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USSR Report

SPACE

(FOUO 4/81)

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MANNED MISSION HIGHLIGHTS

MONOGRAPH BY NIKOLAYEV ON COSMONAUT TRAINING AND SPACEFLIGHT

Moscow KOSMOS--DOROGA BEZ KONTSA in Russian 1979 (signed to press 20 Jul 79) pp 2-5, 240

[Annotation, foreword for second edition and table of contents from book "Space--a Road Without End", by Andriyan Grigor'yevich Nikolayev, maj gen avn, pilot-cosmonaut of the USSR, twice awarded the title of Hero of the Soviet Union, ("Lyudi i kosmos" [People and Space] series, Book 3), 2d edition, enlarged, Izdatel'stvo "Molodaya gvardiya", 100,000 copies, 240 pages, illustrated]

[Text] This pilot-cosmonaut of the USSR, Major General in Aviation, who was awarded the title of Hero of the Soviet Union twice, tells in his book about the training of cosmonauts for long-term flights in space, about his flights aboard Vostok and Soyuz spacecraft, about the work of the crews of spacecraft and stations in orbit. In the final chapter, the author has a conversation with the reader about a new occupation, that of cosmonaut. The first edition of this book was awarded first prize in the competition imeni N. Ostrovskiy.

Foreword for Second Edition

Time is passing uncontrollably and intensively. It would appear that it was not so long ago that we were admiring the flight of the world's first artificial earth satellite, and now the third decade of the space age has begun.... A new generation of people has grown up. The boys and girls who were born the year of the launching of the first satellite have graduated from school and have started on the broad, work-filled path of life.... Our manned cosmonautics has also traveled over an enormous road in these years: From the world's first space voyage of Yuriy Gagarin, which lasted 108 minutes, to the many months of work in orbit of Vladimir Lyakhov and Valeriy Ryumin. From the first Vostok spacecraft to orbital laboratory-stations, outfitted with thousands of unique instruments, complicated units, scientific research equipment, that could be envied by ground-based scientific institutions. From the first visual observations of earth's surface to in-depth scientific research and experiments that are conducted in orbit in the areas of astronomy and meteorology, geodesy and cartography, geology and hydrology, medicine and, finally, industrial technology.

In the 18 years of manned cosmonautics more than 90 people have been in space: 45 Soviet cosmonauts, 43 American astronauts, 1 cosmonaut each from CSSR, Poland, GDR and the People's Republic of Bulgaria. The total time spent by people in space is more than 5 years.

Each space flight is unique and inimitable. When telling about any flight, one can boldly use the term, "for the first time." Each flight adds something new to the development of cosmonauts, and makes it possible to take one more step.

Yuriy Alekseyevich Gagarin performed the first space flight in the history of mankind. He proved that man could live and work in space. German Titov was the first to make a 1-day flight in earth's orbit. Pavel Popovich and I were the first to make a group flight in two spacecraft. Valentina Vladimirovna Tereshkova was the first woman to fly in space. Valeriy Bykovskiy was the first to fly for 5 days. The crew of Voskhod, consisting of Vladimir Komarov, Konstantin Feoktistov and Boris Yegorov, were the first to test a multipassenger spacecraft, and for the first time, a scientist-cosmonaut and physician-cosmonaut flew in space together with the pilot-cosmonaut. Aleksey Leonov was the first man to exit from a spacecraft in orbit and engage in extravehicular activity. Neil Armstrong and Edwin Aldrin were the first American astronauts to step on the surface of earth's natural satellite, the moon. For the first time, an international experiment was conducted on the ASTP program, etc., etc.

Today, as we tell about the new space flights, we use, again and again, these words, "for the first time." When the Salyut-6 was put in orbit with two docking units, the orbital station was serviced simultaneously by two crews for the first time. For the first time, vital products, new instruments, spare parts and fuel were delivered to the station by a space "truck." For the first time, international crews consisting of pilot-cosmonauts of the USSR and socialist countries (CSSR, Poland, GDR, People's Republic of Bulgaria) departed to work in space.... And we could continue on with this list of what has been done for the first time.

However, many elements of space flights are also typical, repeated from flight to flight. All cosmonauts undergo rather lengthy training for flights. Waiting for a scheduled lift-off is exciting for everyone. The cosmonauts experience abut the same sensations at the moment of lift-off and insertion of a spacecraft into orbit. We all have to work in space under the same conditions of long-term exposure to weightlessness, the small cabin or station, without direct contact with the rest of the people. Each of us cosmonauts, who have worked for a long time in orbit, must undergo a rather lengthy and difficult readaptation process, i.e., readjustment to conditions on the ground, to earth's gravity.

It is about these elements in common, inherent to any space flight, that I should like to talk in my book.

Its first edition was published 5 years ago. A received an enormous number of thank-you letters from young (and not only young) readers.

At the request of the "Molodaya gvardiya" publishing house, I have prepared a new edition. There have been so many events, pertaining to the exploration and exploitation of space in 5 years, that I have had to enlarge the book with new data and reinterpret the experience gained through the flights.

Much of what I wrote about hypothetically 5 years ago has now become reality. And it will always be so. Cosmonautics will never stop in its aspirations for new deeds. For expressly this reason, I called my book "Space--a Road Without End."

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CSO: 1866/999

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MONOGRAPH ON MANNED FLIGHTS IN 'INTERCOSMOS' PROGRAM

Moscow KOSMICHESKOYE SODRUZHESTVO in Russian 1980 (signed to press 28 Mar 80) pp 4, 181

[Annotation and table of contents from book "Collaboration in Space" by V. A. Alekseyev, L. A. Gorshkov, A. A. Yeremenko and A. V. Tkachev, Izdatel'stvo "Mashinostroyeniye", 30,000 copies, 181 pages, illustrated]

[Text] This book deals with one of the most important directions of collaboration of socialist nations in the study and use of space for peaceful purposes on the Intercosmos program of manned flights by international crews. The reader will find here information about the equipment developed in the Soviet Union and used during the flights of the space crews on the Intercosmos program.

The book chronicles the flights of space crews consisting of Soviet cosmonauts and cosmonauts from CSSR, the Polish People's Republic, GDR and People's Republic of Bulgaria; it tells about the scientific technological experimental studies conducted on joint programs. The significance and prospects of international collaboration in the field of manned space flights are demonstrated.

This book is intended for a wide circle of readers.

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TWENTIETH ANNIVERSARY OF GAGARIN'S FLIGHT: A COLLECTION OF ARTICLES

Moscow 20 LET POLETU GAGARINA: SBORNIK STATEY in Russian 1981 (signed to press 23 Mar 81) pp 2-7, 64

[Annotation, compiler's note and table of contents from book " Twentieth Anniversary of Gagarin's Flight: A Collection of Articles", compiled by Vladimir Iosifovich Prishchepa ("News in Life, Science and Technology." "Cosmonautics and Astronomy" series, No 4), Izdatel'stvo "Znaniye", 28,640 copies, 64 pages]

[Text] This collection is dedicated to the 20th anniversary of an outstanding event in the history of mankind, the first flight into space made by Yu. A. Gagarin. The articles it contains tell about the role of S. P. Korolev in preparations and performance of the first flight into space, the history of establishment of the Cosmonaut Training Center, inception and development of space medicine, a discipline whose history is inseparably linked with manned space flights.

This pamphlet is intended for lecturers, propagandists and a broad circle of readers.

Compiler's Note

On 12 April 1961, history's first manned flight into space was initiated in the Soviet Union. The spacecraft, Vostok, with pilot-cosmonaut Yu. A. Gagarin on board, entered into a near-earth orbit.

The spacecraft, which weighed 4725 kg, was launched from the Baykonur spaceport at 0907 hours Moscow time; it attained an orbit at an altitude of 181 km in perigee and 327 km in apogee, with an inclination of 64°57'. Throughout the period of injection of the spacecraft, the cosmonaut was in radio telephone communication with the ground-based mission control center. He distinctly confirmed the times when G forces changed, separation of carrier rocket stages and, after ejection of the nose cone, he reported his first observations of earth from space.

After insertion into orbit, a state of weightlessness appeared, and the cosmonaut soon adjusted to it. The entire flight program, which included monitoring the instruments and equipment of the spacecraft, observation of earth and the stars, as well as intake of food and water, was accomplished by Yu. A. Gagarin. He reported the results of his work to earth, entered them in the log and recorded them on tape. At 1015 hours, when Vostok was approaching Africa, the cosmonaut reported that all systems were operating well and the automatic systems of the spacecraft issued the command to prepare for landing. Ten minutes later, the rocket brakes were applied, the spacecraft moved into the descent trajectory, and the descent module with the cosmonaut separated from it. Yu. A. Gagarin landed on USSR soil at 1055 hours.

The first manned space flight lasted 108 min, and these minutes shook the world. The address to the Soviet people, to the people and governments of all nations, made by the Central Committee of the CPSU, presidium of the USSR Supreme Soviet and Soviet government stated that the flight of Yu. A. Gagarin is an unprecedented victory of mankind, the greatest scientific technological achievement and representation of the powerful force of socialism. The feat of the first cosmonaut became the feat of our entire people, the outstanding result of selfless years of work by large teams of scientists, designers, testers, engineers, technicians and blue-collar workers.

Let us recall the main events directly preceding that notable day in April. In the middle of 1946, the party and government made the historical decision of developing a powerful rocket-building industry in our country, for which large funds, material and manpower were allocated. Within a short period of time, existing scientific research institutes, designer bureaus, plants and testing sites were expanded and new ones produced; the institutes of the USSR Academy of Sciences and other scientific centers were involved in solving the problems. Through the joint efforts of all these organizations, a guided ballistic rocket with a range of several hundred kilometers was developed in the USSR In the late 1940's.

High-altitude geophysical rockets outfitted with scientific equipment were developed on its basis. A program of research on the upper layers of the atmosphere started to be implemented with their use starting in 1949. Soon after this, in 1951, the first rocket with living things--two experimental dogs--was launched.

In 1955, it was decided to build a new testing site in the Kazakhstan steppes, the future Baykonur, for launching high-power rockets. On 21 August 1957, there was a successful launching of a ballistic rocket with a range of several thousand kilometers. On 4 October of the same year, the world's first artificial earth satellite, which inaugurated the space era of the history of mankind, was launched, in the form of a modified variant of that two-stage rocket, which was named Sputnik.

This launch confirmed the validity of solutions to such problems of space flight as creating a sturdy and light construction of the carrier rocket, high-power energy-efficient liquid-propellant rocket engines, developing compact precision systems for controlling the flight, etc. The USSR Academy of Sciences mentioned the special role of S. P. Korolev--chief designer of space rocket systems, V. P. Glushko--chief designer of rocket engines, and N. A. Pilyugin--chief designer of carrier rocket control systems, in solving the above problems. The first gold medals imeni K. E. Tsiolkovskiy, "For Outstanding Work in the Field of Interplanetary Travel," were bestowed upon them.

After the first, "simplest satellite," an experimental dog was delivered into near-earth orbit on the second satellite, in 1957. In this experiment, some valuable data were obtained on the effects of long-term weightlessness and other space flight factors on a living organism. At the start of 1960, there were already several artificial earth satellites and automatic stations in space. Everyone waited for man to go there.

The launching into space of man, rather than an automatic vehicle, required solving several cardinal problems. It was necessary to assure the cosmonaut's safety in case of malfunction of carrier rocket systems, to protect him against the environment and assure normal vital functions in orbital flight, reliable operation of equipment in space and, finally, a safe descent of the spacecraft in a specified region to return to earth. In the course of solving all these problems, five satellite spacecraft were launched into space, in four of which there were dogs and other experimental beings.

These satellites were launched with a modified Sputnik carrier rocket with an additional, third stage (subsequently, this three-stage variant of the carrier rocket was named Vostok). The liquid-propellant rocket engine in this stage was developed in the experimental design office of S. A. Kosberg. The retrofire rocket [engine] designed in the experimental design office of A. M. Isayev was used to return the spacecrafts from near-earth orbit to the descent trajectory.

In 1959, before launching the sallites, work began on the screening and training of the first crews for manned spacecraft. The pilot, Yu. A. Gagarin, who had graduated from a military flying school in 1957, was among the many thousands of cosomonaut candidates. It was his fate to be the first man to rise into space.

This pamphlet, which is dedicated to the 20th anniversary of the flight of Yu. A. Gagarin, consists of articles by four Soviet specialists who were directly involved in preparations for this flight. The collection begins with the article of B. V. Raushenbakh, a prominent scientist in the field of cosmonautics, who specializes in control of carrier rockets and space vehicles. Demonstrating the outstanding creative contribution of S. P. Korolev to the solution of the problem of manned space flights, this author also shed light on the main technical problems that had to be solved by Soviet scientists and engineers, the developers of space rocket technology.

The second article was written by Ye. A. Karpov, one of the first organizers and first head of the Cosmonaut Training Center. This article, which is written in the form of a lively story, gives us an idea about the "routine" difficulties that were encountered in creating this center, in screening and training the first cosmonauts, and how these people came to be.

The collection ends with the extensive article by N. N. Gurovskiy and A. D. Yegorov, who witnessed the inception and were among the first representatives of space medicine. This article tells us about the development of this new branch of science, which was born to ordinary terrestrial medicine and absorbed the advances of the most diverse branches of natural science and engineering.

At the end of the pamphlet, there is a list of all of the manned space flights made in the USSR. Starting with Yu. A. Gagarin, 49 Soviet cosmonauts have been in space, and with them 7 cosmonauts from socialist nations. There have also been 43 cosmonauts from the United States in space.* N. Armstrong, the first earthling to step on the moon, in giving credit for the feat of Yu. A. Gagarin,

*These data apply up to 1 January 1981.

wrote the following words in the "Book of Memory" at the museum in the village of Zvezdnyy: "He called all of us into space!" This is a profoundly symbolic statement.

Very recently, our country made a new conquest in the exploration of space. The Soviet cosmonauts, L. I. Popov and V. V. Ryumin were on a flight that lasted 185 days. They worked for almost all of this time aboard the Salyut-6 orbital station, which has been in earth's orbit for more than 3 years. This station was guided into space by the high-power three-stage Proton carrier rocket, which was developed under the guidance of V. N. Chelomey.

A large volume of information was gained on natural resources of earth and the environment in the course of the longest manned space flight. Considerable time was spent on experiments on space materials technology, as well as astrophysical, technical and biomedical experiments. The advances in exploration of space are a substantial contribution to development of science and national economy of our country, and they became a worthy gift for the 26th CPSU Congress.

The "Main Directions of Economic and Social Development of the USSR in 1981-1985 and for the period up to 1990," approved by the 26th CPSU Congress, provide for continued investigation and development of space in the interests of science, technology and the national economy. Of course, manned space flights hold an important place in implementing this program. This is evidenced by the launching of Soviet cosmonauts right after conclusion of the 26th CPSU Congress, on the eve of the 20th anniversary of the flight of Yu. A. Gagarin.

On 12 March, at 2200 hours Moscow time, Soyuz T-4 was launched into space, with cosmonauts V. V. Kovalenok and V. P. Savinykh on board. After docking with the Salyut-6 station, the cosmonauts started on the work watch of the 11th Five-Year Plan. And on 22 March, the eighth international crew was guided into orbit around earth, aboard Soyuz-39, in accordance with the Intercosmos program, consisting of V. A. Dzhanibekov (USSR) and Zhugderdemidiyn Gurragcha (Mongolian People's Republic).

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SPACE SCIENCES

FRANCO-SOVIET ARCAD-3 MAGNETOSPHERE EXPERIMENTS

Paris AIR & COSMOS in French No 869, 18 Jul 81 pp 53-54

[Article by Pierre Langereux]

[Text] The Soviet Arcad-3 satellite, which is to be launched on or after 20 August, by the USSR, is, up to now, the most ambitious production of Franco-Soviet cooperation. This satellite, constructed and operated jointly by CNES [National Center for Space Studies] and INTERCOSMOS, is intended for the Franco-Soviet ARCAD [Arctic Auroral Density] program for studying the physical phenomena of the polar magnetosphere at high latitude (60°) and especially the relationships between the atmosphere and the magnetosphere.

