -\sin J & \cos J & 0 \\ 0 & 0 & 1 \end{Vmatrix} \cdot \begin{Vmatrix} e_{x1} \\ e_{y1} \\ e_{z1} \end{Vmatrix}.$$

In Fig. 5, 6 J is a true anomaly of the SC; Π – perigee of the orbit.

10. Translation of the vector $\bar{e}$ coordinates from barycentric coordinate system $O_2x_2y_2z_2$ into coordinate system connected with a center of mass of the SC is performed ($O_Hx_Hy_Hz_H$)

$$\begin{Vmatrix} e_{xH} \\ e_{yH} \\ e_{zH} \end{Vmatrix} = M_H \cdot \begin{Vmatrix} e_{x2} \\ e_{y2} \\ e_{z2} \end{Vmatrix},$$ where M_H is a rotation matrix (cosines between coordinate axis).

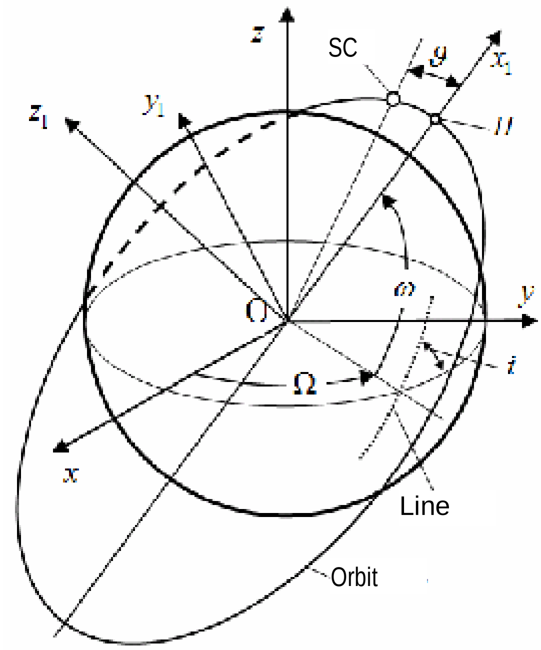


Fig. 5. Fixed geocentric coordinate system *Oxyz* and geocentric orbital coordinate system $O_1x_1y_1z_1$, connected with a pericentre of the orbit

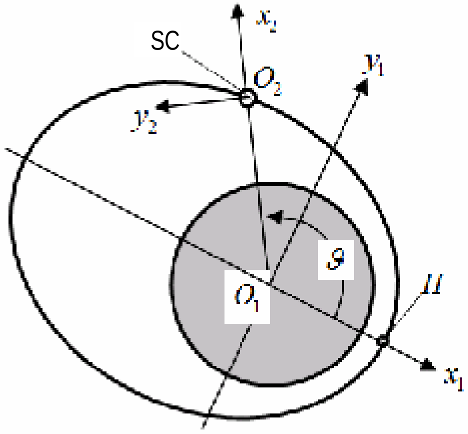


Fig.6. Geocentric orbital coordinate system connected with a pericentre of the orbit $O_1x_1y_1z_1$ and barycentric orbital coordinate $O_2x_2y_2z_2$

For the case when SC design (vertical integration) is connected with a flight route, when $y_Б$ axis of the base coordinate system of the SC is directed at nadir (fig.1), the rotation matrix will be the following $M_H = \begin{Vmatrix} 0 & 1 & 0 \\ -1 & 0 & 0 \\ 0 & 0 & 1 \end{Vmatrix}$. For the case when SC design (horizontal integration) is connected with a flight route, when $x_Б$ axis of the base coordinate system of the SC is directed at nadir (Fig. 7), the rotation matrix will be the following: $M_H = \begin{Vmatrix} -1 & 0 & 0 \\ 0 & -1 & 0 \\ 0 & 0 & 1 \end{Vmatrix}$.

11. Periodically, in a certain time, simulation of SC redirection from one object into another is performed. As some areas of the Earth surface under observation are located arbitrarily, relative to the flight route, a pitch angle q and a roll angle g of the SC (fig. 1) in a coverage area of a conical form is determined with the help of a random-number generator.

$$J = -r_{max} + 2r_{max}x \ , \ g = -r_{max} + 2r_{max}V \ ,$$

$$(\operatorname{tg} q)^2 + (\operatorname{tg} g)^2 < (\operatorname{tg} r_{max})^2$$

where x and V are random numbers with uniform distribution law in a segment [0, 1].

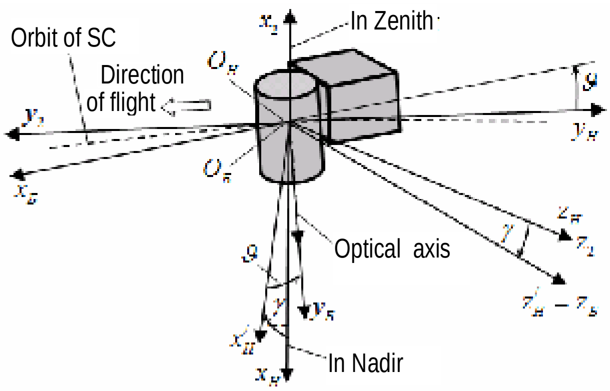


Fig.7. Coordinate system at the time of SC rotation with a transverse optical axis of the observation equipment

The last formula is used to eliminate random angles x and V where deviation angle of optical axis from nadir increases maximal value r_{max}.

12. Translation of vector $\bar{e}$ from coordinate system connected with a center of mass of the SC and with the center of the Earth $O_Hx_Hy_Hz_H$ into a base coordinate system $O_Бx_Бy_Бz_Б$, where pitch angle q and roll angle g are considered, is performed (fig. 1 and 7) $\begin{Vmatrix} e_{xБ} \\ e_{yБ} \\ e_{zБ} \end{Vmatrix} = M_Б \cdot \begin{Vmatrix} e_{xH} \\ e_{yH} \\ e_{zH} \end{Vmatrix}$,

where $M_Б$ is a rotation matrix (cosines between coordinate axis).

For the case when SC design (vertical integration) is connected with a flight route, when $y_Б$ axis of the base coordinate system of the SC is directed at nadir (fig. 1), the rotation matrix will be the following $M_Б = \begin{Vmatrix} \sin q \cdot \cos g & -\cos q & -\sin q \cdot \sin g \\ \cos q \cdot \cos g & \sin q & -\cos q \cdot \sin g \\ \sin g & 0 & \cos g \end{Vmatrix}$. For the case when SC design (horizontal integration) is connected with a flight route, when $x_Б$ axis of the base coordinate system of the SC is directed at nadir (Fig. 7), the rotation matrix will be the following:

$$M_Б = \begin{Vmatrix} \cos q \cdot \cos g & -\sin q & -\cos q \cdot \sin g \\ -\sin q \cdot \cos g & \cos q & \sin q \cdot \sin g \\ \sin g & 0 & \cos g \end{Vmatrix}$$

13. Cosine of e angle between $\bar{e}$ and $\bar{a}$ vectors are calculated (Fig. 1)

$\cos e = a_{xБ} x^e_Б + a_{yБ} y^e_Б + a_{zБ} z^e_Б$, where $a_{xБ}, a_{yБ}, a_{zБ}$ are coordinates of the unit vector $\bar{a}$ (which also depend on the SC design); $x^e_Б, y^e_Б, z^e_Б$ are coordinates of the unit vector $\bar{e}$ in a base coordinate system.

14. If $\cos e$ is positive SR is within a half-space where directed antenna is installed, so transmitting antennas are not shadowed by the SC body.

15. Accumulated time t_{PB} ,when directed antennas of the SC and the SR are under conditions of mutual visibility, is calculated $t_{PB} = t_{PB}+\Delta t$, where Δt – step of calculation during simulation.

16. End of calculation is verified. If calculation is continued, increment of time of the SC and SR simulated flight with a step of Δt is performed and then it goes to the point 1 of the algorithm. If not, the program stops.

On the basis of the described algorithm and models, software module was developed. With the help of such module the older software, used for evaluation of SC effectiveness, has been updated [2].

Conclusion

Selection criterion for the most preferable places aboard the SC to install directed antennas transmitting data to the SR has been offered (maximal relative time when antennas of the SC and SR are under mutual visibility conditions).

Models and algorithms to evaluate criterion parameter (t_{PB}) on the bases of simulated orbital flight, SC design, SC rotation for ground segments mapping and for periodical orientation of solar arrays in the Sun have been developed.

Models, algorithms, and software can be used to define a region of rational solutions when choosing the most preferable places aboard the SC to install antennas at the initial design stages. Together with the other software modules it is possible to solve a task of the SC synthesis concerning external design of the SC.

Scientific novelty of this paper is to relate target specification of the SC (on-line data, bandwidth) to the SC design when choosing places to install antennas transmitting data with the help of the satellite-retranslator according to the offered criterion concerning time of antenna and SR visibility. Stochastic nature of low-orbiting SC operation is considered.