The Arcad-3 program, officially decided on in October 1974 at Kiev (USSR), was established in Marseilles (France). It is a continuation of the French Arcad-1 and 2 experiments onboard Soviet Aureole-1 and 2 satellites, launched on 27 December 1971 and 26 December 1973, respectively, by the USSR. Arcad-3 was to be launched originally in mid-1979, within the framework of the International Magnetosphere Study (IMS), which took place from 1976 to 1979 with the launching of several satellites (GEOS-1 and 2, ISEE-1, 2 and 3), rocket probes (Subtorm, Ipocamp-3, Porcupine programs) and stratospheric balloons (Sambo-2 program).

Arcad-3 is the first satellite actually produced jointly by the USSR and France, which devoted 26 million francs to the operation.

It is a satellite in the "Soviet universal automatic stations" (AUOS) series developed in two versions depending on the missions: the AUOS-T oriented toward the earth and the AUOS-S oriented toward the sun.

The AUOS-T satellite in the Arcad-3 program is a satellite stabilized on the three axes by gravity gradient and magnetic anchoring, with two inertia wheels in addition. It weighs close to 1 ton, including 150 kilograms of scientific payload, consisting for the most part (around 100 kilograms) of French equipment. This equipment includes the scientific experiments, as well as important service equipment: an infrared horizon sensor (SODERN) for altitude control, a CN2B onboard computer (Crouzet) for controlling the satellite and a 136-megahertz telemetering system (EEE) for direct transmission of data from the French experiments to France. It is the first time that a Soviet satellite carries that kind of French equipment.

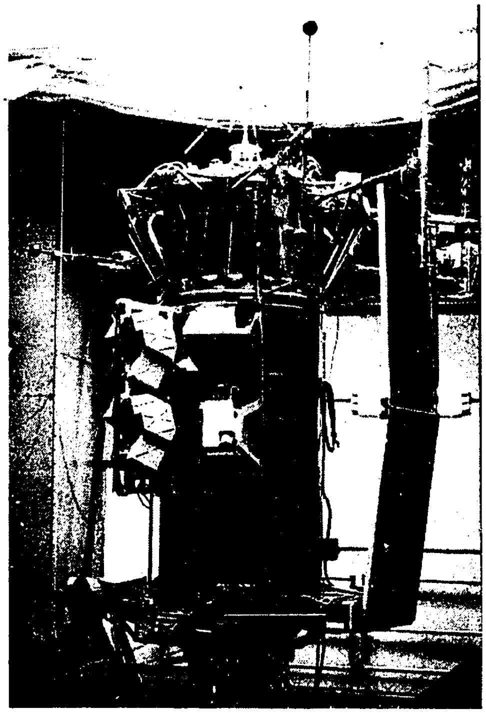
Arcad-3 is to conduct about 10 scientific experiments determined by three French laboratories--the Center for Study of Radiation in Space (CESR) in Toulouse, the Environment Physical Research Center (CRPE) in Orleans and the External Geophysics Laboratory (LGE) in Saint-Maur--in addition to two Soviet laboratories: the Space Research Institute (IKI) in Moscow and the Magnetism and Atmosphere Institute (IZMIRAN) in Moscow.

Certain experiments are devoted to a study of charged particles (Spectro of CESR, FON, Kukuchka and Pietschanka of the IKI) and in particular of electrons (Isoprobe of the CRPE), ions and thermal plasma (Dyction of LGE). Others concern a study of the magnetic and electrical fields of very low frequencies (TBF of CRPE, LGE and IZMIRAN) and fluctuations of the magnetic field (TRAC of LGE and IKI), as well as a photometric analysis of the aurora borealis (ALTAIR of the IKI).

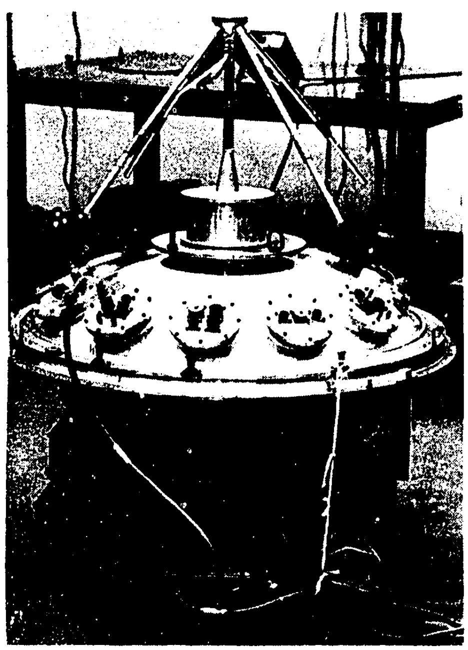
This is the first time that the payload of a Soviet satellite has been assembled jointly and the integration of the complete satellite has been conducted jointly by French and Soviet specialists, in France and in the USSR.

The Soviet satellite underwent space environment and electromagnetic compatibility tests in 1979 and 1980 in the facilities of SOPEMEA in the Toulouse space center. The acceptance tests of the satellite were conducted primarily at Toulouse and Moscow. Finally, the whole payload underwent detailed tests, in May 1981, in the IKI before being incorporated in the satellite by the Kapustin-Yar space-launching site near Volgograd by French and Soviet specialists. Next, Arcad-3 was sent to the top secret north launching field, located near Plesetsk, at about 200 kilometers from Arkhangelsk, where the launching will take place, because Arcad-3 is to be placed in a 400-2,000-kilometer circular solar orbit, inclined 82.5° with a period of 109 minutes. Then, the French teams will return to Moscow where they will receive magnetic tape recordings of the latest tests conducted at Plesetks where the French are not admitted.

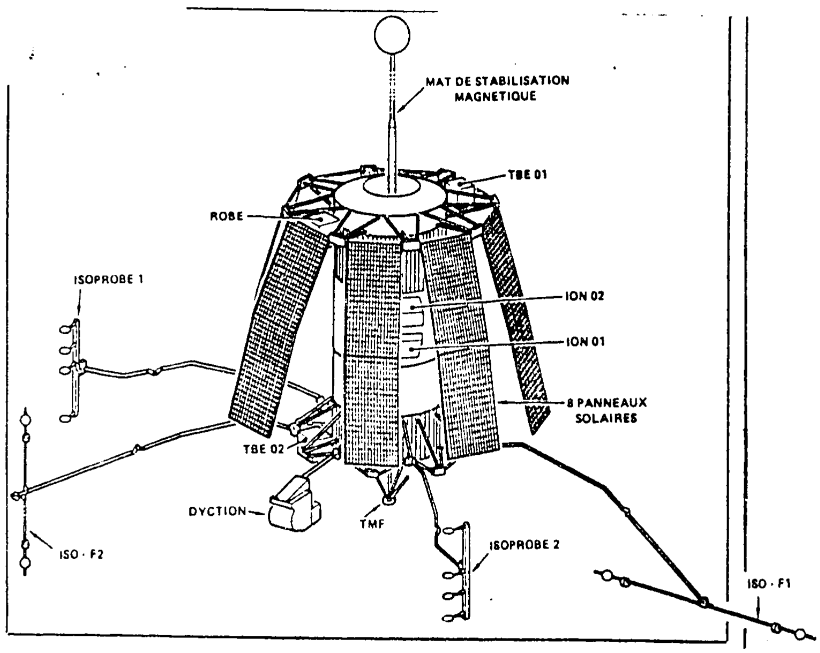
The satellite's life is nominally 6 months, including 1 month for acceptance and 5 months for operation, which will be conducted jointly by France and the USSR for the first time. The remote-control programs will be prepared both in France on a Cyber 170-750 computer (CDC) and in the USSR on a French Solar 1604 computer (CIMSA) and on a Soviet computer. Telemetry signal reception will also be handled jointly by a network of eight stations distributed around the world. On this occasion, the CNES is using the Toulouse (France) and the Kourou (French Guiana) stations, in addition to two stations in the French Southern and Antarctic Lands (TAAF) in Adelie Land (Antarctica) and on the Kerguelen Islands (Indian Ocean), and a station of the Norwegian Scientific and Industrial Research Council (NTNF) at Tromsoe. The USSR is furnishing three stations, respectively at Moscow (IZMIRAN), Apatity (Kola Peninsula) and Norilsk and the foot of the Pontorana Mountains (central Siberia). An agreement was also concluded between CNES and INTERCOSMOS, in March 1979, to handle jointly operational processing of the scientific data at Toulouse (CNES) and at Moscow (IKI and IZMIRAN).



"Arcad 3" satellite being tested in the CNES simulator in Toulouse.



French telemetering unit (with antenna) of the "Arcad 3" satellite.



Orbital configuration of the "Arcad 3" satellite
and layout of French test equipment.

10,042
CSO: 1853/10

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UDC 629.78.523.001.5

EXTREMALITY, STABILITY AND RESONANCE IN ASTRODYNAMICS AND COSMONAUTICS

Moscow EKSTREMAL'NOST', USTOYCHIVOST', REZONANSNOST' V ASTRODINAMIKE I KOSMONAVTIKE in Russian 1980 (signed to press 28 Apr 80) pp 2, 307-309

/Annotation and table of contents from book "Extremality, Stability and Resonance in Astrodynamics and Cosmonautics", by Al'bert Mikhaylovich Chechel'nitskiy, Izdatel'stvo "Mashinostroyeniye", 696 copies, 312 pages/

/Text/ ANNOTATION

This monograph contains a sequential explication of problems of optimization, stability and resonance in astrodynamics and cosmonautics. Special attention is given to extreme variational methods of analysis. There is a discussion of the possibility of investigating problems concerning the Solar System's structure within the framework of the wave concept of astrodynamics: megaquantum wave astrodynamics (using wave equations that are analogs of Schrodinger's equation). This book is intended for specialists in the fields of astrodynamics, cosmonautics and heliogeophysics.

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SPACE RESEARCH IN THE UKRAINE

Kiev KOSMICHESKIYE ISSLEDOVANIYA NA UKRAINE in Russian No 12, 1978 (signed to press 18 Oct 78) pp 2, 95-98

/Annotation and abstracts from collection SPACE RESEARCH IN THE UKRAINE, Committee on Space Research, Ukrainian SSR Academy of Sciences, Izdatel'stvo "Naukova dumka", 700 copies, 98 pages/

/Text/ ANNOTATION

This collection contains works encompassing many aspects of space research: the investigation of space near the Earth; the development of the equipment needed for the study of physical phenomena in space; the study of the properties of the materials used in space technology and so on. There are also articles devoted to biological experiments, with special emphasis on plants and micro-organisms grown during actual space flights.

It is intended for scientific, engineering and technical workers, as well as students in senior courses at higher educational institutions in the appropriate areas.

ABSTRACTS

UDC 629.784:576.851.47:576.8.095.19

RESULTS OF THE 'MICRO-ORGANISM GROWTH' EXPERIMENT ON THE 'SOYUZ-22' SPACECRAFT

/Abstract of article by Kordyum, V.A., Polivoda, L.V., Man'ko, V.G., Babskiy, V.G., Kon'shin, N.I., Gavrish, T.G., Polishchuk, L.P., and Mashinskiy, A.L./

/Text/ The authors present the results of an experiment with the bacteria Proteus vulgaris, which was grown under anaerobic conditions in a ROST-3 unit on board the "Soyuz-22" spacecraft. They show that the conditions of spaceflight proved to have a noticeable inhibiting effect on these bacteria that was expressed as a reduction in cell size in comparison with a laboratory control and a deterioration in the characteristics of postflight biological tests. These tests included an investigation of hemotaxis to the characteristic products of the metabolism in the flat capillaries, growth in linear units of the ROST type, and swarming in solid nutritive mediums with different agar contents. Figures 10; references 13.

UDC 629.620:187.576.851.47

ULTRASTRUCTURE OF CELLS OF PROTEUS VULGARIS GROWN DURING AN ORBITAL FLIGHT ON BOARD THE 'SOYUZ-22' SPACECRAFT

/Abstract of article by Bogachova, O.P., Kon'shin, N.I., Kordyum, Ye.L., and Popova, A.F./

/Text/ The authors present the results of an electron microscope analysis of the cells of Proteus vulgaris culture grown in a ROST unit, in a medium supplemented with 2,3,5-triphenyltetrazole bromide, under anaerobic conditions on board the "Soyuz-22" spacecraft and under laboratory conditions. They point out the common regularities of the growth of the culture in the experimental and control variants, as well as certain differences in the ultrastructure of the organization of the cells in the experimental variant. This experiment differs from the "Micro-Organism Growth" experiment conducted on the "Soyuz-19" because of the number of cells with deposits of readily soluble formazan /translation unknown/. Figures 5; references 2.

UDC 582.288.43.035.2

SURVIVAL RATE OF SEVERAL TYPES OF DARK-COLORED FUNGI UNDER THE EFFECT OF ARTIFICIAL SOLAR RADIATION

/Abstract of article by Zhdanova, N.N., Lyulichev, A.N., Vasilevskaya, A.I., and Antonenko, A.L./

/Text/ The authors establish the high resistance of several melanin-containing, filament-type fungi to high-intensity artificial solar radiation; the more melanin there was in their cell membranes, the higher their resistance. The nature of the survival of these fungi in all the variants of the experiment is described by complex multicomponent curves with an extensive resistance plateau. The phenomenon that was discovered is explained by special features of the melanin pigment's light-shielding function. Figures 3; references 18.

UDC 629.784:576.8.093.3:576.851.47:54.1.148:578.088.2

EFFECT OF SPACEFLIGHT FACTORS ON THE CHARACTERISTICS OF THE NUTRITIVE MEDIUM FOR THE BACTERIA PROTEUS VULGARIS

/Abstract of article by Babskiy, V.G., Man'ko, V.G., Polivoda, L.V., S"yedin, A.A., and Kordyum, V.A./

/Text/ A "Nutritive Medium" experiment was conducted for a period of 3 months on board the "Soyuz-20" spacecraft for the purpose of investigating the effect of spaceflight factors on the characteristics of the nutritive medium that was used repeatedly to cultivate Proteus vulgaris bacteria in units of the ROST type on board different spacecraft. Transportation and other mechanical effects result in a noticeable change in the physicochemical properties of the weak agar gel that is the nutritive medium (viscosity and sedimentation characteristics). Protracted storage of the nutritive medium under any conditions results in the deterioration of its properties that are necessary for maintaining the growth and mobility of Proteus vulgaris. Figures 3; references 18.

UDC 629.783:578.08

SOME QUESTIONS ON THE DESIGNING OF INSTRUMENTS FOR SPACE BIOLOGY AND EXAMPLES OF THEIR REALIZATION

/Abstract of article by Kon'shin, N.I./

/Text/ The author explains the basic principles of the designing of instruments for biological experiments under spaceflight conditions and analyzes the flaws in the instruments previously used. As examples of the realization of the described principles, he presents instruments of the IFS and ROST type, which were developed at the Ukrainian SSR Academy of Sciences' Institute of Molecular Biology and Genetics. References 18.

UDC 629:581.1.035.23

EFFECT OF SPACEFLIGHT CONDITIONS ON THE CELLS OF HIGHER PLANTS IN A CULTURE IN VITRO

/Abstract of article by Sidorenko, P.F., and Mashinskiy, A.L./

/Text/ The authors explain the results of an investigation of the effect of a 10-day orbital flight in the "Soyuz-22" spacecraft on a culture of higher plant tissues. The study of the culture of gaplopappus (Gaplopappus gracilis (Nutt) A. Gray) tissues, grown in solid nutritive mediums at the ship's cabin temperature of 18°C, did not discover any substantial differences in growth, formation of cell reproduction foci, and several cytological features (frequency of mitosis, nucleus dimensions, cariotypical composition of the population) in comparison with a control at the same temperature, but in a control at the optimum temperature of +26°C a greater increase in biomass was noted. Figures 2; references 5.

UDC 629:581.3.582.57+582.89

EFFECT OF ORBITAL FLIGHT CONDITIONS ON THE FORMATION OF THE REPRODUCTIVE ORGANS OF MUSCARI RACEMOSUM AND ANETHUM GRAVEOLENS

/Abstract of article by Kordyum, Ye.L., Mashinskiy, A.L., Popova, A.F., Uvarova, C.S., and Khristenko, L.A./

/Text/ The authors present the results of optical light investigations of the effect of orbital flight conditions on the development of the grape hyacinth's male gametophyte and the formation of the reproductive organs of dill plants, grown from seeds, that were under actual spaceflight conditions on the "Soyuz-20" spacecraft for a period of 3 months. They show that under orbital flight conditions there is acceleration of the development of the grape hyacinth's male gametophyte in comparison with a control under natural conditions. They also note a lowered germinating capacity for dill seeds that have been under orbital flight conditions for 3 months, as well as a certain percentage of loss of sprouts. Experimental dill plants that reached the blossoming and fruit-bearing phase as far as height and number of racemes and leaves were concerned were identical with the control plants. The basic features of the embedding of the reproductive organs, sporo- and gametogenesis, the development of the male and female gametophytes, the fertilization process, and embryo- and endospermogenesis in the experimental plants did not differ from those of the control plants. In weight and size, the seeds of the first-generation experimental plants were analogous to those of the controls. Figures 3; references 2.

UDC 613.693:581.1

STUDY OF THE EFFECT OF SPACEFLIGHT FACTORS ON THE EMERGENCE FROM AN ANABIOTIC STATE OF TURIONS OF A MULTIROOTED SPIRODELA

/Abstract of article by Kutlakhmedov, Yu.A., Sokirko, G.S., Grodzinskiy, D.M., Mashinskiy, A.L., Nechitaylo, G.S., and Kon'shin, N.I./

/Text/ The effect of flight conditions on the process of the emergence of turions from anabiosis was studied in biological experiments performed on the "Soyuz-12" and "Soyuz-13" spacecraft and the "Kosmos-656" artificial Earth satellite. The results showed that the initial stages of the activation of turions are extremely sensitive to spaceflight conditions, which resulted in a reduction in the rate of activation of the turions in comparison with a control experiment. A significant excess in the sizes and numbers of corresponding cymes was observed in the control variants in comparison with the experimental ones. Turions, which manifest clear and variegated reactions revealing the effect of flight factors on the emergence of the organism from a state of rest and on the biorhythm processes, are a convenient object for the performance of biological experiments in space. Figures 3; references 3.

UDC 613.693:581.1

EFFECT OF SIMULATED WEIGHTLESSNESS ON THE REPRODUCTIVE CAPACITY OF A MULTIROOTED SPIRODELA UNDER NORMAL CONDITIONS AND UNDER IRRADIATION

/Abstract of article by Kutlakhmedov, Yu.A., Sokirko, G.S., and Grodzinskiy, D.M./

/Text/ The authors investigated the effect of simulated weightlessness on the generation of offspring of different generations of a multirooted spirodela. The study showed that when cultivated in a klinostat, more generations are generated, as well as offspring in the different generations, and there is also an increase in the rate of offspring generation. The authors compared the radiobiological reaction of spirodela under cultivation in a klinostat and when at rest. It was shown that the radioresistance of spirodela increases noticeably when it is cultivated under conditions of simulated weightlessness. The data that were obtained indicated that this is a promising object for investigating the biological effect of gravitation. Figures 3; references 7.

UDC 538.69:576.355:582.739

EFFECT OF LOW-INTENSITY MAGNETIC FIELDS ON THE REPRODUCTION OF PLANT CELLS

/Abstract of article by Fomicheva, V.M., Bogatina, N.I., Verkin, B.I., and Rudenko, N.B./

/Text/ The autoradiography method was used to investigate the effect of conventionally zero magnetic fields (H_{hor} = 0.2 mOe, H_{vert} = 0.5 mOe) on the reproduction rate and number of proliferating cells in the radical meristem of a pea. The authors show that a reduction in the intensity of the surrounding magnetic field has a substantial effect on the proliferative activity of meristematic cells. In connection with this, the duration of the reproductive cycle is almost 30 % longer in comparison with its control value, which is basically the result of the expansion of the presynthetic phase of the cycle. Under the conditions of a hypomagnetic environment, there is also a significant decrease in the value of the proliferative pool, which is 68% as opposed to the 96% control value. Against a background of increased lability of the G_1-phase, the high stability of the duration of the synthetic phase of the cycle calls attention to itself. These facts indicate the complexity of the regulation of cell proliferation, depending on changes in environmental conditions. Figures 3; references 28.

UDC 541.15+539.412

STUDY OF THE EFFECT OF PROTON BOMBARDMENT ON THE MECHANICAL PROPERTIES OF SEVERAL POLYMER MATERIALS

/Abstract of article by Markus, A.M., Udovenko, V.F., Velichko, N.I., Vinokurov, V.A., Romanov, B.S., and Turov, V.G./

/Text/ The authors investigated the effect of proton bombardment, with particle energy of up to 200 keV, on the mechanical characteristics of a number of polymer materials under high-vacuum conditions. They show that for radiation doses on the order of 10^{16} protons/cm^2, some polymer materials lose 40-50 % of their strength. Even in those cases where the protons' path is only a small percentage of a test piece's total thickness, the mechanical properties can change substantially because of damage to the surface layer. Figures 5; references 5.

UDC 536.45+(536.3:535.34)

INVESTIGATION OF THE CHARACTERISTICS OF THE THERMAL DESTRUCTION OF MATERIALS UNDER INTENSE RADIANT HEATING

/Abstract of article by Pasichnyy, V.V., Dvernyakov, V.S., Podlesnaya, Ye.S., and Kondratenko, A.D./

/Text/ The authors describe a solar power unit and the technique they used to investigate the characteristics of the destruction of thermal insulating materials under intense radiant heating. For radiant thermal heat flows ranging from 100 to 1,100 W/cm^2, they derived experimental dependences of the normal radiating capacity, surface temperature, and rate and effective enthalpy of the destruction of a mica-crystal material on the magnitude of the supplied heat flows. They also present the results of a petrographic analysis of the tested material. Figures 3; references 6.

UDC 620.171.3:620.172.251

ANALYSIS OF THE THERMALLY ACTIVATED PLASTIC FLOW OF ELECTRON-BEAM MELTED MOLYBDENUM AND SOME HETEROGENEOUS MOLYBDENUM-BASED ALLOYS IN THE (0.05-0.3) T_{pl} TEMPERATURE INTERVAL

/Abstract of article by Nadezhdin, G.N./

/Text/ In the temperature interval encompassing the brittle-to-viscous transition, the author investigated the parameters of the thermal activation of the elementary act of the plastic deformation of molybdenum and heterogeneous alloys of it by electron-beam melting. The results obtained make it possible to identify the mechanism of the plastic deformation of the investigated materials in the (0.05-0.3) T_{pl} temperature band as a mechanism for overcoming the (Payyerls-Nabarro) barriers. Figures 7; references 13.

UDC 536.3.681.2.389

THERMOMETRIC INSTRUMENTS FOR MEASURING RADIANT ENERGY IN A VACUUM

/Abstract of article by Gerashchenko, O.A., and Sazhina, S.A./

/Text/ A complex of thermometric equipment for measuring the density of radiant energy flows in a vacuum has been developed. The instruments have high temporal stability characteristics, are heat and vacuum resistant, and have an autonomous energy discharge system and remote control facilities. They were developed on the basis of a thermoelectric converter that acts as the heat flow sensor. The range of measurable flows is 0.1-30 kW/m^2. The authors also describe radiometers with circulation cooling that are used to measure flows of up to 200 kW/m^2. The instruments have metrologically substantiated calibration. Figures 10; references 1.

UDC 536.3.681.2.389

THIN-FILM THERMOMETRIC DEVICES FOR MEASURING RADIANT ENERGY

/Abstract of article by Sazhina, S.A./

/Text/ Two types of thermometric devices for measuring the density of radiant energy in the 0.05-0.3 and 0.5-600 kW/m^2 ranges, at an operating speed of no worse than 0.1 s, have been developed. They are based on a thin-film, thermometric, battery-operated heat flow sensor. Thermal stabilization is achieved with the help of a special electronic temperature regulator or a cooling radiator. The instruments have metrologically substantiated calibration and are used in biology, medicine, solar power engineering and many other areas. Figures 6.

UDC 551.510.535

DETERMINATION OF THE ALTITUDES OF THE LOWER EDGES OF ARTIFICIAL AURORAL RAYS IN THE 'ZARNITsA-1' EXPERIMENT

/Abstract of article by Nesmyanovich, A.T., Zhulin, I.A., Lazorenko, P.F., Dzyubenko, N.I., Ivchenko, V.N., Drofa, V.K., and Dokukin, V.S./

/Text/ The authors present the results of a determination of the altitudes of the lower edge of artificial polar auroras that were observed during the "Zarnitsa-1" experiment. They give a brief explanation of the technique used to define more precisely the trajectory of the rocket and the orientation of the magnetic force line in the area where the experiment was performed by minimizing noncorrelations in the calculated and observed values of the luminescences' coordinates. Attention is also given to some regularities in changes in the altitude of the lower edge of auroral rays as a function of the electron injector's altitude and its operating mode. Figures 4; references 3.

UDC 551.510.535

OPTICAL EFFECTS IN THE 'ZARNITsA-1' SPACE EXPERIMENT

/Abstract of article by Nesmyanovich, A.T., Ivchenko, V.N., Bliznyuk, N.N., Vashchenko, V.N., Dzyubenko, N.I., Dokukin, V.S., and Smelyanskiy, V.N./

/Text/ In May 1973, the "Zarnitsa-1" controlled experiment on the injection of electron beams from a space rocket was conducted successfully at a station for the rocket sounding of the atmosphere near Volgograd. The authors present the operating program for the electron accelerator and the electron beams' parameters, as well as the program for the optical terrestrial observations that were made with highly sensitive television units. They describe and give the general characteristics of the following phenomena that were observed during the experiment: luminescences of artificial polar aurora rays in the upper atmosphere; the luminescence around the rocket; the light "tail" following the rocket, which was moving on a ballistic trajectory. Figures 6; references 6.

11746
CSO: 1866/96

UDC: 629.78.05.001.24

MAN AND SPACE ASTRONAVIGATION

Moscow CHELOVEK I KOSMICHESKAYA ASTRONAVIGATSIYA in Russian 1979 (signed to press 26 Jan 79) pp 2-6, 220-222

[Annotation, introduction and table of contents from book "Man and Space Astronavigation", edited by Valeriy Fedorovich Bykovskiy, candidate of engineering sciences, pilot-cosmonaut of the USSR, V. P. Merkulov, doctor of engineering sciences, and L. S. Khachatur'yants, doctor of medical sciences, Izdatel'stvo "Mashinostroyeniye", 1700 copies, 224 pages, illustrated]

[Text] This book deals with the inception of astronavigation; it demonstrates the link between aviation and space astronavigation. There is discussion of the equipment for space astronavigation, methods of assessing the accuracy of various astronavigation techniques. Analysis is made of cosmonaut work during space flights.

This book is intended for engineering and technical workers involved in development and use of systems of navigation and control of manned space flights.

Introduction

Celestial navigation is an ancient science, that mankind used to solve numerous practical problems for many centuries. The famous seafarer, Christopher Columbus, who discovered America, realized even then, in 1492, the great importance of astronomy in determining the location of a ship at sea. He said: "There is only one error-free naval calculation, astronomic; fortunate is the one who is familiar with it" [47]. Without the help of celestial navigation it would be extremely difficult for man to orient himself, not only in the open sea, but, in many cases, on land as well.

For a long time, celestial navigation was an area of applied astronomy. With the development of all types of transportation and, in particular, aviation, astronavigation gradually developed into an independent branch of science dealing with the patterns and methods of spatial orientation with the help of heavenly bodies.

Aviation astronomy is a relatively young discipline, which took over many of its methods from naval astronomy. However, because of the differences in aviation, as compared to the fleet (for example, higher speeds), these methods underwent substantial refinement and changes.

For example, it is considerably more complicated to measure the altitude of heavenly bodies above the planet's horizon in aviation. The reasons for this are, in the first place, the great distance from the horizon, which makes it difficult to superimpose precisely the image of such a body on the horizon due to atmospheric haze; in the second place, inaccurate knowledge about the aircraft's altitude above the surface of the earth and irregularity of the earth's topography at the horizon, as well as bumpiness of the aircraft in some cases, which makes it difficult to take precise readings. These differences are so significant, that they led to the use in aviation of sextants with an artificial horizon, which is formed on the basis of diverse pendulums, often of the liquid type. In order to reduce reading errors related to bumpy flight, special integral averaging devices are also used. In addition, by now some high-precision automatic and automated (i.e., those operating with the participation of an aircraft navigator) navigation systems have been developed and constructed, which permit continuous determination of the geographic coordinates of an aircraft in flight, automatic astronomic course instruments, astrocorrectors for inertial guidance [navigation] systems and many other.

Launching in the Soviet Union of the Vostok spacecraft, manned by Yuriy Gagarin, inaugurated the era of manned space flights. As time passes, the duration of space flights is increasing and their programs are growing more complex. The knowhow gained in flying aboard modern aircraft and manned spacecraft showed the great importance of operational and accurate navigation support. The increasing complexity of space flight programs makes it necessary to develop and use autonomous ways and means of space navigation involving the use of modern onboard computer equipment.

It is an important task to develop and improve effectiveness of the ways and means of astronomic navigation of manned spacecraft. In this regard, cosmonautics must determine the duties of a spacecraft navigator, his role and place when performing the main operations for autonomous navigation.

There are a number of distinctions to solving problems of celestial guidance of spacecraft, and they affect the professional performance of the cosmonaut.

The navigation methods that are guided by the sun, stars and planets, which are very accurate and unrelated to distance or duration of flight are quite promising. Astronavigation systems are autonomous in nature, and they require no additional information from ground-based equipment. They can operate at infinitely long distances from earth. These systems, which use heavenly bodies as reference points, are quite resistant to possible artificial interference.

Development of celestial guidance systems is a complex technical task, and it requires work on a wide range of interrelated problems referable to optics, light engineering, precision mechanics and a number of other branches of modern science and technology. The difficulty of guidance support of spacecraft flights lies in the fact that each flight must provide for laying out the optimum trajectories for effective performance of the set assignment with the specified energy resources. This means that there is a rigid flight schedule that is planned on earth for each mission. However, because of errors in guidance [into orbit?], use of correcting maneuvers and possibility of "overshooting" in flight, it becomes necessary for autonomous calculation of many navigational data aboard the spacecraft. In this regard, the effectiveness of performing the set assignment aboard a manned spacecraft will depend significantly on the specifications of its navigational equipment and the crew's ability to solve navigation problems at different stages of a flight.

In recent times, the development of navigation equipment resulted in the use of inertial guidance systems with and without platforms. Those without platforms have several advantages over those with them. Development of such systems, with the use of inertial elements based on new physical principles, will make it possible to create inertial systems that will provide for a high degree of precision in determining piloting-navigational and orbital parameters of flights.

Pressing problems of theory of inertial systems have been studied comprehensively by Soviet and foreign authors [2, 36, 42, 66].

The requirement that the accuracy of inertial navigation systems had to be increased first led to an effort to make use of classical statistical methods, such as the method of least squares or of maximum plausibility. Subsequently, to improve the accuracy of inertial navigation, recurrence methods of statistical evaluation became popular. Analysis of the error factor of inertial elements (accelerometers, gyroscopes) revealed that it is impossible, at the present time, to assure the necessary precision of solving navigation problems, by inertial systems with or without platforms, without making use of additional external information.

The following sensors of external information can be used to correct inertial guidance systems aboard manned spacecraft: automatic astronavigational devices (astrotelescopes); Doppler flight speed and altitude indicator; unit for determining the direction of the local vertical (IK [true course?] vertical, radio vertical); visual optic device for determining direction toward heavenly body reference points (optical sight); optical visual devices for determining altitude of heavenly bodies.

For a long time, space flights will continue to be unique events, and the capabilities of the spacecraft will remain limited. For this reason, the developers of space equipment will be faced for a long time with the specifications of low weight, small size and low energy consumption. In this respect, the use of optical visual means of correction (sights and sextants) is the most acceptable variant. The expediency of such devices is also due to the fact that the operator-cosmonaut can determine with their help, independently and without communication with earth, not only the coordinates of the location of his spacecraft, but can control [or check] such navigational parameters as the direction of the local vertical and altitude of flight.

Man aboard a spacecraft will remain for a long time as the principal link in a semiautomated system of self-contained astronavigation.

As we know, the psychophysiological functions of a cosmonaut change during flight, and this is manifested the most obviously by the change in sensorimotor fine coordination functions which constitute the foundation of professional skill in astronavigational orientation [38, 73, 75].

A designer planning and designing some system or other that operates with the participation of a human operator must take into consideration the psychophysiological capabilities of man, not only under conditions of normal function, but with exposure to the different space flight factors which alter the level of his fitness.