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(in Russian version of article)

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Numerical investigation of complex cooling systems with internal channels network

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As the Mach number and range of aerial vehicles increases, the heat protection of the combustion chamber has been a more and more important issue. Besides developing heat-tolerant materials and new combustion chamber cooling techniques, the development of advanced cooling technology is also a significant way to the thermal protection of combustion chambers.
Film cooling is the most conventionally and widely applied cooling method. The gas film from the holes of combustion chambers forms a piece of film on the internal surface of them, which separates the wall from the hot gas and meanwhile takes away the radiation of hot gas and flame. Thus cooling and heat insulation can be achieved.
Intersecting-grids cooling configuration with internal network channels is a new scheme of cooling configuration with wall cooling and film cooling combined. Such film cooling structure could strengthen the cooling effect and reduce the usage of coolant. If the mechanics of enhancement of heat transfer and the dominating factor for cooling features can be discovered, then disciplines of the application of such structures in the design process of wall cooling in combustion chambers are available. Highly efficient cooling structure ensures higher combustion chamber temperatures and consequently increases the thrust and efficiency of aero engines. Usually the combination of full-coverage film cooling and impingement, convection and film cooling are employed in flame tube cooling. In recent years composite cooling structures are being investigated here and abroad.
Except conventional film cooling, new cooling techniques are being developed, for example the combination of thermal barrier and film cooling, taking advantage of each, could greatly enhance the cooling effect, which has good prospect in aero engines. However the effectiveness is related to the quality of coating craftwork. Laminate cooling also belongs to a new technology and USA and Russia have long before applied it to flame tube cooling. It is essentially a composite of impingement, convective and film cooling, which has good cooling performance but with complex manufacturability. In applications blocking appears very often and the weld spots crack easily. And it's not feasible for our country.
In this cooling configuration the cooled wall is divided into units, in which the cooling gas flows intersected and cools down the wall and then forms the gas film through the holes on the external surface of the wall, which provides further heat protection. The intersecting gas flow inside the wall can at meantime result in impingement effect, which is more effective. Furthermore, the arrangement of the units can be adjusted due to the thermal load of the external surface. It shows that the manufacturing of this cooling structure is feasible and has pretty good prospect in applications. This technique is found at present only in patent and no experiments or numerical investigations are carried out, which provides large development potential.
The internal flow condition and cooling features of the intersecting-grids cooling structure that can be applied in the combustion chambers and turbine vanes and blades of modern gas turbine engines is investigated numerically, to get knowledge of the cooling features of such structure and discuss the feasibility of applying it in cooling of combustion chambers and turbine vanes and blades in aero engines.

1. Structures

The configuration of internal channel networks is shown in figure 1.This structure is able to be applied to the cooling of either a turbine blade or the wall of combustion chamber. In this paragraph it will be demonstrated for a turbine blade. Each set of internal network channels forms a single unit. And a certain number of unites locate in the solid body of the blade, protecting the entire entity. The coolant is supplied from the root into the blade cavity, some of which flows into the network channels transferring heat convectively, then out of the holes and forms a cooling film. Detailed structure is specified in fig.2.

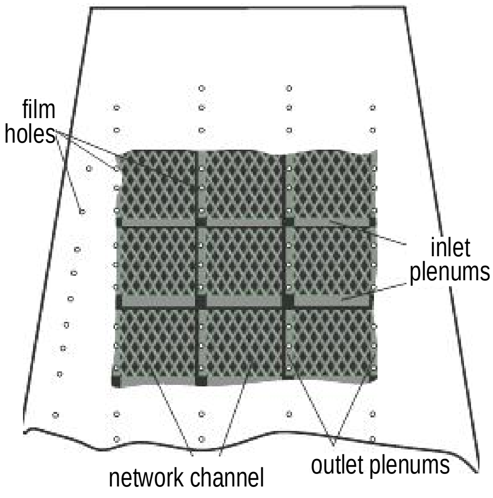

Fig.1. Configuration of internal network channels within a turbine blade.

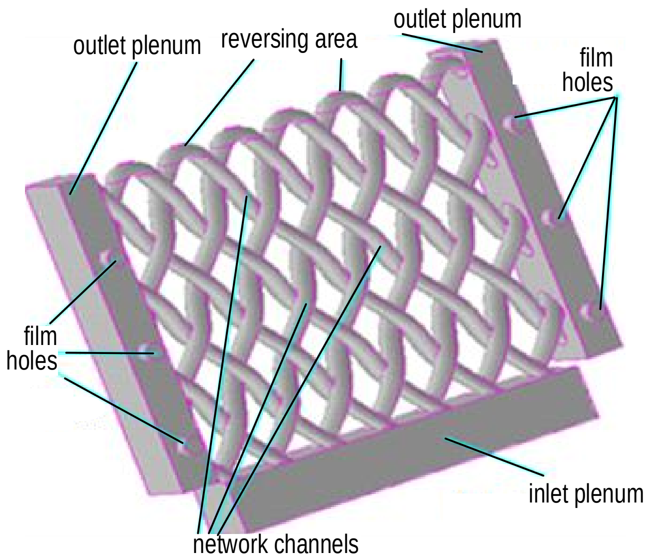

Fig.2. Configuration of a single internal network channel unit.

The coolant first enters the inlet plenum which is connected with the channels where the cooling gas exchanges heat with the solid body. The coolant flows out of the channel into the outlet plenum and forms film through the holes, thus the wall temperature is reduced. The channels wind in the wall, interfering each other.

The front view of the cooling unit is specified in figure 3. It can be observed that the reversing angle on the top of the channel is 60 degrees, after which the coolant continues its way to the outlet plenum. Disturbing between gas flows exists at the interfering area of the channels, which increases the turbulence intensity, consequently the heat transfer of the coolant is enhanced. The A-A and B-B cross sections are shown in figure 4 and 5.

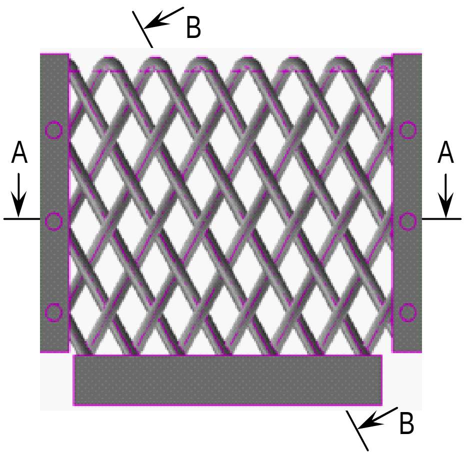

Fig.3. Front view of internal network channel unit

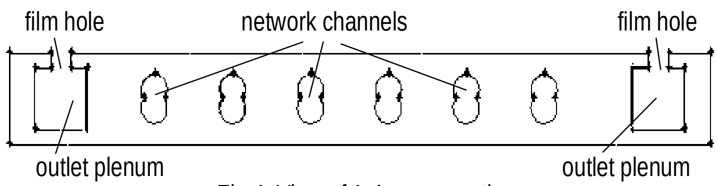

Fig.4. View of A-A cross section

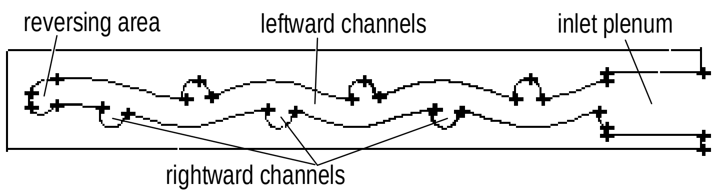

Fig.5. View of B-B cross section

A clear view of the degree of the interfering is specified in stream wise in figure 4. The total length of the cooling unit is 27mm, width 24mm, thickness 3mm. The outlet plenum (height 2mm) on lateral sides is connected with film holes which is 0.5mm long. In the middle the network channels have a diameter of 1mm. The distance between the centers of the interfering circles is 0.6mm.
The disturbance of a flow in a single channel is illustrated in figure 5. The flow in the channel can be affected by the other 6 channels, and meanwhile influencing the others, which is of great benefit to the convective heat transfer.

2. Calculation model and numerical method

2.1. Calculation model of the internal network channels.

The target calculation zone in this paper is illustrated in figure 6. It consists of two zones, one is the fluid area, and the other is the metallic wall, inside of which lay the internal network channels.