Thus, space astronavigation of today is based on many branches of knowledge, which often appear to be very remote from one another at first glance. For this reason, this monograph is the collective work of different specialists--engineers and psychophysiologists, cosmonauts and physicians, psychologists, mathematicians and methodologists.

The authors concentrated primarily on shedding light on questions of improving the effectiveness of operation of a semiautomated system of self-contained astronavigation and formation of recommendations on optimizing its operation.

Contents

10,657
CSO: 1866/999

INTERPLANETARY SCIENCES

UDC: 629.788.523.4(023)

MONOGRAPH ON DEVELOPMENT OF INTERPLANETARY STATIONS

Moscow NA KOSMICHESKOY VERFI (POISKI I SVERSHENIYA) in Russian 1979 pp 2, 4-6, 167

[Annotation, preface by S. Sokolov, doctor of engineering sciences, foreword and table of contents from book "On the Space Dock (Research and Achievements", by M. Borisov, 2d edition, revised and enlarged, Izdatel'stvo "Mashinostroyeniye", 168 pages, illustrated]

[Text] This book tells, in popular language, about development of automatic space stations, the problems that are solved in this regard, as well as people that are developing these stations. A special place is reserved for a description of development of the Luna-16 [Moon] station, which was the first to automatically collect and deliver to earth samples of earth soil, the Lunokhod [LEM] and automatic stations that have landed on Venus.

Unlike the first edition (1976), this one offers the most complete information about the multifaceted process of developing automatic interplanetary stations; it acquaints the reader with chief designer G. N. Babakin, under whose guidance many automatic stations were developed for exploration of the moon, Mars and Venus.

This book is intended for a wide range of readers.

Preface

In the short time that has elapsed form the start of the space age, inaugurated on 4 October 1957 by the launching of the first artificial earth satellite, various types of space vehicles have been developed in the USSR, ranging from automatic stations serving different purposes to manned spacecraft and orbital stations.

Practical cosmonautics has created new conditions for in-depth and comprehensive study of the solar system. The information scientists have gained about the moon, Venus and Mars in the first 10-15 years of development of cosmonautics exceeds, both qualitatively and quantitatively, the entire volume of information gained about these heavenly bodies before the start of the space age. We have turned from the study of different properties of the moon and planets by astronomic and astrophysical methods to new methods, which make it possible to solve basic problems of the origin and evolution, not only of the moon, Venus and Mars, but our own planet, the entire solar system as a whole.

The following is a list, which is far from complete, of the achievements of Soviet cosmonauts in the matter of developing automatic vehicles--these priceless research tools in the hands of scientists: many months of operation of the self-propelled "Lunokhod-1" [lunar excursion module--LEM] and "Lunokhod-2" under the difficult conditions of lunar day and lunar night, at temperature gradients of 300 degrees, delivery to earth of soil samples from the maria and continental regions of the moon, the artificial satellites of Mars and descent vehicles, two of which landed on Mars, the automatic "Venera" [Venus] stations with descent vehicles, which transmitted rather valuable information about this planet, including the world's first television panoramas of the surface in the landing region and the world's first artificial satellites of this planet.

This book brings the reader into the work environment of one of the design bureaus, which developed automatic stations for exploration of the moon, Venus and Mars; it acquaints him with the designers, radio operators, controllers, ballistics specialists.... The reader will see the multifaceted nature of the creative process in the routine work days.

On its pages, the reader will meet Georgiy Nikolayevich Babakin, chief designer, an enthusiastic proponent of development of automatic stations for the exploration of space. Many automatic stations for exploration of the moon, Mars and Venus were created under his guidance.

Foreword

Something new, on a more sophisticated level than before, is created each day, each hour in any design bureau.

This is also very typical of a "space" design bureau. New space stations are intended for solving increasingly complex problems. This is expressly how space builders are directly involved in overall scientific and technological progress.

It is not easy to grow grain crops; it is complicated to build a GES, and it is difficult to erect a television tower many hundreds of meters tall. It is also not a simple matter to develop a space vehicle which, having overcome the extremely difficult conditions at inconceivable cosmic distances, would obtain the information needed by man. For this reason, dozens of design bureaus, research institutes, plants, thousands of engineers and blue-collar workers, scientists and technicians, talented and enthusiastic people are involved in creating space stations.

In this book, I shall talk about only one of the design bureaus, about how the designers and engineers of this bureau are solving the problems put to them routinely by life. I should like to tell about more than the tasks or specific situations in which specialists were placed, more than and not mainly about the stations that they are developing.

I viewed my task differently: not to simply demonstrate how ETO [expansion unknown] was done, but to explain with specific examples and situations why ETO was made in expressly this way; in other words, to involve the reader in the creative process.

By far not all of those who participated in developing and were instrumental in the successful operation of the automatic interplanetary stations, "Luna" and

"Venera" [Moon and Venus] were talked about in this book; here, only some were mentioned, of those whom I had occasion to encounter in specific, described situations.

Not all of the episodes described here are equal in importance, and probably not all of them are the most important elements in the process of creating our space stations, starting with the design and ending with flight.

I wish that the different aspects of research and achievements presented will be helpful in allowing the reader to comprehend, at least to some degree, what the "space" design bureau routine is prior to the departure of the next automatic station on its unique journey.

This book is not an offical account of the work done by the design bureau over a specific period of time. These are the notes of a designer and, like any notes, they are subjective in some way and express the author's personal point of view.

I hope that my colleagues (and among them are "literate" talented narrators) will, in time, also submit their notes to the reader. The more such works are published, the more fully will be disclosed the entire multifaceted work of people who dedicated themselves to the noble cause of exploration of the mysteries of the universe. Academician B. N. Petrov stated that development of AMS [automatic interplanetary stations] of the "Luna," "Venera" and "Mars" series, which was begun under the guidance of S. P. Korolev, was successfully continued by the team (headed by the gifted designer, G. N. Babakin, corresponding member of the USSR Academy of Sciences), which developed the next generations of these extremely complex space machines. The book is dedicated to these people.

I am profoundly grateful to all those who found the time, in spite of being loaded with work, to help in the publication of this book with their advice or recollections of some episode or event.

Contents

10,657
CSO: 1866/999

UDC 52(092):521+522

GEODYNAMICS AND ASTROMETRY: PRINCIPLES, METHODS, RESULTS

Kiev GEODINAMIKA I ASTROMETRIYA: OSNOVANIYA, METODY, REZUL'TATY in Russian 1980 (signed to press 22 Aug 80) pp 4-5, 165

/Annotation, editor's foreword and table of contents from book "Geodynamics and Astrometry: Principles, Methods, Results", edited by Academician Ye.P. Fedorov, Ukrainian SSR Academy of Sciences, Izdatel'stvo "Naukova dumka", 1,000 copies, 168 pages/

/Text/ ANNOTATION

The basic theme of this collection of works is the study of the rotation and tidal deformations of the Earth in connection with the construction of models of its internal structure. These phenomena were the subject of the research done by A.Ya. Orlov (1880-1954) throughout his more than half a century of scientific activity.

In several articles there is a discussion of A.Ya. Orlov's scientific legacy and the prominent role he played in the development of geodynamic and astrometric research in the Ukraine. In this collection of works there is also a discussion of the principals and interrelationships among those sciences, facilities and methods that are enlisted in the study of the Earth's rotation and deformations. In connection with this, special attention is focused on new techniques that are just now being mastered, such as radiointerferometry, or on techniques that are still in the development stage. The latter include astrometric instruments on artificial Earth satellites. A description of the plan of such an instrument is published in the Soviet press for the first time in this book.

This book is intended for specialists in astrometry, geophysics and geodesics, as well as the broad circle of readers who are interested in the principles, the contemporary problems and the future of these sciences.

EDITOR'S FOREWORD

This collection is dedicated to the 100th anniversary of the birth of Aleksandr Yakovlevich Orlov, a great scientist who made an especially large contribution to the development of research in astronomy and geodynamics in the Ukraine.

In the years when he began his scientific activity, a transition from surveying to a planned offensive was taking place in the study of the Earth's internal structure. Systematic observations were organized for those phenomena in which the effect of deformations of the Earth and changes in its gravitational field are manifested; these observations were then analyzed and compared with the results of theoretical calculations that were based on different models of the Earth's structure.

A.Ya. Orlov became one of the most active participants in this work: in this country he organized observations of tidal tilts in the Earth's surface and various investigations of the variability of latitudes and the movement of the Earth's poles. A summary of his scientific legacy gives us a sufficiently full picture of the development of the study of the Earth's mechanical properties by means of astrometry and gravimetry in the first half of this century. We can also see how A.Ya. Orlov's ideas and concepts affected the further development of this work. His ideas will undoubtedly also be of assistance in selecting paths for future geodynamic research based on the use of new observational facilities and techniques that did not appear until after his death.

The term "geodynamics" was first used by Schiaparelli in the famous lectures he gave at the Russian Academy of Sciences in 1889. This term is encountered again in the title of a monograph by the English geophysicist Love[1], in 1911, in which he discussed, given the various hypotheses about the mechanical properties of the Earth as a whole, such global phenomena as its general tidal deformations, natural oscillations and so forth. That is the same meaning attached to the term "geodynamics" in the title of this collection and the articles published in it.

A.Ya. Orlov was educated as an astronomer, and he always related the study of the Earth's rotation to other fundamental questions of astrometry and celestial mechanics. He thought a lot about plans for the development of astrometric work in the Ukraine, but he was able to set about implementing them only in the last years of his life: in 1944, by his initiative, the Main Astronomical Observatory of the Ukrainian SSR Academy of Sciences was founded. In the field of astrometry, this observatory has now become one of the leading scientific establishments in the Soviet Union.

In this collection there are articles illuminating the life and activities of A.Ya. Orlov, as well as the development of work in geodynamics and astrometry begun by him at the Poltava Gravimetric and Main Astronomical Observatories of the Ukrainian SSR Academy of Sciences. A significant place is also occupied by an analysis of what has been achieved, an evaluation of the possibilities and a definition of the basic problems in those areas of natural science with which A.Ya. Orlov was occupied. Thus, on the whole this collection is more a glance into the future rather than the past of geodynamics and astrometry.

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[1]Love, A.E.H., "Some Problems of Geodynamics", Cambridge, 1911, 88 pages.

11746
CSO: 1866/94

LIFE SCIENCES

UDC 523

MONOGRAPH ON POSSIBILITY OF EXTRA-TERRESTRIAL LIFE

Moscow VSELENNAYA, ZHIZN', RAZUM in Russian 1980 (signed to press 12 May 80) pp 2-6, 13-14

/Annotation, table of contents, foreword and excerpt of introduction of book "The Universe, Life and Intelligence", by Iosif Samuilovich Shklovskiy, 5th edition, revised and enlarged, Izdatel'stvo "Nauka", 100,000 copies, 352 pages/

/Text/ ANNOTATION

This book is devoted to the problem of the possibility of the existence of life, including intelligent life, in other planetary systems. At the same time, it contains a quite full and easily understood explanation of the results achieved by modern astrophysics. The author has included in it a number of original ideas and hypotheses. At the "Znaniye" Society's competition, this book received the first prize for the bext popular scientific book. The fifth edition has been reworked in accordance with the author's new point of view, as put forth by him in the magazines VOPROSY FILOSOFII and ZNANIYE -- SILA.

This book is intended for a broad circle of readers with a secondary education who are interested in the urgent problems of contemporary natural science.

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FOREWORD TO THE FIFTH EDITION

The first edition of this book was written in the summer of 1962. The publication of the book was timed for a great celebration: the fifth anniversary of the launching of the first Soviet artificial Earth satellite, an event that, at the suggestion of M.V. Keldysh, who was then president of the USSR Academy of Sciences, had to be mentioned widely in our national press. I will never forget the high heat of the passions and the marvelous nervousness we were constantly feeling during the time of our -- witnesses and participants in the Great Enterprise -- first, still timid, steps on man's long path to the conquest of space. Events unfolded with fantastic rapidity. The first Soviet "Lunniki," the fantastic feeling caused by the first, extremely incomplete pictures of the far side of the Moon, Gagarin's magical flight and Leonov's first walk in space. And even then we had the first working plans for long-distance space voyages to Mars and Venus. It is unfortunate that in our era we grow accustomed to everything so quickly; the generation of people born at the beginning of the space era has already grown up. They have become witnesses of ever greater and more daring feats. However, man's first breakthrough into space will undoubtedly always remain the greatest landmark in his history.

I write this so my readers can understand the atmosphere in which I created this book. To some extent, it demonstrates that long-known phenomenon that man's thought always outstrips his actual capabilities and thereby serves as a kind of guiding star pointing to new goals and problems. From man's first, "childish" steps in space, witnesses of which we were, to the future reorganization of the Solar System by man is a huge distance. But no matter what man has already organized, he still has to have prospects.

The subject of this book is as old as human culture itself. However, it is only in our time that we have seen the first possibility of making a truly scientific analysis of the problem of a plurality of inhabited worlds. It is already obvious that this problem is a complex one that requires the most serious attention of the broadest spectrum of the scientific professions: cyberneticists, astronomers, radiophysicists, biologists, sociologists and even economists. Unfortunately, previously this problem seemed much simpler to us than it has turned out to be. From the epoch of "juvenile enthusiasm," which was of such a black-and-white nature ("Well, we'll just build a great big radiotelescope and establish contact with people on other planets"), the investigators have advanced to a more mature analysis of this extremely difficult problem. And the deeper the understanding we bring to it, the clearer it becomes that intelligent life in the Universe is an unusually rare phenomenon and may even be unique. This means that the greater the responsibility laid on man that this spark of consciousness not be extinguished by his unintelligent actions, but blazes into a bright bonfire that can be seen even from the far edges of our galaxy.

INTRODUCTION /excerpt/

The purpose of this book is to acquaint a wide ci.cle of readers who are interested in the fascinating problem of life in the Universe with the modern status of this problem. Let me emphasize the word "modern," since the development of our ideas about the plurality of inhabited worlds is going forward quite rapidly right now. Besides this, in contrast to other books devoted to this problem ("Zhizn' vo Vselennoy" /"Life in the Universe"/ by A.I. Oparin and V.G. Fesenkov, "Life on Other Worlds" by G. Spencer Jones/), where the primary question discussed is that of life only on the planets of the Solar System -- Mars and Venus -- on the basis of hopelessly unreliable data, I have given quite a bit of attention to other planetary systems. Finally, insofar as I know, in no book before 1962 (when this book was written) was there an analysis of the possibilities for intelligent life in the Universe and the problem of establishing communication between civilizations separated by interstellar distances.

This book consists of three parts. Part 1 contains the astronomical information that is necessary in order to understand the modern concepts of the evolution of galaxies, stars and planetary systems. In the second part there is a discussion of the conditions for the appearance of life on some planet. In addition, here I discuss the question of the inhabitability of Mars, Venus and the other planets in the Solar System. In the conclusion of this part there is a critical discussion of modern variants of the panspermia hypothesis. Finally, Part 3 contains an analysis of the possibility of intelligent life in different areas of the Universe. Special attention is given to the problem of establishing contacts between civilizations in different planetary systems. By nature, Part 3 of this book differs from the first two parts, which present specific results and the results of the development of science in the appropriate areas. By necessity, in this part the hypothetical element predominates, and this will be true until we do establish contact with a civilization on another planet and, plainly speaking, it is unknown when this will happen or even if it will. However, this in no way means that this part is devoid of scientific content and is pure fantasy. On the contrary: it is here that I analyze -- and rigorously, where possible -- the most recent achievements of sciences and technology that may lead to success in the future.

At the same time, this part of the book makes it possible to give some real idea about the power of human intelligence even at its present stage of development. Actually, man has already become a factor of cosmic significance by his activities. What awaits us a few hundred years from now?

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RATS' REACTIONS TO BEHAVIORAL TASKS DIFFERING IN DIFFICULTY AFTER FLIGHT ABOARD 'COSMOS-782' BIOSATELLITE

Moscow ZHURNAL VYSSHEY NERVNOY DEYATEL'NOSTI IMENI I. P. PAVLOVA in Russian Vol 30, No 3, May-Jun 80 (manuscript received 5 Mar 79) pp 507-512

[Article by N. N. Livshits, Ye. S. Meyzerov, Z. I. Apanasenko and M. A. Kuznetsova, Moscow]

[Text] The studies of rats conducted within the first 2 weeks after their flight aboard the Cosmos-782 biosatellite revealed that they had appreciable difficulty in retaining and regaining a previously developed skill in maze tests, but it was totally restored by the 11th postflight day.