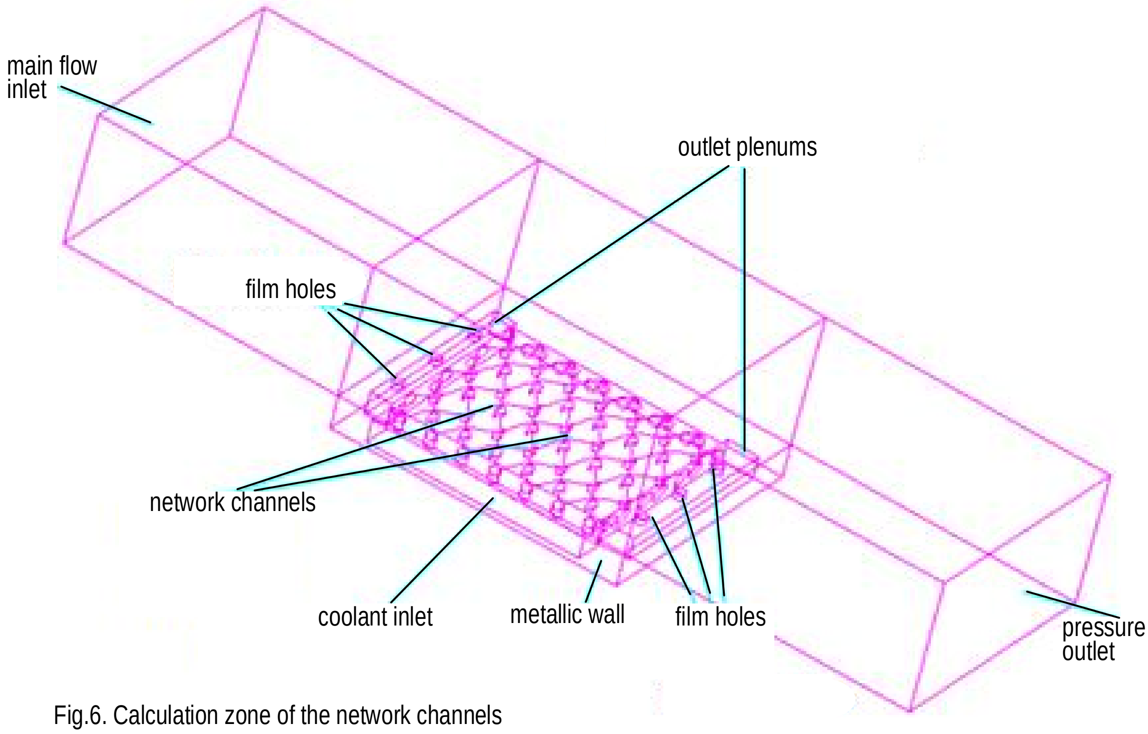

Fig.6. Calculation zone of the network channels

Coolant enters the network channels through the inlet plenum on lateral side, and exchanges heat with the wall. After that the cooling gas flows into the outlet plenums which are connected to the main stream via six film holes. The main stream enters through the inlet with a height of 12mm and a width of 24mm. The main stream heats the wall convectively and mixes with the secondary flow, after which the mixture flows out through the outlet. Conjugate flow and heat transfer calculation is employed, as the heat transfer between the two parts of the calculation model is taken into consideration. The numerical grid consists totally about 2,600,000 points.

2.2. Numerical method.

In the numerical model both the main stream and the secondary flow are set to mass flow inlet, normal to the inlet boundary. The outlet boundary is pressure outlet, which equals one standard atmosphere.
To investigate the cooling efficiency in real conditions, the calculation is made under a large temperature difference, with the temperature of main flow 1800K and the secondary flow

800K. In this condition the properties of air are handled as follows: density considered as ideal gas, heat conductivity, heat capacity, viscosity and other properties are derived by Lagrange interpolation.

The numerical simulation employs the separated implicit solver in Fluent 6.3. The method is Semi-Implicit Method for Pressure Linked Equations, i.e. the SIMPLE. A turbulence model of Realizable k-ε is applied and the near wall treatment is Enhanced Wall Function method. A double-preciseness upwind formula is employed for the segregation of each parameter. The pressure correction equation, mass conservation equation, momentum equation, k and ε equation are confronted with under-relaxation treatment, in which the under-relaxation factors are adjusted during the iteration process. The judging of convergence is determined by the comparative residual of lower than 1×10^{-5}, with no tend of further increase.

The calculation is made with a blow ratio of 1:1 and the Reynolds number of the main stream 40000.

3. Results

The directions in the calculation model are defined as follows: the stream wise of the main flow is x axis, the inlet direction of secondary flow as y axis and the normal direction of the metallic wall side exposed to the main flow as z axis.

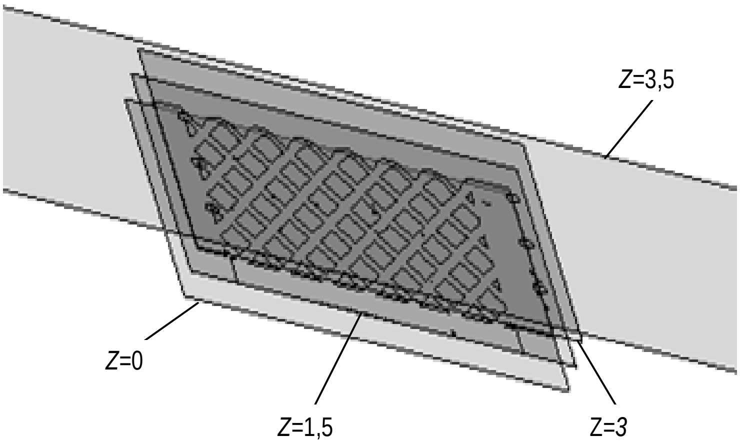

Fig.7. Positions of the cross sections along the z axis

Positions of cross sections alongside the thickness of the metal are specified in figure 7.The thickness of the metallic wall is 3mm, thus the three representative cross sections are z=0 cross section as the bottom boundary, z=3 cross section as the border of wall and main flow z=1.5 as the middle cross section of the wall, containing the internal network channels and z=3.5 as a cross section within the main flow near the wall.

Figure 8 illustrates the temperature distribution on the middle cross section of the wall, which tells that the temperature increases upward within the wall. The temperature at the beginning of the channels stays low then an obvious raise can be observed until the maximal magnitude at the reversing area. Due to the disturbance of gas flows at the interfering cross sections, the temperature there varies a lot, especially when the reverse flow confronts the previous secondary flow. This is to be observed in the upper half of the metallic wall. As a result of the high heat conductivity the temperature change within the metallic wall is not too sharp. The temperature gradient change broad wide is relatively small while the temperature gradient end wide varies gradually. The top area in Figure 8 has the highest temperature on account of no internal channels. The

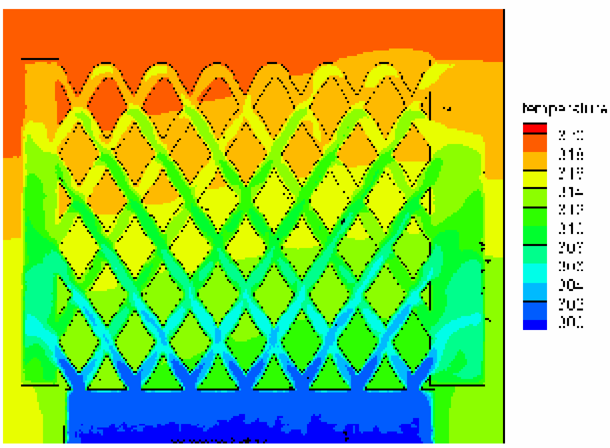
Fig.8. Temperature distribution of z=1.5 cross section

large temperature gradient in outlet plenums relates to the temperature magnitudes of the gas flows into the outlet plenum. There's a total trend of rising of the temperature in y axis direction.

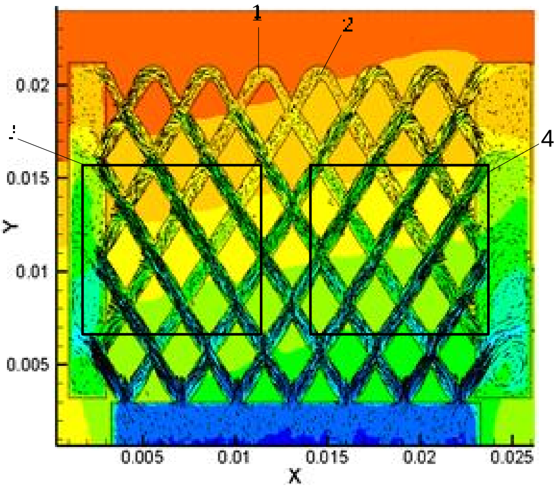

Fig.9. Velocity vector distribution on z=1.5 cross section

In figure 9 the velocity vectors are illustrated. The velocity magnitude near the inlet plenum is relatively high, while goes down as the gas flows toward the reversing area. The mass flow rate in channels without a reversing area is larger because the resistance is relatively much smaller. Two channels named 1 and 2 in the figure have extremely low mass flow, that's probably because the entrance of them locate at the two ends of the inlet plenum and influenced by the side wall. What's more significant, the channels linked to them leads directly to the outlet plenum without too much resistance, consequently gains more mass flow and reducing that in 1 and 2. Therefore the temperature near 1 and 2 is higher. Local vector distribution in zone 3 and 4 is specified in Figure 10.