Our objective here was to demonstrate finer changes in higher nervous activity (HNA) at both the early and late stages. For this purpose, we gave the animals tasks differing in difficulty at different stages of the study. It was equally important to determine both impairment and preservation of different functions of higher branches of the central nervous system (CNS).

Methods

Experiments were conducted on Wistar rats free of pathogenic flora, which weighed 215 g at the beginning of the flight.

The experimental animals (7 rats) flew for 19.5 days aboard Cosmos-782. The data pertaining to upkeep conditions aboard biosatellites of this type were published previously [3]. After the flight, the animals were kept in seperate cages.

Control rats were kept in the vivarium during and after the flight of the biosatellite; some were kept in separate cages and some in groups of five animals. Since we failed to demonstrate substantial differences between these control groups, we took seven pairs out of the entire number of control animals in such a manner that each flight group rat had two control partners similar to it with regard to preflight parameters.

The HNA tests before the flight and during the first 20 days after it were conducted using a maze of the type described by Ya. Dombrovska [2]. The maze consisted of five parallel pathways, each of which contained three locked doors and one tightly shut door (but not locked), through which the rat could pass into the next run. The fifth path led to the feed compartment. There was only one way to reach the feed compartment in this maze. In the standard experiment, the animals ran through the ma:e three times.

Adaptation of the rats to experimental conditions and development of skill in finding feed in the maze were started 2 weeks before the flight and ended 5 days before the flight. We resumed work with rats in the experimental and control groups on the third day after the biosatellite landed.

The following tests were conducted with the above-mentioned maze after the flight.

We tested the reaction to a special stimulus on the 6th-7th day against the background of restoration of the previously developed maze skill, for which purpose we turned on a bell for 3 s while the animals ran through the first path during the second passage through the maze.

On the 11th-13th day, we conducted the experiment with an increased functional load in order to examine fatigability of higher branches of the CNS: the number of runs through the maze was increased from 3 (standard experiment) to 16, while the amount of feed was reduced appropriately to avoid satiation.

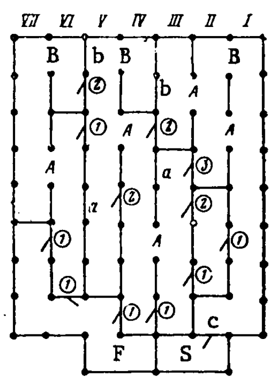

Figure 1.
Diagram of maze proposed by the authors
Key:
- S) start
- F) finish (feed compartment)
- I-VII) runs
- A, B) open ("gates")
- 1,2,3) unlocked
- a, b) locked doors
- c) entrance to maze

On the 15th-20th days, we tested the animals' ability to develop a new behavioral skill in the same maze, but with a change in alternation of locked and unlocked doors. The task put to the animals remained essentially the same as the preceding one.

As a rule, there is faster development of the second skill, since the animals use the same rules of behavior they acquired when learning the first skill. The ability to use prior experience in a new situation is a more complex form of HNA than simply the development of a skill. In the literature it is called generalization of experience [7] or (more often) transfer thereof [9].

We recorded the following parameters when testing reactions in a maze of the type described by Ya. Dombrovska: refusal to go through maze, time in which the rat passed from the first to the feed compartment and mistakes made. When processing the data, we also took into consideration the percentage of neurotic reactions, as manifested by inadequate behavior in the maze: shuttling back and forth on one path, refusal to pass through an unlocked door, return to a pathway already traveled, etc.

On the 21st-25th days, we used a more complicated maze that we developed, which is basically of a different design. The maze consisted of a starting compartment, main working part consisting of seven parallel pathways, and a feed compartment. A system of blind alleys and successive passages from one path to another was created in the working part by means of locked and unlocked (but tightly shut) doors, open gates, longitudinal and transverse dead ends (Figure 1). Unlike the maze of the Dombrovska type, the rats could travel over many routes in our maze to reach the goal. The length of the route, measured by the number of working blocks traveled, each 10×10 cm in size, arbitrarily called "steps," served as the criterion of development of skill. The shortest route was considered the optimum, when the animal found unlocked doors situated in each path at the shortest distance from the goal. Its length constituted 10 "steps." Obviously, the use of doors and "gates" that were farther away, entering into blind alleys, returning and moving in the wrong direction extended the animal's route. During the experiment, the animals were put in the complex maze twice.

Along with testing of HNA, we graded the animals' feeding activity in the feed compartment of the maze on a 5-point scale, and we also kept a record of feed intake in the vivarium.

We submitted the results to statistical processing with the use of criteria for comparison of two series of regression according to quantitative and qualitative tags [6] and, in some cases, Student's criterion.

Results and Discussion

The behavior of rats in the flight group was more active than that of control animals in the tests conducted with the relatively simple maze of the Dombrovska type.

A special stimulus extended time of passage through the maze in all animals. However, the reaction to the bell of rats flown aboard the biosatellite was appreciably milder than that of control partners. There was negligible slowing of their passage through the maze immediately after the bell, and in the next run through the maze it did not differ from the standard test in any way. In the control, however, movement through the maze was substantially slower in both tests (Figure 2). The differences between these groups are reliable ($P<0.05$).

The animals flown aboard the biosatellite endured the increased functional load on the CNS better than control animals. There was reliably less increase in number of refusals with increase in number of runs in the flight group than the control group ($P<0.01$; Figure 3). No differences between these two groups were demonstrated with regard to other parameters.

The flight group of rats were also somewhat superior to their control partners in ability to transfer experience. Development of the second behavioral skill in the Dombrovska maze occurred without failures in both groups, with the same acceleration (according to number of mistakes and time required to reach their goal), as compared to development of the first skill. However, acquisition of the new stereotype of behavior by animals flown aboard the biosatellite was associated with manifestation of experimental neurosis in a significantly smaller percentage of cases ($P<0.001$).

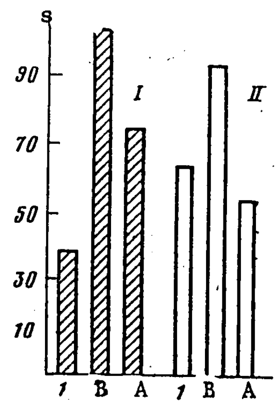

Figure 2.
Effect of special stimulus (bell) on time of passage through maze; y-axis, time, s
I) control partners
II) rats flown in biosatellite
1) run through maze prior to bell
B) run when bell is on
A) run after bell is turned off

The opposite relations were demonstrable between groups when developing skill in finding feed in the complicated maze. All of the animals started the first run through the maze in each experiment (Figure 4A). However, there was a substantial difference between the flight and control groups (Figure 4B) in the second runs through the maze: the former chose the longer route to the goal and made more "steps" in moving through the maze ($P<0.001$).

The following fact merits special attention. On the last day of the study, the experiments in the complicated maze were conducted in the morning, rather than the afternoon, as usual, in view of the fact that the animals were to be sent off to be sacrificed. More people were in the laboratory, and more work than usual was being done. This change in the situation did not have an appreciable effect on control animals' however it caused considerable worsening of passage through the maze by rats that had been on the flight, and this only when the runs were repeated. Along with a marked increase in number of "steps," there was a significant increase in time taken to run through the maze, and this was related more to the animals' general inhibition than to the change in the first parameter. The flight group of animals had traveled over a route of the same length when they first ran through the maze on the first 2 days of developing this skill, but they spent considerably less time on it.

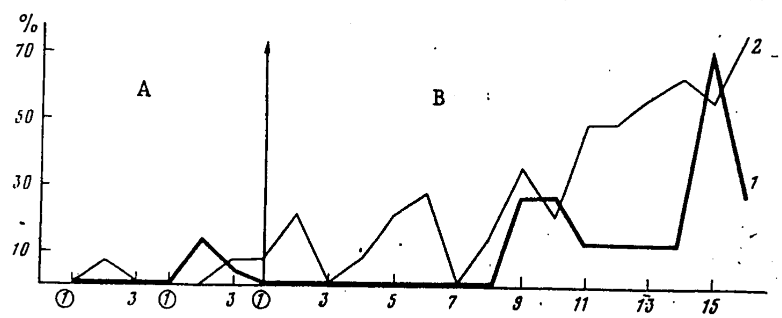

Figure 3. Mean number of refusals to run through maze by rats in the presence of greater functional load. X-axis, numbers of run starts; the circled digits refer to first start in each experiment; y-axis, mean number of refusals to start run, %

Key: A) last 2 days before experiment with increased functional load
B) experiment with increased functional load, arrow showing when it started
1) flight group of rats
2) control partners

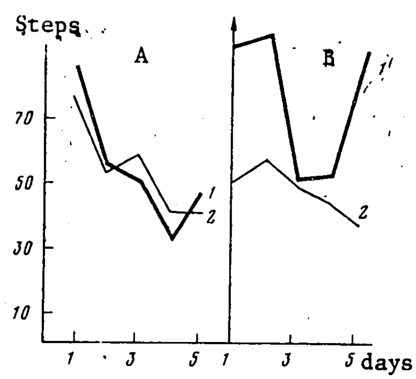

Figure 4.
Mean length of route during development of skill in complicated maze. X-axis, day of test; y-axis, length of route to goal ("steps"). Other designations are the same as in Figure 3.
A) first start through maze
B) second start " "

There are no grounds to relate the poorer development of behavioral skill in the complicated maze to either a change in alimentary excitability or muscular weakness, which develops after the flight [1]. The latter circumstance should have been manifested, first of all, in the experiment involving a larger functional load on the CNS, where the rats had to perform more exercise. Yet in that experiment, the flight rats achieved better results than the controls.

The alimentary activity of rats in the flight group was reliably diminished only when we tested their behavior in the Dombrovska type maze (diminished feed intake was recorded in the vivarium for 9 days, and diminished intake in the feed compartment of the maze was observed for 12 days after the flight. However, it is expressly in this maze that the flight group of animals performed the tests used better than their control partners. The difficulties they had in adjusting to the complicated maze occurred against the background of completely restored alimentary excitability, and they could not have been attributed to diminished motivation of their behavior.

Thus, there are grounds to believe that the demonstrated changes in maze behavior of animals in the flight group are attributable to processes in the CNS. In rats flown aboard the biosatellite, we found retention not only of the capacity to transfer experience to a maze of analogous design, but capacity to develop a new, more complex behavior stereotype (absence of differences from control group with regard to parameters of first starts through complicated maze; Figure 4A) on the 15th-25th postflight day. These facts are indicative of complete preservation of linking ["closing"] function of the cerebral cortex during the time period studied.

The serious difficulty demonstrated during the second run through the complicated maze is indicative of increased depletion of the main nervous processes of the CNS. The increase in depletion was not very significant, since it only had an effect when solving a complex problem. However, the flight group of animals ran through the simple maze, which they knew quite well, even better than control animals, even on the 16th run (Figure 3). Development of a second skill in a maze of the Dombrovska type is a task that does not require as complex processing of information as passage through the complicated maze, and these animals also performed it better than the controls.

Such findings, when along with difficulty in solving complex problems there was facilitation of solution of simple ones, have been reported in the literature. They are described with reference to exposure of animals to ionizing radiation and some pharmacological agents [4, 5], as well as humans in a stress state [8]. This phenomenon is attributable to the fact that there is attenuation of reactions to random stimuli with exposure to adverse factors of a certain force. Such "narrowing of attention" makes it possible to perform simple tasks normally or better; however, it is not sufficient to assure the solution of difficult problems.

The probability of manifestation of such a compensatory mechanisms in our experiments on the flight group of animals is confirmed by the test with the use of a special stimulus [bell]. Evidently, because of this mechanism, the reaction of flight rats to the bell (a stimulus that is not of vital importance and present for a brief time) was appreciably milder than that of controls.

The above-described changes in HNA were less marked than those we demonstrated after the flight aboard the Cosmos-605 biosatellite. In the latter case, there was both an increase in number of refusals and drastic worsening of the ability to transfer experience. Such attenuation of the effects could have been related to the improved upkeep conditions for the animals aboard Cosmos-782. Nor can we rule out the influence of individual distinctions of the organism, since rats from different colonies were used in the compared experiments.

There are no grounds to consider the demonstrated changes in HNA in rats under the influence of the space flight and readaptation to be pathological. Nor can they be considered severe; they were manifested only when performing more difficult tasks. Nevertheless, they are indicative of the adverse effect of the above factors on efficiency of the higher branches of the CNS. Special consideration must be given to the fact that this change in efficiency in the presence of an unusual situation could impair a skill that has already been developed.

Conclusions

1. The reaction to a special stimulus (bell) on the 6th-7th postflight day was less marked in rats that participated in the space flight than in control animals.

2. Endurance of an increased functional load referable to a relatively simple maze was better in flight rats on the 11th-13th postflight day than in controls.

3. The capacity to transfer experience, tested in the relatively simple maze on the 15th-20th postflight day, remained intact.

4. When acquiring a new skill in a complicated maze, increased exhaustion of the main nervous process was demonstrated on the 21st-25th postflight day in the flight group of rats, while linking function of higher branches of the CNS remained intact.

5. The above facts are indicative of diminished efficiency of higher branches of the CNS after a space flight, which is manifested in the reactions to complex behavioral tasks.

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SPACE ENGINEERING

UDC 629.7.015.3

ADAPTIVE ALGORITHMS FOR CONTROLLING DESCENT OF SPACE VEHICLE WITH HIGH AERODYNAMIC QUALITY INTO EARTH'S ATMOSPHERE

Moscow KOSMICHESKIYE ISSLEDOVANIYA in Russian Vol 19, No 3, May-Jun 81 (manuscript received 26 Mar 80) pp 359-366

[Article by V. L. Balakin and L. V. Morozov]

[Text]

Abstract: A study was made of the descent of a space vehicle with high aerodynamic quality ($k \geqslant 1$), controllable with respect to banking angle, into the earth's atmosphere with a lateral maneuver. Adaptive algorithms for autonomous terminal control with prediction of the final state of motion, parrying constantly operative perturbations, are investigated and an evaluation is given of their effectiveness on the basis of compensation of the deviation from the stipulated landing point.

1. In [1] the authors proposed multistep algorithms for forming a command banking angle for a space vehicle making a descent into the earth's atmosphere to a stipulated landing point and an evaluation of their effectiveness was given in the presence of perturbations on the basis of the initial conditions for entry into the atmosphere.

Constantly operative perturbations caused by deviations of the aerodynamic characteristics of the space vehicle and atmospheric parameters exert a strong influence on the difference between the actual landing point and the stipulated landing point. In order to parry their effects it is necessary to carry out corrections of the control program during the entire time of descent.

In a general case the operative perturbations have a random character. They result in a change in the form and extent of the "region of attainability," being a set of space vehicle landing points on the surface of the sphere of reduction. Therefore, it may be found that the stipulated landing point $C(L_s, D_S)$, situated within the region of attainability with nominal values of the aerodynamic characteristics, as a result of their perturbation will be beyond its limits. Computations reveal that the linear control correction algorithm considered in [1] does not give satisfactory results in this case.

In order to ensure the greatest accuracy in landing when there are constantly operative perturbations in this study we investigate quasilinear and nonlinear adaptive descent control algorithms.

2. If the stipulated landing point $C(L_s, D_s)$ is situated within the region of attainability, the space vehicle can make a landing at this point since it has an "excess" of maneuvering capabilities. With a location of the point $C(L_s, D_s)$ outside this region a landing can be made only at the boundary of the region of attainability.

In this connection we will use the following control strategy. When the point $C(L_s, D_s)$ is situated within the region of attainability the command program for control of the banking angle $\gamma_{com}(t)$ is determined from the condition of a zero deviation of the predicted landing point $K(L_p, D_p)$ from the stipulated point:

$$\rho_p(\gamma_{com}(t)) = 0, \quad (1)$$

and with the presence of the point $C(L_s, D_s)$ outside the region of attainability, from the condition of the minimum of such a deviation

$$\rho_p(\gamma_{com}(t)) = \min. \quad (2)$$

Here ρ_p is the distance on the sphere of reduction of the radius r_p between the stipulated $C(L_s, D_s)$ and predicted $K(L_p, D_p)$ landing points lying on this sphere, determined using the formula

$$[K = p;\ c = s] \qquad \rho_K = r_K \arccos\left[\sin\frac{D_K}{r_K}\sin\frac{D_c}{r_K} + \cos\frac{D_K}{r_K}\cos\frac{D_c}{r_K}\cos\left(\frac{L_K - L_c}{r_K}\right)\right]. \quad (3)$$

For evaluating the effectiveness of the proposed control algorithms we will construct a region of attainability determined by the aerodynamic quality. With fixed initial conditions for entry into the atmosphere and for the adopted structure of the reference program for control of the banking angle $\gamma_{ref}(t)$ (Fig. 1) the boundary of the region of attainability, symmetric relative to the trajectory of descent with a zero banking angle, consists of three parts (Fig. 2). The boundary B of the region corresponds to the maximum of the lateral range of descent D with different fixed values of longitudinal range L

$$D_{max}(L) = \max_{ref} D(\gamma_{ref}(t), L). \quad (4)$$

The boundaries A and E correspond to descent with nominal control programs (Fig. 1) with different moments of switching of the sign of the banking angle t_{sw} $[t_0, t_p]$:

$$D(L) = D(\gamma^A_{nom}(t_{sw}, t), L), \quad (5)$$

$$D(L) = D(\gamma^E_{nom}(t_{sw}, t), L). \quad (6)$$

The reference programs on the basis of which the nominal programs $\gamma^A_{nom}(t_{sw}, t)$ and $\gamma^E_{nom}(t_{sw}, t)$ are formed ensure (respectively) the maximum of the lateral range of descent with an unfixed longitudinal range and a maximum of the longitudinal range with an unfixed lateral range.

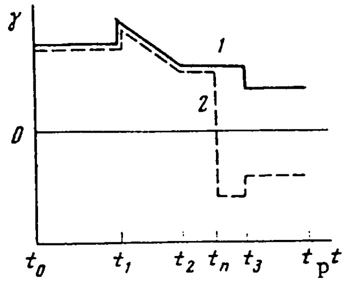

Fig. 1. Control program. 1) reference program $\gamma_{ref}(t)$; 2) nominal program $\gamma_{com}(t)$.

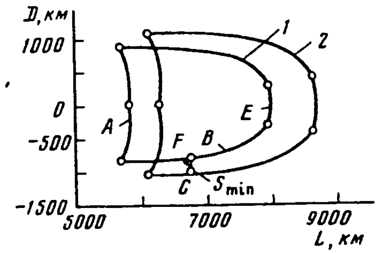

Fig. 2. Region of attainability. 1) k = 0.814; 2) k = 0.903.

3. On the basis of a prediction of the coordinates of the final landing point we will carry out a multistep control correction for the forming of the command dependence of the banking angle using the modulating function $W = W(W_1, W_2, \lambda_W)$ [1]. In each N-th correction interval $\Delta T_N = t_N - t_{N-1}$ ($N = 1, 2, 3, \ldots$) the new command dependence for the banking angle for the descent segment remaining to landing

$$\gamma_{com}^{(N+1)}(t \geqslant t_N)$$

is computed in conformity to the rule

$$\gamma_{com}^{(N+1)}(t \geqslant t_N) = W_{com}^{(N)}(W_1^*, W_2^*, \lambda_W)\, \gamma_{com\ opt}^{(N)}(t \geqslant t_N). \tag{7}$$

The control program $\gamma_{com\ opt}^{(N)}(t \geqslant t_N)$ is formed on the basis of the preceding command control

$$\gamma_{nom}^{(N)}(t \geqslant t_{N-1})$$

from the condition of minimizing of the predicted final miss relative to the time of switching of the sign of the banking angle $t_{sw} \in [t_N, t_p]$:

[K = p; KOM = com; π = sw]

$$\rho_{\kappa\,min}(\gamma^{(N)}_{\text{ком opt}}(t \geqslant t_N)) = \min_{t_\pi \geqslant t_N} \rho_\kappa(\gamma_\kappa(\gamma^{(N)}_{\text{ком}}(t_\pi, t \geqslant t_{N-1}))),$$
$$\gamma^{(1)}_{\text{ком}}(t_\pi, t \geqslant t_0) = \gamma_{\text{ком}}(t). \tag{8}$$

Since the command control program in each of the correction intervals is dependent on the parameters of the modulating function, the deviation of the landing point will also be a function of these two parameters

$$\rho_p = \rho_p(W_1, W_2). \tag{9}$$

In each current correction interval ΔT_N it is necessary to determine such values of the parameters of the modulating function W_1^* and W_2^* which in accordance with the selected control stategy either reduce to zero the deviation of the predicted landing point from the stipulated landing point

$$\rho_p(W_1^*, W_2^*) = 0, \tag{10}$$

or minimize it

$$\rho_p(W_1^*, W_2^*) = \min. \qquad (11)$$

Here we will assume that the point $C(L_s, D_s)$ falls within the region of attainability if the coordinates of the predicted landing point $K(L_p, D_p)$, corresponding to descent with the command control program

$$\gamma_{com\ opt}^{(N)}\ (t \geqslant t_N)$$

and the nominal modulating function

$$W_{nom} = W(1, 1, \lambda_W), \qquad (12)$$

satisfy the condition

$$L_p \geqslant L_s, \quad |D_p| \geqslant |D_s|. \qquad (13)$$

In the case of impairment of condition (13) the point $C(L_s, D_s)$ will be considered as falling outside the region of attainability.

4. Thus, the problem of forming the command control program is reduced to a determination in each correction interval of the parameters of the modulating function W_1^* and W_2^* in accordance with the adopted control strategy.

For the purpose of ensuring convergence of the correction process with removal of the stipulated landing point beyond the limits of the attainability region we will examine a quasilinear method for determining the parameters of the modulating function W_1^* and W_2^*, using the results of of the linear method for the correction of control [1]. It is based on an approximation of the dependence of the longitudinal $L_p(W_1, W_2)$ and lateral $D_p(L_p, D_p)$ ranges of the predicted landing points by the parabolas

$$\bar{L}_p(x) = a_L x^2 + b_L x + c_L, \quad \bar{D}_p(x) = a_D x^2 + b_D x + c_D, \qquad (14)$$

in the neighborhood of the point of the reference prediction of the coordinates of the landing point with the nominal modulating function (12). The x value is the distance in the coordinate plane OW_1W_2, measured from the point H(1,1) in the direction of the point $P(1 + \Delta W_1, 1 + \Delta W_2)$. Its coordinates are the values of the parameters of the modulating function determined by the linear control correction method. The constant coefficients of the parabolas (14) are determined from the condition of their matching with the corresponding coordinates of the target function $\rho_p(L_p, D_p)$ at three points: H(1,1), $P(1 + \Delta W_1, 1 + \Delta W_2)$ and $F(1 + \Delta W_1^F, 1 + \Delta W_2^F)$. The F point is the intersection of the segment HP with the straight line passing through two points on the coordinate axes OW_1 and OW_2:

$$\left(1+\varepsilon_1+\frac{\varepsilon_1}{\varepsilon_2},\ 0\right) \quad \text{and} \quad \left(0, 1+\varepsilon_2+\frac{\varepsilon_2}{\varepsilon_1}\right).$$

The ε_1 and ε_2 values are small increments of the parameters of the modulating function used in computing the partial derivatives in the linear correction method. The values of the coordinates of the target function at the point F are found under the condition of approximation of the surfaces $L_p(W_1, W_2)$ and $D_p(W_1, W_2)$ by planes in the neighborhood of the nominal parameters of the modulating function from the expressions:

$$L_к^r = L_к(W_{ном}) + \frac{\partial L_к(W_{ном})}{\partial W_1}(W_1^r - 1) + \frac{\partial L_к(W_{ном})}{\partial W_2}(W_2^r - 1),$$

[K = p; HOM = nom]

$$D_к^r = D_к(W_{ном}) + \frac{\partial D_к(W_{ном})}{\partial W_1}(W_1^r - 1) + \frac{\partial D_к(W_{ном})}{\partial W_2}(W_2^r - 1). \quad (15)$$

From the condition of a minimum of the sum of the squares of the deviations

$$f_{min}(x^*) = \min_x f(x), \quad (16)$$

where $f(x) = [\bar{L}_p(x) - L_s]^2 + [\bar{D}_p(x) - D_s]^2$, we determine the sought-for parameters of the modulating function

$$W_1^* = 1 + \Delta W_1 x^* / \sqrt{\Delta W_1^2 + \Delta W_2^2}, \quad W_2^* = 1 + \Delta W_2 x^* / \sqrt{\Delta W_1^2 + \Delta W_2^2}. \quad (17)$$

In order to determine the parameters of the modulating function (17) by the quasi-linear method in each correction interval it is necessary to carry out a fourfold prediction of the coordinates of the space vehicle landing point.

5. In order to ensure a higher accuracy in the landing of a space vehicle in the case of positioning of the stipulated landing point $C(L_s, D_s)$ outside the region of attainability we will examine a nonlinear method for correcting control. It is a nonlinear gradient-free method for finding the extremum of the nonnegative function of two variables (see Appendix). The method is based on an approximation of the target function (9) by the surface of a hyperbolic paraboloid in the neighborhood of the point of reference prediction with a nominal modulating function (12). For determining the parameters of the modulating functions W_1^* and W_2^* by this method in each correction interval it is necessary to carry out a fivefold prediction of the coordinates of the space vehicle landing point.

6. We will examine the descent of a space vehicle in the nonrotating atmosphere of a spherical earth under the condition of ideal navigation and stabilization of a space vehicle relative to the center of mass. As perturbations we will use the extremal values of variations of atmospheric density $\delta\rho^{min}_{atm}$ and $\delta\rho^{max}_{atm}$, on the average constituting ~ 40% of the nominal values for the CIRA-65 model of the atmosphere [2], and deviations of the values of the aerodynamic coefficients of drag δc_x and lift δc_y from their nominal values.

When carrying out numerical modeling of descent of a space vehicle with correction of control we will assume that the equations for prediction of the coordinates of the landing point coincide with the equations of motion of its center of mass [1]. In addition, the prediction is made with a nominal atmospheric density value. We will carry out the modeling with a constant duration of the correction interval and a constant value of the λ_W parameter, equal to 100 sec and 0.5 respectively, and for a space vehicle with nominal aerodynamic quality values k_{nom} equal to 1.0 and 1.7. If the predicted miss becomes less than 1 km, no further correction is made.

Table 1 gives the values of the final miss ρ_p obtained as a result of correction of the trajectory of descent in the atmosphere with perturbations of its density. Without correction the miss is about 50-80 km. Both control algorithms ensure a sufficiently high accuracy of space vehicle landing. In the case of maximum perturbation of density $\delta\rho^{max}_{atm}$ an increase in the deviation of ρ_p for space vehicles with an aerodynamic quality 1.0 occurs in the last correction intervals and causes their relatively great duration. In order to reduce the final miss it is desirable to carry out correction in the final descent segment more frequently.

Table 1

Influence of Perturbations of Atmospheric Density on Final Miss ρ_p

Method for correcting control	k_{nom}	ρ_p, km	
		$\delta\rho^{min}_{atm}$	$\delta\rho^{max}_{atm}$
Quasilinear	1.0	0.2	13.1
	1.7	0.1	0.6
Nonlinear	1.0	2.6	10.8
	1.7	0.1	6.0

Tables 2 and 3 give the values of the final miss ρ_p and the corresponding number of corrections made N_ε, obtained with different deviations of the aerodynamic characteristics. An identification of aerodynamic quality assumes a determination of its actual perturbed value k

$$k = k_{nom} \frac{1 + \delta c_y}{L + \delta c_x} . \tag{18}$$

If no identification of aerodynamic quality is made, in the prediction of the final landing point use is made of its nominal value. The results show that with identification of the aerodynamic quality landing accuracy increases. Control of the descent of the space vehicle with correction of the command control program by a quasilinear method makes it possible to accomplish a highly precise landing with a small number of corrections at the stipulated point lying within the region of attainability; a nonlinear control algorithm is more effective in comparison with a quasilinear algorithm in a case when the stipulated landing point is situated outside the region of attainability and ensures the landing of a space vehicle on its boundary with a relatively small number of corrections. For example, with the actual value of the aerodynamic quality 0.814 the landing point lies outside the region of attainability and its minimum distance S_{min} from the boundary is 160 km (Fig. 2). However, the uncompensated miss with correction by the nonlinear method is 163.3 km (Table 2).

For a space vehicle with a nominal aerodynamic quality 1.0, Fig. 3 shows the process of change of the miss with corrections for a nonlinear control algorithm with a 10% level of deviations of the values of the aerodynamic characteristics and Fig. 4 shows the reference and command programs for control of the banking angle. The command program for a space vehicle with an aerodynamic quality of 1.222 corresponds to the landing point being situated within the region of attainability and with a quality of 0.814 -- outside its boundaries. It should be noted that the nature of the command program for the control of descent at the boundary of the region of attainability corresponds qualitatively to an optimum program for the continuous control of the banking angle [3], obtained from the condition of a maximum approach to the stipulated landing point.

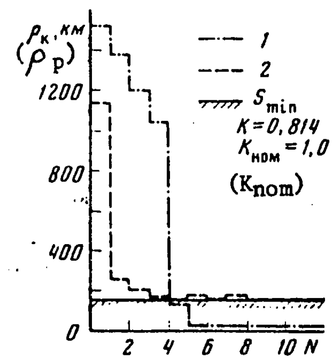

Fig. 3. Convergence of correction process. 1) k = 1.222; 2) k = 0.814; k = 0.814, k_{nom} = 1.0.

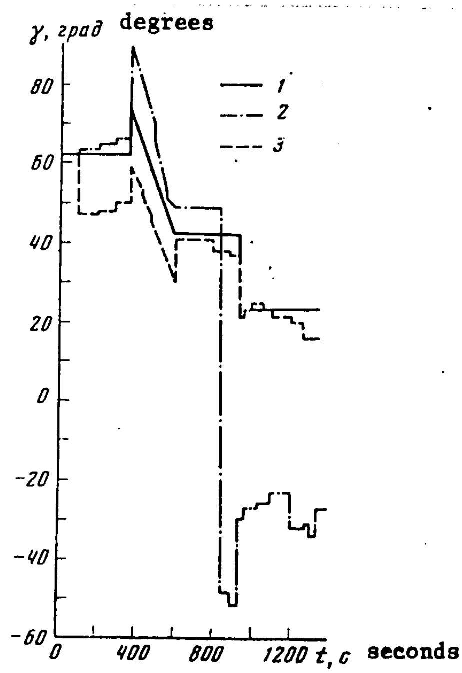

Fig. 4. Programs for control of banking angle. 1) γ_{ref}, k = 1.0; 2) k = 1.222; 3) k = 0.814.

7. On the basis of the results of modeling of descent of a space vehicle with high aerodynamic quality with constantly operative perturbations into the earth's atmosphere it can be concluded that the proposed algorithms are highly effective. With the considered levels of perturbations and with identification of aerodynamic quality the difference between the landing point and the stipulated landing point, situated within the region of attainability, does not exceed 1 km. With the stipulated landing point being situated outside the region the shifting to its boundary is accomplished with an error not exceeding 3-5 km.

Appendix. Nongradient Method for Seeking the Minimum of the Nonnegative Function of Two Variables

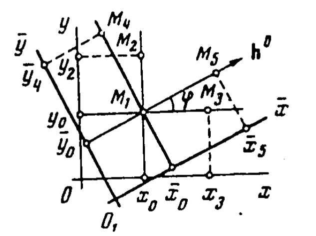

Fig. 5. Diagram explaining nonlinear minimum method.