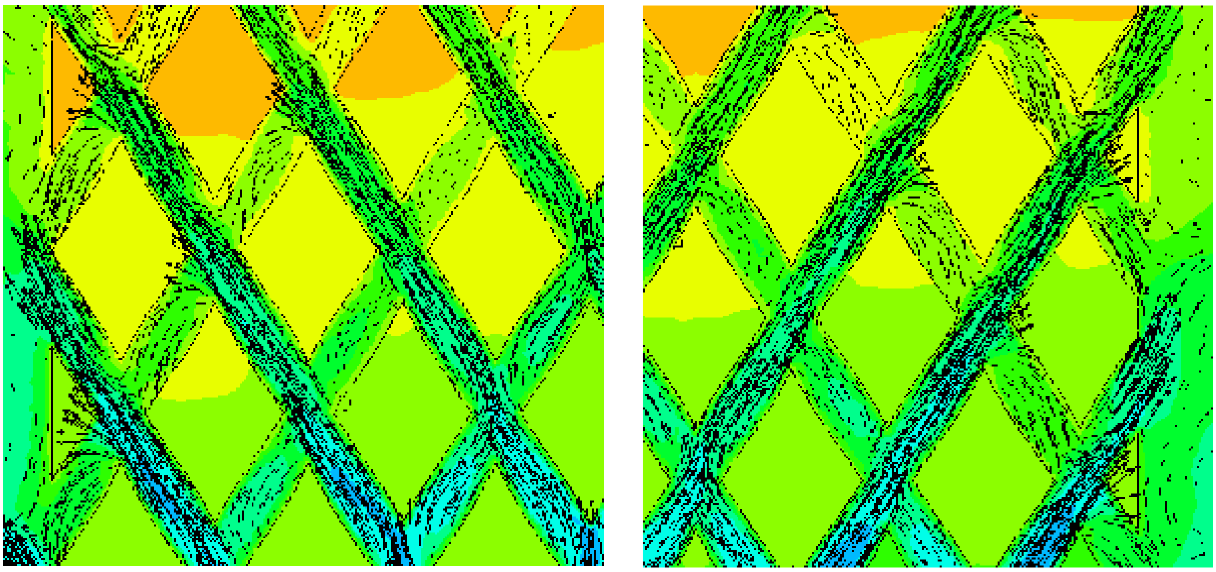

Fig.10. Local velocity vectors on z=1.5 cross section.

The vectors upwards in Figure 10 indicate the gas flow that has not jet encounters the reversing areas, while those down wide have confronted and head toward the outlet plenum. It is to be seen that some of the gas flow upward turns into the passage downwards and meantime some downwards goes up. So the direction change in the channels is a common phenomenon. What is certain is that the gas in all the channels flows from the inlet plenum towards the outlet plenum. In figure 9 it is found that the mass flow rate after reversing in channels increases as it passes each crossing till the arrival in outlet plenum.

Figure 11 illustrates the turbulent intensity of the cross section of z=1.5. It's obviously seen that the turbulence intensity of the gas flow gains a sudden raise at the crossings and falls again in the channel, varying regularly inside the channels. The 1 and 2 area in Figure 9 have relatively smaller turbulence intensity owing to the small mass flow rate. Besides, the turbulence intensity change at the crossings varies obviously. In case the directions of flow of

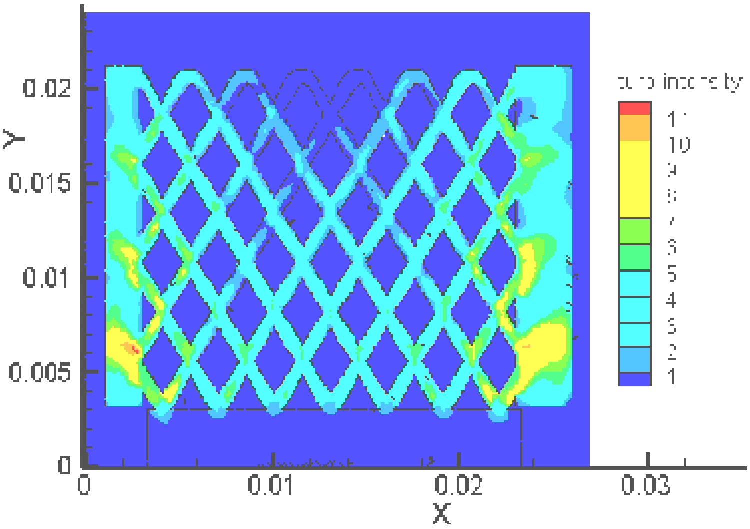

Fig.11. Distribution of turbulence intensity on z=1.5 cross section

two channels have a intersection angle of 60 degrees, the maximal turbulence intensity at the next crossing is definitely smaller than that of the last crossing. However, when the flow directions at the crossings have a intersection angle of 120, the maximal turbulence intensity at the next crossing turns out to be greater than the last one. In conclusion, the turbulence intensity of the gas flow at the crossings from inlet plenum toward the reversing areas becomes smaller and smaller, and that of the opposite direction gets gradually larger and reaches a peak value at the outlet plenum.

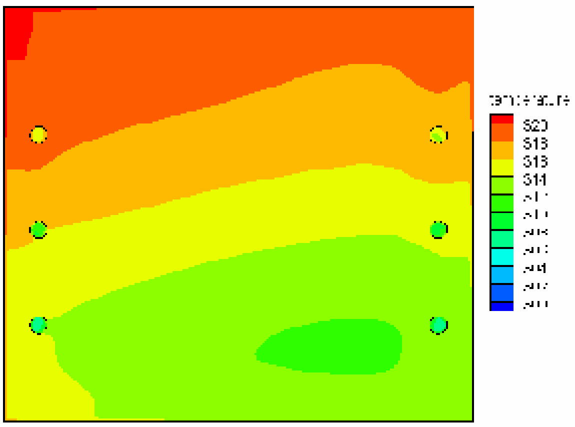

Fig.12.Temperature distribution of z=3 cross section.

Figure 12 shows the temperature distribution of the intersection of metallic wall and main flow, which is generally in accordance of that in figure 8. The total tendency is the lower area at right hand has a lower temperature while the upper area at left hand has a higher temperature. This is a result of the configuration of the model investigated. A single unit is investigated in this paper and no others exist in upstream or downstream. The high temperature main flow from upstream hits the metallic wall directly thus creating a high temperature. In contrast, the right hand part of the metallic wall has a relatively lower temperature as it’s protected by both the film holes at front and in the rear. Minimal temperature did not occur at the lower right, but a little upper left where the influence of inlet and outlet plenum both take effect. The high temperature in both the upper area and the main stream create the high temperature zone in the upper left.

Mean temperatures of the gas in six film holes are specified in figure 13. It can be perceived that the corresponding holes in the main flow direction have little difference in temperature, while the temperature of gas in holes connected to the same outlet plenum varies much. The gas in upper holes has higher temperature and its potential developed relatively better.

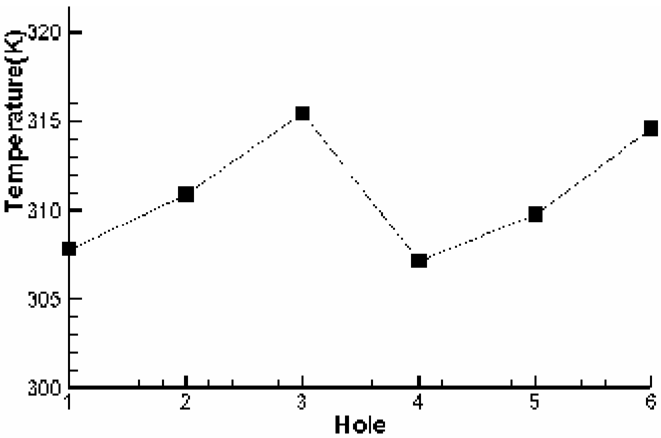

Fig.13. Mean temperatures of each film holes

Figure 14 illustrates the temperature distribution of the cross section in middle downstream of main flow, 0.5mm from the surface of the metallic wall. The temperature difference of the gas from film holes can also be observed in this figure. The affection of the cooler gas from the holes below sustains farther yet that of the upper holes lasts relatively short, consequently provides less protection from the thermal load. The holes in later positions have better performance due to the absence of other units and the boundary condition of adiabatic wall, what's more, the composition of the upstream and downstream coolant flow at the same time contributes to the longer effective distance in downstream. The well-bedded core area and dissipation area of the film hole protection further convinced the good convergence of the calculation.

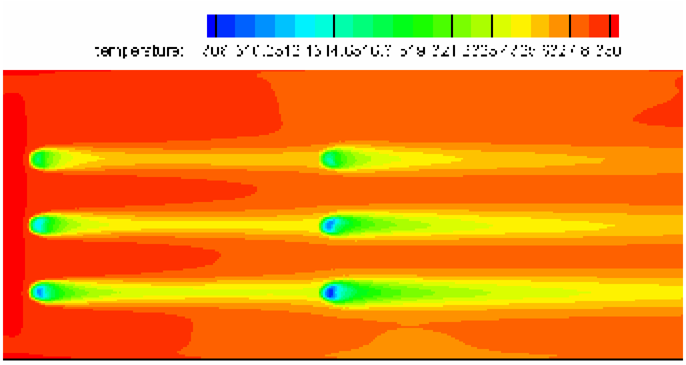

Fig.14.Temperature distribution of z=3.5 cross section

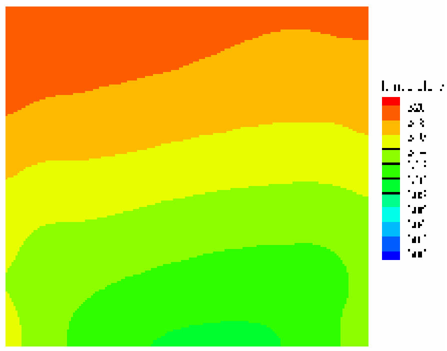

Fig.15.Temperature distribution of z=0 cross section

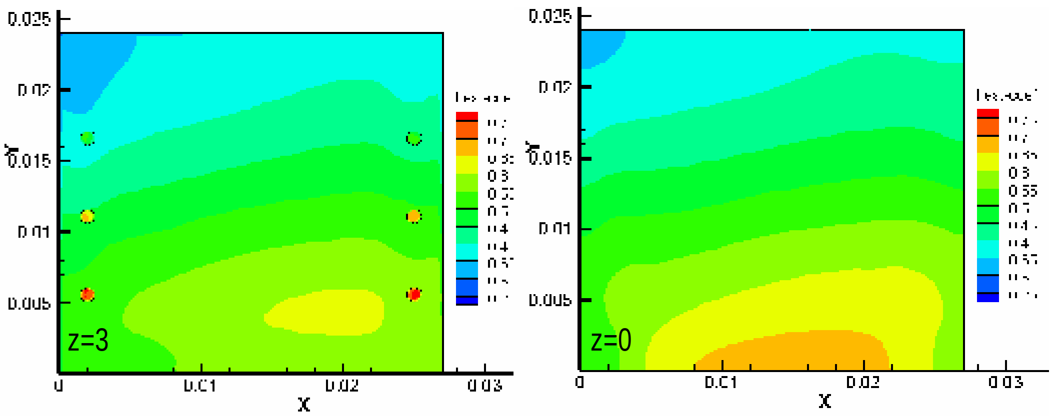

Figure 16: Cooling effectiveness distribution on two surfaces of the metallic wall

The temperature distribution of the bottom of the metallic wall is shown in figure 15. The boundary condition of this cross section is adiabatic wall temperature. In regard of the good heat conductivity of metal, the temperature distribution is approximate to the other two cross sections. As the influence of the film holes is weakened, cooling effect of the secondary flow into the inlet plenum appears clearer. As a result the lowest temperature appears at the foot, meanwhile the upper temperature distribution stays the same.

Table 2:Cooling effectiveness of wall under standard working condition of the unit

cross section	z=0	z=3	average
channels	0.504	0.482	0.493

4. Conclusion

The following conclusions can be drawn from the past calculation and analysis:

1. The secondary flow after passing the internal network channels in the wall performs more potential of the coolant. The cooling effect of such structure can be as much as three times of that with round film holes only, which has excellent cooling performance.

2. In the direction of the inlet secondary flow, the mean temperature and mean velocity magnitude of the gas out of the film holes successively increases. Meanwhile in the same direction the temperature of the metallic wall increases gradually.

3. Mixing appears at the crossings of the channels where change of directions of some flows take place. And the turbulence intensity augments at the interfering area, especially obvious when the intersection angle is an obtuse angle, which is beneficial to internal convective heat transfer.

The investigation in this paper indicates that the intersecting-grids composite cooling structure with internal network channels has pretty good cooling performance under calculation condition of normal temperature.

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To problem of engineering education quality in aerospace
(specialty "Aero-spatial control engineer")

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The computer-aided teaching process has increased the interaction between students and professors thus improving the learning process. The goal of courses for graduate students is to teach both a higher level of theoretical and methodological matters and how to design systems. This goal needs a project-based education that is an education performed while implementing a project. In the present paper, our project-based education deals with the implementation of an AFTCS (Active Fault Tolerant Control System) for a UAS (Unmanned Aerial System). The activity to be dealt with is twofold: one is of a methodological type and the other of a technical applicative type.

1. Introduction

The quality of education in engineering faculties greatly relies on computer-aided tools mainly applied to electrical, mechatronics and automatic control courses. The computer-aided teaching process has increased the interaction between students and professors thus improving the learning process for many students. Simulation software is often used as a replacement for experimental training of under-graduate students; this way they can highlight their own theoretical knowledge by performing different case-studies, yet they can acquire only a limited hands-on experience for some important reasons:

- the students cannot observe the influence of the real effects on tested systems;
- a few computer-aided tools deal with fault detection analysis and none of them with vibration analysis;
- all systems require a multidisciplinary approach to be designed, and this is particularly true for aeronautic systems since they deal with many technical areas of which the most important are: mechanics, aerodynamics, flight mechanics and automatic control.

On the other hand, the goal of the courses for under-graduate students is mainly to understand the way systems function, while the goal of the courses for graduate students is to teach both a higher level of theoretical and methodological matters and how to design systems. This educational goal cannot be reached only by means of classroom lessons and of computer-aided tools, but it needs a project-based education that is an education performed while implementing a project (Sivaselvan, 2011), (Grega, 1999), (Dormido et al., 2005), (Oliveira et al., 2011).

This method has several advantages since it leads to understand:

1. Which level of accuracy the model of the system to be designed must be, both as to the knowledge of its parameters and as to the knowledge of its interaction with the environment.
2. Which real problems the system functioning may present; in particular the possible faults, their importance and the modalities of the control reconfiguration.
3. The methodologies which make for solving the project problems as well as the advantages and disadvantages of each methodology according to the actual experimented situations.
4. The possible limits to a satisfactory solution of the examined problem; these limits may entail the need for improving the available methodologies or even the need for innovative approaches come to light by the results obtained in the early implementations.

5. How the application of the two previous points is important, from the point of view of a correct management of the project as well as its formative aspect since it leads students to understanding the requirements of the necessary technological innovations directly.
6. The real difficulties of the implementation and/or the acquisition of hardware and software components necessary to the realization of the project and the structural limits of the components themselves (data resolution capability, power computation, etc.).
7. Limits to the rules to comply with, both as to the safety of the operators and the surrounding environment.
8. The aptitudes of the students working in this project in the different areas (if they are more inclined to the aspects of methodological research or to the technical-operative ones, since both these aspects are widely present in the project development).
9. The possibility for the students of a given training to acquire direct competences also in the other technological areas involved in the project.
10. The most critical elements regarding the subsequent engineering of the project.
11. The possibility of upgrading the student industrial training (which is usually almost neglected by university educational curricula) mainly for students planning to attend a PhD degree; obviously, such an upgrading implies the involvement in the project of industrial partners and prescriptive bodies.

In the present paper, our project-based education deals with the implementation of an AFTCS (Active Fault Tolerant Control System) for a UAS. The activity to be dealt with is twofold: one is of a methodological type and the other of a technical applicative type.
In particular, an ultra-light aircraft demonstrator (namely an Ultra-pup Preceptor) is used and its technical preparation will include suitable procedures which lead to introduce actual faulty situations which are easy to be removed at a pilot’s command. In this a way it is possible to test the system without the risk of destroying the aircraft as often happens using aero-models.

2. Methodological activity

As to the methodological activity implied by the project-based education the main topics involved are the following.

2.1 Determining the model of the ultra-light aircraft’s demonstrator

This phase can be split into the following points:

- implementation of a linear model by means of classical methodologies for the determination of stability and control derivatives through the evaluation of the aircraft’s geometrical characteristics
- design, by means of the above mentioned first stage model, of the flight tests necessary to the identification (based on the actual flight data) of the aircraft’s real parameters; choice of the necessary instrumental equipment for the measurement of the variables to be used
- determination both of a linear model by means of the above mentioned parameters and of a non-linear model obtained by using aerodynamics coefficients.

The activities depicted in the previous points lead, on one hand, to understanding the validity fields of the different types of model, on the other hand, to understanding the interdisciplinary activities (in particular flight dynamics and control theory) in which each participant, in order to cooperate in the success of the project, has to acquire a good knowledge even in fields not directly experienced by him (Bertoni et.al., 2011).
Another important educational aspect of this phase of the project is verifying that the determination of an accurate non-linear model is almost unavoidable.
In fact, substituting the use of a non-linear model by means of procedures of gain-scheduling of linear models could be very difficult to be implemented due to the unmanageable

complexity that the FDD (Fault Detection and Diagnosis) project modalities would call for (Iserman, 2011).

2.2. Fault detection and diagnosis systems (FDDS)

The faults that can occur during aircraft flights are obviously manifold, but the most critical ones are those related to control surfaces and to engine (elevator, ailerons, rudder and lever).

As to fault identification procedures, until some decades ago, the only method available was the utilization of hardware redundancy, namely to employ a greater number of sensors of the same variable; it was then possible to use voting techniques in order to understand if a fault had occurred and in which component.