We will examine a nonnegative function of two variables $z = z(x, y)$, determined on the plane Oxy in an orthogonal coordinate system Oxyz (see Fig. 5). It is necessary to determine the minimum of the function in the set for the entire coordinate plane. Assume that the initial approximation $z_0 = z(x_0, y_0)$ is stipulated. On the plane we select the points $M_2(x_0, y_2)$ and $M_3(x_3, y_0)$ at which we determine the values of the target function z_2 and z_3. On the plane Oxy we find the unit vector $h^0 = (h_1^0, h_2^0)$, indicating the direction of the greatest change in the target function at the point $M_1(x_0, y_0)$ [1]. We will approximate the function $z = z(x, y)$ in the neighborhood of the point z_0 by the surface of a hyperbolic paraboloid

$$\frac{(\bar{x}-\bar{x}_m)^2}{\bar{p}}+\frac{(\bar{y}-\bar{y}_m)^2}{\bar{q}}=2(\bar{z}-\bar{z}_m). \tag{A.1}$$

The surface (A.1) was stipulated in the coordinate system $O_1\overline{xyz}$, obtained by rotating OXYZ by the angle φ relative to the point $M_1(x_0, y_0)$ for the purpose of a more precise approximation of the target function (Fig. 5). In order to stipulate the surface (A.1) it is necessary to determine $\bar{x}_m$, $\bar{y}_m$, $\bar{z}_m$, $\bar{p}$, $\bar{q}$ from the condition of its matching with the surface $z = z(x, y)$ at five points. In order to establish analytical relationships between the sought-for values and the values of the target function we will select the remaining two points $M_4(\bar{x}_0, \bar{y}_4)$ and $M_5(\bar{x}_5, \bar{y}_0)$ on the straight lines parallel to the $O_1\bar{x}$ and $O_1\bar{y}$ axes. The target function at these points has the values z_4 and z_5. Subtracting term-by-term the expressions (A.1), written for the points M_1 and M_4, M_1 and M_5, we obtain

$$\bar{q}=A+B\bar{y}_m, \quad \bar{p}=C+D\bar{x}_m, \tag{A.2}$$

where

$$A=\frac{y_0-\bar{y}_4^2}{2(z_1-z_4)}, \quad B=\frac{y_0-\bar{y}_4}{z_1-z_4}, \quad C=\frac{x_0-\bar{x}_5^2}{2(z_1-z_5)}, \quad D=\frac{x_0-\bar{x}_5}{z_1-z_5}.$$

Table 2

Influence of Perturbations of Aerodynamic Characteristics on Final Miss ρ_p, $k_{nom} = 1.0$

δc_x, %	δc_y, %	k	With identification of aerodynamic quality				Without identification of aerodynamic quality			
			quasilinear method		nonlinear method		quasilinear method		nonlinear method	
			ρ_p, km	N_ε	ρ_p, km	N_ε	ρ_p, km	N_ε	ρ_p, km	N_ε
-10	+10	1.222	0.0	5	22.4	14	41.2	11	16.6	12
-5	+5	1.105	0.0	4	9.8	10	10.3	11	11.5	13
0	0	1.000	0.0	1	0.3	1	10.8	13	3.1	13
+5	-5	0.903	42.9	13	1.0	13	251.3	13	157.9	13
+10	-10	0.814	736.1*	11	163.3*	3	699.9*	12	562.6*	12

*The landing point is situated beyond the zone of attainability.

Table 3

Influence of Perturbations of Aerodynamic Characteristics on Final Miss ρ_p, $k_{nom} = 1.7$

δc_x, %	δc_y, %	k	With identification of aerodynamic quality				Without identification of aerodynamic quality			
			quasilinear method		nonlinear method		quasilinear method		nonlinear method	
			ρ_p, km	N_ε	ρ_p, km	N_ε	ρ_p, km	N_ε	ρ_p, km	N_ε
-10	+10	2.077	0.1	4	12.4	11	20.7	18	10.1	19
0	0	1.700	0.0	3	0.5	21	4.2	19	4.9	21
+10	-10	1.385	1229.2*	18	554.1*	8	1292.2*	18	1028.2*	18

* The landing point is situated outside the zone of attainability.

Similarly, subtracting expressions (A.1) for the points M_1 and M_2, M_1 and M_3 and taking expression (A.2) into account, we will have

$$C_1\bar{x}_m+C_2\bar{y}_m+C_3\bar{x}_m\bar{y}_m+C_4=0, \quad D_1\bar{x}_m+D_2\bar{y}_m+D_3\bar{x}_m\bar{y}_m+D_4=0, \qquad (A.3)$$

where

$$C_1=2ADz'-AB_1-A_2D, \quad C_2=2BCz'-A_1B-B_2C,$$
$$C_3=2BDz'-BB_1-B_2D, \quad C_4=2ACz'-AA_1-A_2C,$$
$$D_1=2ADz''-AB_3-A_4D, \quad D_2=2BCz''-A_3B-B_4C,$$
$$D_3=2BDz''-BB_3-B_4D, \quad D_4=2ACz''-AA_3-A_4C,$$
$$A_1=x_0^2-\bar{x}_2^2, \quad A_2=y_0^2-\bar{y}_2^2, \quad A_3=x_0^2-\bar{x}_3^2, \quad A_4=y_0^2-\bar{y}_3^2,$$
$$B_1=-x_0+\bar{x}_2, \quad B_2=-y_0+\bar{y}_2, \quad B_3=-x_0+\bar{x}_3, \quad B_4=-y_0+\bar{y}_3,$$
$$z'=z_1-z_2, \quad z''=z_1-z_3.$$

Using (A.3) we obtain an equation for $\bar{y}_m$

$$\alpha\bar{y}_m^2+\beta\bar{y}_m+\gamma=0, \qquad (A.4)$$

where $\alpha = C_2D_3 - C_3D_2$, $\beta = C_2D_1 + C_4D_3 - C_1D_2 - C_3D_4$, $\gamma = C_4D_1 - C_1D_4$, and the x_m value is determined from the second equation of system (A.3)

$$\bar{x}_m=-\frac{D_4+D_2\bar{y}_m}{D_1+D_3\bar{y}_m}. \qquad (A.5)$$

We will examine possible variants of the form of the surface (A.1).

Variant 1. With $\bar{p}>0$, $\bar{q}>0$ expression (A.1) describes the surface of an elliptical paraboloid, convex downwards. With $\bar{z}_m \geqslant 0$ the minimum of the approximating function is at the point $M(\bar{x}_m, \bar{y}_m)$. If $\bar{z}_m < 0$, the algorithm of variant 2 is used.

Variant 2. With $\bar{p}<0$ and $\bar{q}<0$ expression (A.1) corresponds to the surface of a convex upwards elliptical paraboloid with a minimum (A.1) equal to zero. The vector h_0 indicates the direction of the greatest change in the target function and therefore the minimum point $M^*(\bar{x}^*, \bar{y}^*)$ will be sought in the direction of this vector. Accordingly, $\bar{y}^* = y_0$, and the coordinate $\bar{x}^*$, determined from the equation

$$a(\bar{x}^*)^2+b\bar{x}^*+c=0, \qquad (A.6)$$

where

$$a=\frac{1}{\bar{p}}, \quad b=-\frac{2\bar{x}_m}{\bar{p}}, \quad c=\frac{\bar{x}_m^2}{\bar{p}}+\frac{(\bar{y}_0-\bar{y}_m)^2}{\bar{q}}+2\bar{z}_m,$$

should satisfy the condition: $\bar{x}^* > \bar{x}_0$.

Variant 3. With $\overline{pq} < 0$ expression (A.1) describes the surface of a hyperbolic paraboloid. The coordinates of the minimum point are determined by the signs of the values $A = -2\bar{p}\bar{z}_m$ and $B = -2\bar{q}\bar{z}_m$. If $A<0$ and $B>0$ and the condition

$$\bar{y}_m-\sqrt{B}<\bar{y}_0<\bar{y}_m+\sqrt{B}, \qquad (A.7)$$

is satisfied, then the coordinate $\bar{x}^*$ is assumed equal to $\bar{x}_m$. If (A.7) is not satisfied, then $\bar{x}^*$ is determined from (A.6) with the following coefficients

$$a=-B,\quad b=2B\bar{x}_m,\quad c=-B\bar{x}_m^2+(\bar{y}_0-\bar{y}_m)^2|A|-|A|\cdot B.$$

If $A>0$ and $B<0$, $\bar{x}^*$ is determined from (A.6) with the following coefficients

$$a=|B|,\quad b=-2B\bar{x}_m,\quad C=|B|\bar{x}_m^2-(\bar{y}_0-\bar{y}_m)^2A-A\cdot|B|.$$

Since equation (A.4) has two solutions, each of them corresponds to its own minimum point of the approximating surface. As the sought-for point of the minimum we use a point for which the coordinate $\bar{x}^*$ is greater than x_0 and is situated closer to it.

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TESTS OF SPACE ELECTRIC ROCKET PROPULSION SYSTEMS

Moscow ISPYTANIYA KOSMICHESKIKH ELEKTRORAKETNYKH DVIGATEL'NYKH USTANOVOK in Russian 1981 (signed to press 29 Sep 80) pp 3-11, 202-203

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[Text] Foreword

In the materials of the 25th CPSU Congress mention was made of the outstanding achievements of domestic science and engineering in the mastery of outer space and a determination was made of the most important trends in the further development of scientific research. An important objective was set--of continuing the study and mastery of outer space and of expanding research on the application of space facilities in studying the natural resources of the earth, in meteorology, navigation, communications and for other needs of the national economy.

The solution of many problems in astronautics in the immediate future will involve the extensive utilization of space electric rocket propulsion systems (ERDU's). Among these problems must be included problems of orienting, stabilizing and correcting the orbits of artificial satellites and longterm orbital stations, as well as enabling interorbital and long-range space flights to planets of the solar system.

Much work has been done on the development of ERDU's of various types in a comparatively short time (the beginning of work on space electric rocket propulsion systems occurred in the second half of the 50's). Many space ERDU's created have successfully passed bed tests simulating the effects of the conditions of outer space and space flight factors, as well as space flight tests. Progress in the development and creation of high-efficiency space ERDU's was achieved on account of the extensive utilization of the achievements of many fields of modern science and engineering.

In the creation of ERDU's for spacecraft for different purposes great attention is paid to questions relating to the methodology of bed and space flight tests in the experimental trial process, to the equipment supply of test beds simulating the influence of the physical conditions of outer space, as well as to the use of diagnostic methods and equipment for making various physical studies and measurements. In this textbook descriptions are given of the equipment for producing a vacuum, for simulating solar radiation, heat transfer, cosmic radiation, zero gravity, and streams of charged particles in solid matter, as well as of test beds with vacuum chambers, the procedure and measuring equipment for performing various measurements utilizing modern physical diagnosis equipment such as spectral, electrophysical, radiophysical, etc.; various kinds of bed tests are discussed, including tests for reliability, as well as questions relating to the automation of tests by means of digital control computers (UVM's), mathematical statistical methods of processing and analyzing experimental data, as well as aspects of conducting space flight tests of ERDU's.

The objective of this textbook is to acquaint students in higher technical educational institutions with the methodological and engineering and technical aspects of tests of modern space ERDU's.

Introduction

A space propulsion system (KDU) with electric rocket engines (ERD's) is called an electric rocket propulsion system (ERDU) and consists of two main parts: the power (electric power) plant (EU) and the propulsion system (DU). Sometimes this combination is also called the power plant or power system of a spacecraft (KLA).

A modern airborne space propulsion system with electric rocket engines represents a complicated engineering system whose structure includes sources of primary energy, converters of this energy into electrical, units for the removal of high- and lower-temperature heat, and various converters which are consumers of electric power (ERD's and converters into electromagnetic radiation energy, thermal energy, etc.). A block diagram of an airborne space ERDU is shown in fig 1. The structure of an ERDU also includes a control, testing and regulation system which is connected by means of a command radio line and radio telemetry system to a command measuring complex. A distinctive feature of an ERDU is the fact that the thrust developed by the ERD's in relation to the mass of the propulsion system equals a total of only 10^{-2} to 10^{-3} N/kg. ERDU's come under the heading of low-thrust propulsion systems and their advantages are evidenced to the full extent only under conditions of prolonged space flights; therefore they must possess high reliability and long life.

The various types of ERD's used in ERDU's make it possible to obtain exceptionally high (as compared with chemical rocket engines) values of specific thrust momentum: 10^4 to 10^6 m/s.

ERDU's can be used for solving the following problems: 1) for correcting the orbit of artificial earth satellites (ISZ's); 2) for stabilizing ISZ's; 3) for orienting ISZ's; and 4) for accomplishing interorbital and crusing flights to other planets of the solar system.

Modern space power plants (EU's) and propulsion systems (DU's) differ widely. They differ both in design and characteristics and in the operating process.

EU's contain the following three main elements: a primary energy source, a converter of primary energy into electrical (sometimes these two elements are combined), and a unit for the removal into outer space of the heat unutilized in the conversion process.

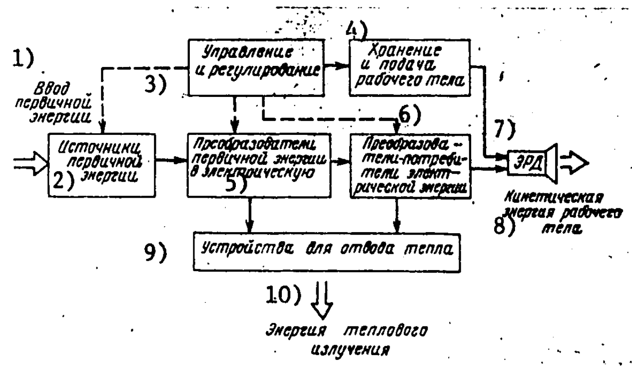

Figure 1. Diagram of Airborne Space ERDU

Key:

1. Input of primary energy
2. Primary energy sources
3. Control and regulation
4. Storage and supply of working medium
5. Converters of primary energy into electrical
6. Converters which are consumers of electric power
7. ERD
8. Kinetic energy of working medium
9. Units for removal of heat
10. Heat radiation energy

Primary energy sources are subdivided into two categories: airborne, i.e., found on board the spacecraft, and external, found outside the spacecraft. Under the heading of airborne energy sources come nuclear and chemical. Two types of nuclear sources--radio isotope and reactor--have received practical application. The chief external source of energy is solar radiation, which can be used in the light or heat form.

Converters of primary energy into electrical can be of three kinds: converters of the thermal form of energy (heat), of solar light energy, and of chemical energy.

Converters of heat are divided into machine-type and non-machine-type (sometimes also called direct or immediate converters). In machine-type converters the heat is partly converted into mechanical work and then by means of electric current generators into electric power; in direct converters the conversion of heat into electric power is accomplished directly.

Steam turbine plants (PTU's), gas turbine plants (GTU's) and Stirling engines come under the heading of machine-type converters.

The main types of direct converters of heat which are of interest for airborne space power plants are thermoelectric (TEG's) and thermionic emission (TEP's).

Under the heading of direct converters come fuel cells and storage cells, as well as photoelectric batteries. The first and second types convert chemical energy, and the third type the light energy of solar radiation.

The supply of heat energy to converters and the removal of energy from converters is often accomplished by means of heat transfer agents (primarily liquid-metal) circulating in closed circuits, as well as by means of heat pipes.

The following thre_ main types of ERD's are differentiated as a function of the mechanism for accelerating the working medium: electrothermal (ETD's), electromagnetic (EMD's) and electrostatic (ESD's). A distinctive feature of an ERD is the independence of the delivery of the working medium and of the supply of energy to it.

In ETD's heating of the working medium is accomplished either on account of the Joule heat released in a solid high-melting conductor of electric current--an ETD with resistance heating--or on account of an electric arc--arc-heating ETD's.

EMD's are subdivided into two groups: continuous-action and pulsed-action. Continuous-action EMD's can have an internal or external magnetic field. Two main types of EMD's with an internal magnetic field exist: coaxial and end-type. EMD's with an external magnetic field differ widely: those with acceleration of a plasma in orthogonal (crossed) electric and magnetic fields; linear Hall-effect; and end-type Hall-effect.

Pulsed EMD's (also called pulsed accelerators) are designed primarily according to coaxial or end-type circuits. Liquid or solid working media are used in them. Pulsed EMD's in which dielectrics are used as the working medium are called erosion EMD's.

The operating principle of an ESD is based on the acceleration by means of an electrostatic field of like-charged particles of the working medium. ESD's are of two types with respect to the kind of working medium: ionic and colloidal.

A space ERDU is characterized by the following: 1) by complexity, occasioned by the presence of a great number of systems, assemblies, units and the like which are functionally interrelated; 2) by high reliability (i.e., failure-free functioning) in the situation of the total absence of or limited ability for repairs in space; and 3) by long life, i.e., longterm failure-free functioning reaching 10^4 hours and longer.

Production uniqueness and singleness are also characteristic of the present stage of development of ERDU's. The majority of ERDU models created are experimental and do not have prototypes.