Yet, there is no doubt that, especially for small aircraft, and in particular for UAS, such a type of redundancy is very difficult to implement, both due to the lack of room onboard, and because of the great weight increase and the cost entailed. In recent years, therefore, the use of the so-called analytic redundancy (or software) has begun. This redundancy is implemented by utilizing a mathematical model of the system to be monitored so that the FDD obtained is referred to as a Model Based FDD (MBFDD).

Essentially, it can be said that the use of the hardware redundancy can be avoided taking into account the fact that an output variable of a system can contribute to the observability of different state variables of the same system. In other words the same variable is present in the measurements of different outputs and, then, what happens is as if the same variable was measured by different sensors namely in a redundant way without adding further sensors. In short an analysis of the faults can be obtained by exploiting the analytical relationship among the different variables of the process.

Figure 1 describes the concepts of hardware redundancy (upper part) and analytical redundancy (lower part).

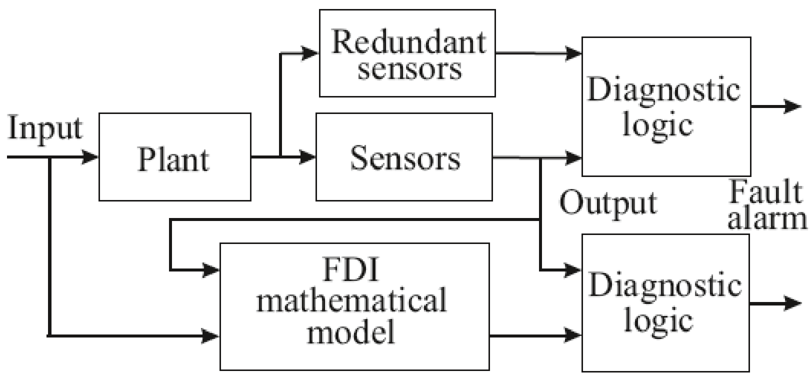

Fig.1. Hardware and software redundancy of an MBFD system.

By means of the analytical redundancy, it is possible to define some symptom signals, called *residual signals* or simply *residuals,* obtained by means of appropriate processing of the estimate of the output variables and of the measurement of these variables (Castaldi et.al., 2010). One of the most important problems in the choice of procedures aimed at the fault identification lies in the fact that the procedure itself proves to be robust as to the presence of disturbances, namely, in other words, that faults and disturbances turn out to be decoupled.

For this purpose the Air Navigation Laboratory in Bologna (see Appendix) has implemented new FDI (Fault Detection and Isolation) and FDD methods based on a nonlinear modelling (as aerospace systems often are) and on the use of methodologies based on differential geometrics.

In particular, the so-called Non-Linear Geometric Approach (NLGA) is used (De Persis et al., 2001), since, as far as the residual computation is concerned, it leads to a theoretically perfect decoupling between faults and disturbances by changing the system descriptive variables (Bonfè et al., 2009).

Obviously, in practice the disturbance rejection is not perfect, it is only robust. In fact, the most frequent method of diagnosis is monitoring the residual trend and taking a decision when the signal reaches a given threshold.
Such a method can be implemented without further hardware expenses, simply by using the on-board computer where the control algorithm is already present.
Figure 2 describes the ***topology*** of faults on a dynamic system. Faults on sensors, actuators and system components are indicated in it. Moreover, it is worth noting that measurement ***u*(t)*** of the ***plant*** input (namely of the variable really actuated) is supposed to be not available. This means that it is not possible to have a direct infor-mation of the presence of faults on the actuators since it would call for the introduction of additional hardware. Conse-quently, the information on the actuator's faults (modified by the system's dynamics) can be obtained only by the output variable ***y*(t)***.

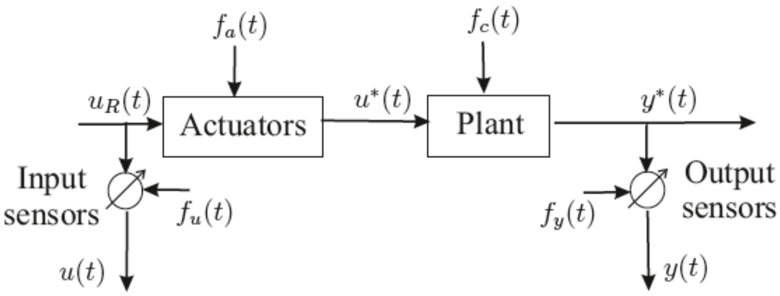

Fig.2. Topology of faults of a dynamic system.

As to the educational aspect of what above mentioned, it must be emphasized that the methodological themes involved deal mainly with very advanced topics of the system theory such as NLGA, simulators and estimators; as already mentioned this implies a deep involvement of all participants independently from their basic training.
In the full paper the results of the utilization of the FDD methodology proposed are reported, showing a bank of residual generators to perform the fault diagnosis and isolation with reference to the main actuators (elevator, ailerons, rudder, throttle) of the above mentioned ultra-light aircraft. Each residual will be sensible to only one fault on each actuator and decoupled from wind. The result of the comparison between the true faults and the estimated ones turns out to be very good.

2.3 Active fault tolerant control systems (AFTCS)
Figure 3 represents the basic diagram of an AFTCS. In this scheme the *characteristic* element is the FDD module (but also, simply, an FDI module); its information is utilized to reconfigure the controller so as to ensure satisfactory performances even when there is a fault.
In the event that an FDD module (not only FDI) is utilized, an $\hat{f}$ estimate of the f fault is available, so that an AFTC structure can be represented as in fig.4. It is worth noting that the AFTC scheme is obtained simply by ad-ding an $\hat{f}$ feedback loop without altering the NGC system (namely the Navigation Guide and Control already available on the air-craft) (Bertoni et al., 2009), (Bertoni et al., 2010).

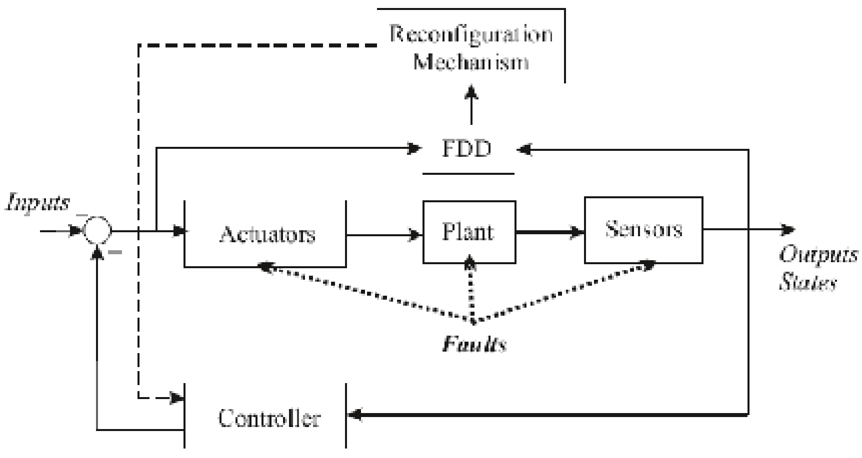

Fig.3. Control system resistant to faults by means of self-reconfiguration

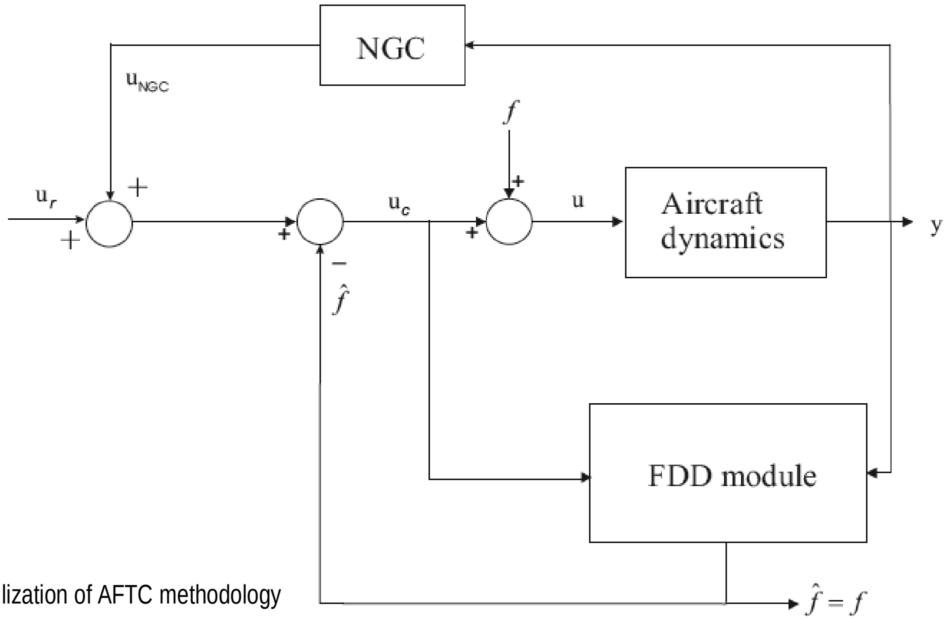

Fig.4. Utilization of AFTC methodology

Such a characteristic makes this scheme particularly appealing from the industrial point of view thanks to its *modularity.*

It is the case to point out the advantage that the AFTC system presents in terms of performance compared to merely robust systems (the so-called *Passive Fault Tolerant Control Systems,* PFTCS) which do not imply the control system reconfiguration in case of faults.

Also in this case, the ultra light aircraft will serve as a case-study showing the performances of the AFTCS when the above mentioned FDD system is the one implemented.

3. Technical activity

As to the technical applicative activity implied by the above mentioned project-based education, its main goal is to equip the demonstrator so as to be capable of managing the real-time problems which might occur during the autonomous flight.

In particular the demonstrator will be based on a platform having the following features:

- a two-seater aircraft in a tandem configuration of which one seat is for the pilot, who makes for the elimination of all the limitations of a ground-based remote control; the other seat can be used to house the payload represented by the avionics system which is to be developed and tested. In this case the payload could be increased up to 60-70 kilograms and over;
- the possibility that the aircraft has a pilot makes for reaching a distance of tenths of kilometers from the starting point so as to test the navigation variables in a reliable way. Moreover this aircraft is permitted to take off from any aerial surface or directly from the Forlì airport where the aircraft is housed;
- an ultra-light model aircraft does not have to comply with the strict aeronautic regulations related to the homologation and periodical compulsory maintenance;
- the periodical inspection on behalf of the aeronautical authorities (ENAC) to which the general aviation aircraft are submitted is not required; this is a great advantage as to time and costs;
- the NGC system which is being tested requires some configuration changes onboard the aircraft; in particular the instalment of servo-motors for the implementation of guidance and control laws interacting with flight commands; on an ultra-light aircraft this kind of instalment does not require official authorizations by ENAC.

Obviously an ultra-light aircraft has operational limitations in terms of maximum altitude, which however do not affect the planned experimentation.

4. The response of the students

As previously said, students who take part in this project share training which essentially concern the following fields:

– system theory and control with application to aircraft modelling, flight trajectory control and state variable transformation by means of NLGA;
– applied computer science to manage measurements and data;
– flight dynamics to determine stability derivatives and aerodynamics coefficients.

As the students say, the most difficult problem is the acquisition of the skills regarding disciplinary fields different from their own cultural background.

This acquisition is nevertheless greatly made easier by the fact that, for each topic (both methodological and applicative) the project is able to examine the behaviour of the case-study system in different situations (for example changing the initial conditions and input functions) thus increasing the comprehension of the occurred phenomena as well as the effectiveness of the implemented procedures.

An example of the efficiency of the adopted procedure is given by the change of the state variables of a system by means of NLGA. In this case it is easy to show that this procedure really implies the decoupling of disturbances (wind) and faults; in fact the residuals obtained this way are the same obtained by running a simulation where faults but not wind turbulence are present.

In conclusion it can be said that project-based education contributes to build a new figure of technician who could be defined an aero-spatial control engineer; in fact, the design of modern aircraft implies aerodynamics skills as well as automatic control and system theory ones. As a further example it is worth remembering that, in order to limit the weight of Airbus 380 wings, their shape is the result both of a proper stiffness of the mechanical components and of an active surface control.

5. Conclusions

The two most innovative points of project-based education presented in the paper are basically the following:

– the possibility for the students of a given training to acquire direct competences also in the other technological areas involved in the project;
– the definition of the limits of a methodology to give a satisfactory solution of the examined problem and, possibly, the need for upgrading the methodology chosen or for changing the methodology itself;
– the way to understand the influence of disturbances in the proposed methodology (that is its robustness) in order to avoid false alarm.

Further advantages of the project-based education are the evaluation of following items:

– computing power needed;
– the way to implement product engineering;
– limits of the available technology;
– limit to the rules to comply with.

6. Appendix

LASIM is a laboratory of the ARCES electronics research centre of the University of Bologna and it is dedicated to the investigation of automatic control systems applied to vehicle navigation and to positioning and telecommunications technologies. The application fields are mainly aerospace and land/surface vehicular navigation; infomobility and wireless position-based services are also subjects of experience for the laboratory.

The laboratory has performed many projects in collaboration with the Italian Space Agency (ASI), the Italian Ministry of Transportation, the Ministry of University and Research and relevant aerospace industries. These projects have been devoted to:

- automatic port approach and docking for ships;
- development of new ways to use Global Navigation Satellite Systems (GNSS) in civil aviation;
- exploitation of GNSS for vehicular traffic monitoring and control in urban environments and highways;
- airport surface traffic monitoring via 1090 MHz ADS-B Data Link;
- design and realization of a UAS avionics package.

Research activities of LASIM deal with Navigation Satellite-based position determination (GPS, EGNOS and other GNSS systems) and the design of automatic guidance systems.

Main expertise and activities of the laboratory are:

- Design and realization of an ADS-B based system comprised of:
  - a vehicular transponder (ADS-B transponder) for airport-surface traffic surveillance and monitoring;
  - an ADS-B ground station for fleet management;
  - a low cost ADS-B Traffic Collision Avoidance System for general aviation and ultra light aircraft.
- Design of a differential GPS ground station (GBAS), with three geo-referenced stations, that broadcast correction signals to be applied by GPS user receivers within a local area around Forlì airport in order to improve their position accuracy.
- Design of a positioning and attitude GPS-Inertial system for flying vehicles.
- Development and test of algorithms for satellite signal Integrity (RAIM-like algorithms).
- UAS project: realization of an Unmanned Aerial System (UAS) with autonomous guidance and navigation capabilities (flying capabilities without human pilot intervention).
- As to the demonstrator, it is going to be made up a two-seater (tandem configuration) ultralight aircraft Ultra-pup Preceptor, available at the Hangar housing the Forlì Aerospace laboratories of the II Faculty of Engineering of the University of Bologna. In this demonstrator, added to the usual navigation, guidance and control system, mechanical systems and proper procedures will be implemented in order to obtain real fault situations; it will thus be possible to test the effectiveness of guidance and control systems when fault occurs. This testing will result to be safe by the presence of a pilot onboard, who will be able to intervene in case of misfunctioning of fault tolerant control devices, thus avoiding the loss of the aircraft, as it often happens when using air models.
- Development of guidance laws and algorithms for tracking ground targets by means autonomous flying pursuers (e.g. mini UAV, quad rotors and others).
- Development of fault tolerant guidance systems with reconfigurable architecture and fail active behaviour.

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SCIENTIFIC CONFERENCE

Actual problems of Russian Cosmonautics

XXXVII Academic Conference on Cosmonautics
(Moscow, Russia, January 29 – 1 February, 2013)

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The 37th Academic Readings on astronautics devoted to the memory of Academician S.P.Korolev and other Russian scientists – pioneers of space exploration were held in Moscow on 29 January – 1 February 2013. They were traditionally organized by the Russian Academy of Sciences, Commission of RAS on development of heritage left by the pioneers of space exploration, in particular, together with the Federal Space Agency. The forum took place in the auditoria of N.E.Bauman MSTU with the active assistance of the University's administration and professors. Three sessions were held in the rooms accommodated by Khrunichev State Research and Production Space Center, NPO Mashinostroeniya and S.A.Lavochkin NPO.

More than 1500 participants attended the Readings. Each of twenty odd sessions was attended by 20-40 participants (reports, questions, attendance) representing RAS Institutions (ISR, Keldysh IAM, Ishlinskiy IMP, IMBP, Vavilov IHST, JIHT, Dorodnicyn Computing Centre), dedicated Research Institutes (Maksimov RI SS, Keldysh RC, "Agat", TsNIIMash, Research Institute of Parachute Design and Production, TsAGI, Kuznetsov RI AM, TsIAM), largest centers and manufacturers of the branch (S.P.Korolev RSC Energiya, NPOL, MITT, Glushko NPO Energomash, Khrunichev SRPC, TsSKB Progress, NPOMash, RSS, Gagarin CTC, VNIIEM Corporation, SPC Recod, Arsenal DB, branches of COSGBI: Barmin NIISK, Motor Design Bureau, universities (MSU, SPbSU, MPhTI, Ordzhonikidze MAI, MSTU, MPEI, A.N.Tupolev KAI, Ustinov "Voenmekh", MSARTU, Siberian SAU, universities of Krasnoyarsk, Chelyabinsk, Kazan, Samara, Orel, Smolensk, Omsk, and Volgograd), museum community (Moscow Space Museum, museums of Poltava, Zhitomir and Kaliningrad). Veterans' organizations and Children and Youth Creativity Centers, researchers from Vietnam, Portugal, Belarus, Ukraine, USA and Germany were among the participants.

New session No.22 named after Academician V.N.Chelomey is remarkable for its active work. Session 14 "Aerospace education and youth problems" comprised "Youth scientific projects", where students, postgraduates and professors submitted their projects. Round table "Man in space. Difficulties of overcoming. Veterans' recollections" was a twist of the 37th Readings. Lastly, the first meeting of the recreated Session 16 took place (results of space activity in socioeconomic development of Russia).

It is worthy of note that the head of Federal Space Agency spoke at the opening ceremony for the first time in a long period and it was not a brief speech of welcome, but a comprehensive illustrated report on the prospects of rocket-and-space branch developing on the basis of strategic proposals submitted by scientific community allowing for the benefit of the Ministry of Defence and international commitments of Russia. V.A.Popovkin gave a detailed account of the current state of space grouping and its prospects (95 spacecrafts by 2015, 113 – by 2020), emphasized "lunar", not "martian", priority of manned not-near-Earth Program. He recalled the experience of extensive inter-branch cooperation within the framework of Energiya-Buran Program (the flight of super rocket and Soviet shuttle will turn 25 this autumn).

Rector of MSTU A.A.Alexandrov opened the conference speaking briefly of the educational infrastructure in MSTU. Afterwards, Academician V.P.Legostayev, scientific supervisor of the Readings, told about the Readings' history. Six papers of the plenary session dealt with the jubilees of leading space organizations and scientists. Three papers concerned the developments performed at Academician V.P.Makeyev State Rocket Centre (city of Miass), Moscow Institute of Applied Mathematics and Research Center (the last two named after Academician M.V.Keldysh). Three other papers covered scientific and managerial activity of Academicians B.N.Petrov, V.I.Kuznetsov and A.F.Bogomolov (each of them turn 100 this year).

The work of sessions was traditionally active. The latter can be classified into three categories (directions):

1) analysis of basic scientific problems in application to the development of rocket-and-space activity – sessions 4, 5, 7, partly session 17;

2) research in certain scientific and technological areas, specific projects and developments – sessions 2, 3, 11-13, 15, 17-29, 21;

3) humanities (including history, economics, ecology, culture) – round table, sessions 1, 6, 8-10, 14, 16, partly session 22 (history of projects).

Perhaps, the fact that the second, "practical", direction was the most comprehensive one caused the interest to its sessions.

Some facts and evaluation of a number of sessions

Session 4 (space power engineering) – 25 papers considered the urgent issues of power system of the country on the whole, development of solar and chemical power sources for spacecrafts, system of current conversion, wireless power transmission in space over large distances. Besides, authors showed that it is possible to use different types of electrojet engines for space flights, considered the characteristics of processes in such engines.

Clear practical orientation was characteristic of papers that dealt with power and propulsion system of a small spacecraft, a vernier engine for promising spacecrafts of remote Earth sensing, inner/outer short-circuit protection of chemical current sources. The authors took part in development and testing of these objects.

Development of a demo prototype of 100 kW laser space solar power station on the basis of a solar array intended for power transmission to the Earth was considered. It was suggested that a centralized system of predictive monitoring of technical condition and emergency protection of Russian power system using the achievements of Russian space engineering should be developed.

Postgraduates and students presented 4 of 5 papers of Session 3 (engines). The number of young participants of session 5 (celestial mechanics) has grown (12 papers were delivered by students and young researchers). Their keen interest was evident through the reports on asteroid danger, means of reaching asteroids, inspection of asteroids. Attention was paid to papers on new methods of building the systems of ground surveillance using multilayered observation systems, on introduction of geometrical method of building the systems of periodical survey, on the ways to fly to the Moon using chemical engines and low thrust engines.

18 of 26 papers of Session 18 (unmanned spacecraft) were delivered by young scientists and specialists. Paper on detection and identification of radiation component of space debris in

near-Earth space was prepared by the young scientists of National research nuclear university “MEPhI”, VNIIEM Corporation, Institute of Astronomy.
Original materials of Session 6 (historical) were submitted by L.N.Tararin (NPOMash) and S.I.Pernitskiy (Gromov Flight Research Institute). The latter takes part in the development and testing of Bor-4 aerospace vehicle, the first orbital flight of which aimed at marginal testing of thermal protection of Buran orbiter was performed on 4 June 1982. A controlled flight in the atmosphere within the whole range of velocities (from orbital to supersonic) was fulfilled for the first time in Russia. There were 5 flights of Bor-4 program: one suborbital flight and four orbit ones according to the main routine program.
L.N.Tararin devoted his presentation to the 40th anniversary of the first flight of Cosmos-881-882 vehicles. In his paper on return space vehicle of CDBM he noted that in conditions of “lunar race” with the USA V.N.Chelomey proposed an outrunning manned circumlunar flight to be performed using a spacecraft developed by OKB-52 (Design Bureau 52). The spacecraft incorporated a single-seat capsule-type manned return vehicle, which was designed to reentry after its lunar flight. It was in 1964 when the Soviet Union started the development of its first military manned orbit station S-1 (Almaz). A cargo resupply vehicle included a return vehicle, the construction of which was tested in ten unmanned orbit flights. Two vehicles performed two space flights each.
Session 7 was reflective of two characteristic trends: integration of basic and applied research to solve the problems of gas dynamics, combustion and heat transfer associated with operation and improvement of existing spacecrafts and development of new ones; strengthening of relationships between design organizations, academic and educational institutes.
Session 12 (launch systems) considered practical issues: try-out of 200-tonne-thrust launcher’s gas dynamics on small- and medium-scale models; results of the research of Soyuz rocket’s launch facilities with various vent depth; analysis of schematic variants of a tank for new promising rocket propellants.
Paper “Control of supersonic streamlining of a multiunit launcher aimed at reduction of maximum heating” (A.S.Kudinov, I.I.Yurchenko, I.N.Karakotin) of Session 13 is valuable because it is based on calculations and experimental research, therefore the obtained results are of high practical importance. The Session supervisors highly appreciated a group of students from Korolev SSAU, who submitted their paper at high scientific level.
According to the supervisors of Session 14, 33 presentations were made on “Aerospace education of youth” (more than 130 participants). Student projects of ultra-small spacecrafts (V.I.Mayorov, A.S.Popov) can be applied both in space and on earth to teach design to students, to make presentations of scientific works, to try-out conference presentations, to prepare scientific papers. The same Session considered A.V.Morozov’s paper on the development of personnel qualimetry and selection. He believes that such a model of assessment of qualification level according to a new state educational standard allows identification of both a qualification of graduates according to main educational programs and a maturity of social and professional clusters on the basis of educational standards of EUR-ACE of European Network for Accreditation of Engineering Education.
Scientists from NPO Technomash submitted their results on diagnostics of technology equipment for machinery in Russia at Session 19 (rocketry construction). The main conclusion is that new equipment imported in Russia is rather imprecise, which is typical of developing countries. Improvement of technological processes in rocket engineering was covered by young specialists, postgraduates and students of Bauman MSTU. Besides, MSTU students presented their results in friction welding, behavior of thermally insulated pipes and meteorite shield of spacecrafts.

Representatives of IMBP RAS were dominant at the Session of medical and biological problems (No.20). About fifteen presentations dealt in particular with the methods of control of microbiology situation on board space stations, research of ISS means and methods of leak detection caused among all by microdegradation of pressure hull. The conclusions are of critical importance for safe extraterrestrial human activity.

Session 22 ("Chelomey's"), which was a new one at the Readings, allowed discussion of NPOMash history, little-known facts about the projects of 1960-1980 and presentation of educational programs intended for young specialists of NPOMash. By the way, new "Yarkiy Sled Krylatogo "Meteorita" ("Bright trail of winged Meteorite") book was presented in Reutov.

Conclusions and suggestions

1. Academic Readings keep proving themselves as a leading event among the scientific forums of this direction held in Moscow, Gagarin, Kaluga, Samara. Being complex, the Readings allow combining thorough theoretical research and hypotheses with search in the history of the branch and science, with discussion of practical projects, suggestions concerning improvement of equipment and systems, the development of economics and benefits from space activity, with important topics of humanitarian, general civilization orientation.
2. Prominent scientists (including those from RAS) participated in the Readings and supervised the sessions, raising the level of the event and allowed gaining the information on new developments, and theories and significant projects, change of some views on goals and tasks of space research from the primary source, bringing the audience (first of all the young participants) nearer to the high standards of analysis and generalization.
3. The total number of universities participating in the forum at MSTU has grown. It makes the session supervisors be more careful of the quality of papers and strict to young participants' proceedings. The supervisors should also awake interest in participation on the part of universities, higher schools and educational centers that have not taken part in the Readings so far.
4. It should be noted that the growing number of active participants of the Readings resulted in the extended content of the conference proceedings. The 30th Readings' proceedings numbered 488 pages, the 35th ones were 628 p., and the present are already 650 p. The Session supervisors are encouraged to promote publication of the best works in transactions, mass media, etc.
5. It was suggested that the laureates of Junior Readings on astronautics (held in Memorial Cosmonautics Museum) should be invited to the plenary session. They will be able to breathe the air of major problems and communicate with veterans, designers, scientists, gaining an impetus to extend their knowledge.

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А.А.Баренбаум. Галактоцентрическая парадигма в естественных науках, часть II.
Е.В.Горбенко. О разработке новой схемы воздушного старта.
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НАУЧНО-ИНФОРМАЦИОННЫЙ РАЗДЕЛ

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