Tests are the most important part of development, experimental trial and creation programs for high-efficiency, reliable and long-life ERDU's designed for spacecraft for different purposes. Problems relating to the organization, equipment supply and conduct of tests of space ERDU's have a number of distinctive features and are distinguished by sufficient complexity and labor intensiveness.

Soviet scientists and engineers have made a great contribution to the development, creation and accomplishment of extensive programs for testing various types of ERDU's. First place in the development and creation of high-efficiency and reliable ERDU's belongs to them.

K.E. Tsiolkovskiy as early as 1911 in the "Future of Rocket Devices" section of his celebrated study "Investigation of Outer Space by Means of Rocket Devices" indicated the possibility of using electricity for the purpose of creating the jet propulsion required for flights in outer space. Tsiolkovskiy was a staunch supporter of the most extensive utilization of solar energy in astronautics. He anticipated the creation of space airborne power plants utilizing the thermal energy of solar radiation and developed a number of sketches of such plants. For the purpose of concentrating solar energy in space he suggested that parabolic, spherical or cylindrical mirrors with a metalized reflecting coating be used. Tsiolkovskiy foresaw the two basic methods of producing electric power on board a spacecraft: direct conversion by means of a thermoelectric battery, and the machine type by means of piston machines or steam turbine plants operating in a closed cycle.

Tsiolkovskiy attached great importance to tests and trials of space systems under test bed conditions, on the earth. He believed that the program of tests for a space propulsion system should include bed tests and the use of rocket trolleys and hydroplanes and then of rockets launched first in a ballistic trajectory. Tsiolkovskiy believed a gradual increase in the loads and the duration of tests of a rocket engine to be necessary.

Considerable attention was paid to ERDU's by F.A. Tsander, who was a great scientist and theoretician, a talented engineer and designer and researcher, and a great enthusiast for the development in our country of work in the area of rocket engineering and interplanetary flights. In his works Tsander paid great attention to theoretical studies, questions relating to tests and to experimental trials and final adjustment of rocket engines and spacecraft. He attached great importance to bed tests which simulate the conditions of a space flight and the influence of the physical conditions of outer space on a spacecraft and its systems. Tsander suggested the basic design of a power plant with the machine conversion of solar heat energy into electrical.

The prominent scientist in the field of space rocket engineering, the founder of Soviet rocket engine building, twice a Hero of Socialist Labor and winner of the Lenin and State prizes, Academician V.P. Glushko, in 1928-1929 developed a project for an interplanetary spaceship with electric rocket engines (ERD's) and a solar thermoelectric power plant. A second division directed by V.P. Glushko was created at the Gas Dynamics Laboratory (GDL) in Leningrad in 1929 for the purpose of carrying out work on ERD's and ZhRD's [liquid-propellant rocket engines]. Tests of an experimental pulsed thermal ERD took place in the laboratory of the GDL second division in the beginning of 1933.

An artificial earth satellite was launched into orbit for the first time in the world on 4 October 1957 in the USSR. This historical event represented the natural result of the systematic development of Soviet society, of socialist economics and of the enormous successes of domestic science and engineering.

Intensive research on ERD's began in the second half of the 50's. A powerful incentive for the development of these studies was the successes in the mastery of outer space and the achievements of the physics of a high-temperature plasma.

The eminent Soviet physicists academicians I.V. Kurchatov and L.A. Artsimovich, who headed research in the field of plasma physics, paid serious attention to the development of studies on ERD's. Academician S.P. Korolev rendered fervent support for these studies.

By 1963-1965 a number of experimental models of ERD's had been tried under test bed conditions as the result of the performance of theoretical calculation, planning and design and scientific research work in the USSR. It was necessary to solve a number of new complicated problems for the purpose of carrying out space flight test programs for ERD's. Primarily there was the question of the supply of power for ERD's. For such tests it was necessary to develop and create an airborne space power plant taking into account limitations with regard to weight and overall dimensions. The need also arose to develop a closed system for the automatic control of a space ERDU through commands from the earth and through the telemetric transfer of information.

All this required the development of an entire complex of complicated testing and measuring systems for the purpose of checking the electrical parameters and thrust characteristics of ERD's, the parameters of outer space, and the like. In the course of carrying out space flight test programs it was necessary to discover how effectively ERDU's which had successfully passed bed tests would function in a space flight.

Space flight tests of various types of space ERDU's, ERD's and EU's have been conducted systematically in the USSR.

On 30 November 1964 the automatic interplanetary station "Zond-2" was launched toward Mars, and on board this station were installed six erosion-thermal pulsed plasma-jet ERD's. The ERD's were supplied with power from solar batteries. The test program included the problem of orienting the panels of the solar batteries, which were designed for charging the storage batteries.

Fifteen 24-hour periods after the launch, when the "Zond-2" station was at a distance of 5.370 million km from earth, the system for orienting from the ERD's was switched on through a radio command. The ERD's worked steadily for 70 min and enabled orientation of the solar batteries.

Space tests of plasma-jet ion ERD's were carried out in the USSR beginning in 1966 in the "Yantar'" [Amber] automatic ionospheric laboratory. Tests of an ion ERD with the surface ionization of cesium on tungsten were conducted in the "Ion" space laboratory in 1969-1970. Space flight tests according to the "Yantar'" and "Ion" programs were conducted at altitudes of 160 to 400 km from the surface of the earth during travel in ballistic trajectories. High-altitude vertically launching geophysical rockets were used for the purpose of launching the research laboratories.

At the end of December 1971 the "Meteor" ISZ was launched into orbit, on which were installed stationary plasma-jet ERD's with azimuthal drift and an extended acceleration zone (abbreviated, SPD's).

Space flight tests of pulsed erosion EMD's were carried out with high-altitude atmospheric probes in the USSR at the beginning of 1974.

In 1975 the "Kosmos-728" ISZ was launched, on which end-type EMD's were tested (stationary end-type plasma accelerators).

On 30 June 1977 in the USSR the artificial earth satellite "Meteor-Priroda [Nature]" was launched into orbit, designed for completing an extensive program of national economic research. A variety of experimental scientific apparatus was installed on board the ISZ for this purpose. The ISZ had an improved power supply system utilizing solar batteries. ERD's were installed in the ISZ for the purpose of maintaining stability of its orbit.

Space flight tests of various types of power plants have also been carried out in addition to space flight tests of ERD's.

The "Kosmos-84" ISZ was launched in the USSR on 3 September 1965, and the "Kosmos-90" ISZ on 18 September 1965. "Orion-1" radio isotope power supplies with a thermoelectric converter, which had successfully passed space flight tests, were installed in these ISZ's.

Power plants with the direct non-machine conversion of nuclear energy into electrical, which are of great interest for astronautics, are being developed and tested in the USSR.

An example of a high-temperature reactor-converter employing fast neutrons with thermoelectric converters is the "Romashka" [Camomile], which was created at the Institute of Atomic Energy imeni I.V. Kurchatov and worked at a rated power of 500 W for 15,000 hours.

An example of another highly effective type of power plant is the "Topaz" plant created at the Physics and Power Engineering Scientific Research Institute. The "Topaz" is a thermionic emission reactor-converter. Tests of three "Topaz" plants have confirmed the possibility of the stable generation of 5 to 10 kW of electric power. Uranium dioxide serves as the nuclear fuel for the "Topaz."

Systems for orienting and correcting spacecraft (the ATS-IV, ATS-V, LES-VI, SERT-II, etc.) in which various types of ERD's have been used have been tested abroad in recent years under space flight conditions.

Let us mention in conclusion that work on the creation of plasma-jet and ion ERD's has to a considerable extent stimulated the development of an applied branch of plasma physics--the physics of plasma and ion accelerators. At the present time electromagnetic plasma accelerators and charged-particle accelerators are of great interest for thermonuclear research and for technological purposes, as well as as sources for pumping lasers operating in the ultraviolet region of the spectrum.

Arc-heating, induction and microwave accelerators are used for applying coatings and films, cutting, welding and remelting high-melting metals and their alloys, in plasma chemistry, etc. Ion accelerators make it possible to accomplish the process of ion-implanted doping of semiconductor materials.

CONTENTS

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LIQUID-FUELED ROCKET ENGINES

Tallinn TEHNIKA JA TOOTMINE in Estonian No 2, Feb 81 pp 41-44

[Article by A. Künnapuu: "Liquid-Fueled Rocket Engines in Space"]

[Text] "To continue exploring and exploitation of space by utilizing the achievements of science and technology in the interest of science, technology, and national economy." [in boldface]

Extract from the draft program on Soviet economic and social directions submitted to the 26th Party Congress.

One of the most important aspects of space exploitation is the need for powerful energy sources. The father of cosmonautics and rocket construction, Soviet scientist K. Tsiolkovskiy showed as early as 1903 that the rocket engine was the only possible power source for space flight. A quarter century ago Soviet scientists and engineers successfully solved the problem of making such engines and laid the foundation for the space age. A rocket engine is a power source in which all components necessary for jet propulsion are stored within the rocket. The working of the rocket engine is thus independent of the outside environment and can be used in space conditions. Engine power does not depend on the speed of flight and changes very little with increased altitude. Contemporary space flight depend primarily on liquid-fueled rocket engines.

In a liquid-fueled rocket engine (diagram 1) the fuel is burned in combustion chamber 1 in the presence of an oxidizer. Fuel and oxidizer are forced into the combustion chamber from tanks (5) by pumps (2) through valves (4) and atomizers. The pumps are activated by a turbine (3), itself driven by a gas generator (7). The emptying tanks are filled with an inert gas from a special reservoir with the help of a motor (6). In smaller engines the fuel pumps can be replaced by gas pressure in the tanks. The power of a rocket engine can be determined by formula $R = mc(P_a - P_h)F$, with m being the volume of the gas emanating from the jet, c the speed of the gas in the jet opening, P_a the pressure in the combustion chamber, P_h the pressure of external environment, and F the area of the jet opening. As the formula indicates, the efficiency of a rocket engine is greatly dependent on the velocity of exhaust gases. To achieve a great exhaust velocity, high pressure must be maintained in the combustion chamber by intensive burning at temperatures from 3,000 to 4,000 degrees C. For example, the pressure in the combustion chamber of the Soviet Vostok space rockets of the type RD 107 rises

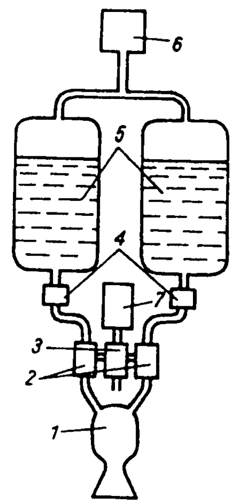


Diagram 1.

to 60 Atm, in some solid fuel engines it is as high as 300 Atm. The velocity of exhaust from liquid-fueled rocket engines ranges from 2 to 4.5 km/sec, in the RD 107 motors it is 3.0 to 3.1 km/sec.

One of the most popular fuels for liquid-fueled rocket engines is kerosene burned in oxygen. Oxygen is stored in liquid form. Oxygen is preferred for rocket engines primarily because of ample supply and low production costs. It is obtained by compressing and cooling air repeatedly. Since the boiling point of nitrogen (-196° C) is lower than that of oxygen (-183°C) the nitrogen in the air evaporates and oxygen remains. It is a non-poisonous and chemically non-aggressive substance. Pure oxygen is generally non-explosive but an explosive mixture can result when it comes into contact with fuel, especially oils. This property of oxygen requires a careful degreasing of rocket tanks before filling.

Independently fed liquid-fueled rocket engines also use other substances besides petroleum and liquid oxygen. Kerosene as well as a mixture of aniline and ethyl alcohol can be burned in nitric acid, petroleum in tetranitromethane, a mixture of methyl alcohol and hydrazinehydrate in hydrogen peroxide, hydrazine in liquid fluorine, etc. To achieve better mixing the fuel and oxidizing agent are put into revolution in the atomizers. In larger engines scores of atomizers are placed in checkerboard fashion. Fuel coming into the engine is usually also used to cool the combustion chamber. The placing of smaller engines inside fuel tanks to achieve cooling is conceivable. Various methods are used to ignite the components of liquid duel. Pyrocartridges offer a relatively simple and reliable ignition method. To a lesser extent electrical ignition is used, mostly in smaller engines. The ignition system, however, can be eliminated by the use of so-called unique fuels. This "liquid gunpowder" consists of substances igniting spontaneously upon mutual contact. For example, the orientation and adjustment motors of the "Salyut-6" orbital station are powered by asymmetrical dimethylhydrazine and nitrotetroxide (an oxidizer) that ignite upon contact.

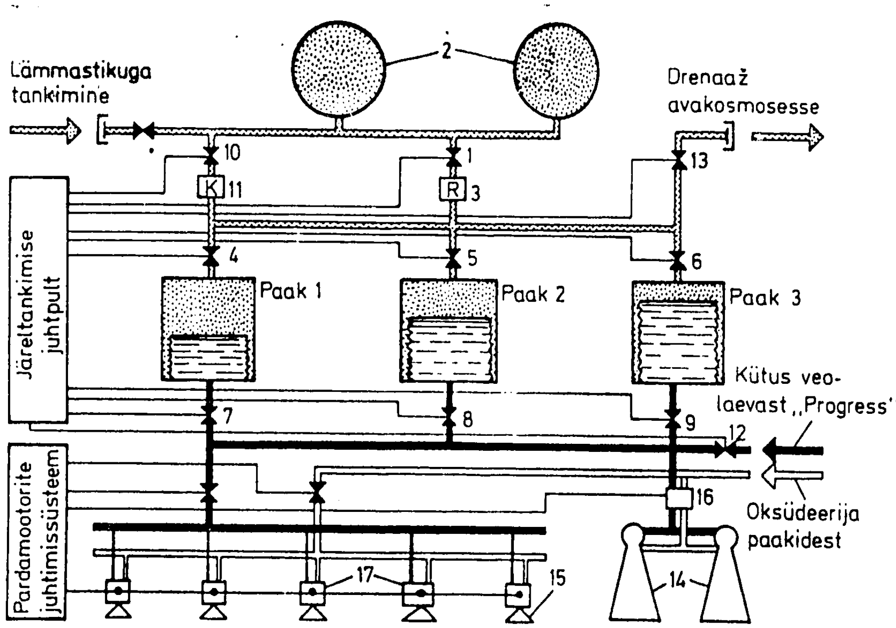
Liquid-fueled engines are widely used in space flight rockets. A rocket consisting of several stages has separate engines and tanks for each stage. After the burnout of the first stage the now useless engines are discarded and the second stage takes over, then the third. Three-stage rockets are the most popular. The following comparison illustrates the need for multistage rockets. For achieving orbital speed (almost 8 km/sec) with a one-stage rocket would mean that at least 93 to 96 percent of the starting weight would consist of fuel. The frame and payload of the rocket would thus have to be unrealistically light. In multistage rockets the share of fuel in the total weight can be reduced well below 90 percent. Fuel tanks usually serve as structural elements, especially if internal pressure has been used to have the tank walls exert tensile strength.

To characterize carrier rockets a few data of the Saturn V rockets used for the US moon missions are shown. That rocket, 112 meters high including fuel tanks, was able to bring a payload of 120 tons to orbital velocity. The launch weight of the three-stage rocket was 2,890 tons, with 2,526 tons (87.3 percent) consisting of fuel. Most of the fuel supplies were spent within 11 minutes, an average of more than 3.8 tons per second. In the rocket's first stage the five engines burned as much as 13.5 tons per second. Liquid oxygen was used as oxidizer in all three stages of the Saturn V, with the first stage fueled by petroleum, and the second and third by liquid hydrogen.

Engineers building liquid-fueled rocket engines encounter many problems posed by weightlessness in space, especially in the case of half-empty tanks. In weightless state there is no clear distinction between liquid and gas. The location of fuel in the tanks depends greatly on the wetting properties of the tank walls. Should fuel coat the inner walls of the tank, then gas will collect in the center of the container. In a reverse situation liquid droplets would remain suspended in the gas. Neither situation is acceptable in space engine fuel systems that require extreme accuracy. Gas bubbles in fuel disturb a smooth, calculated flow and combustion; in an extreme case they can even interrupt the flow of fuel components into the combustion chamber. Mixing gas and liquid in space fuel systems must be avoided. Separation of gas and liquid in the tanks with the help of movable membranes is not satisfactory, since each liquid contains dissolved gas particles. Moreover, the greater the pressure under which a liquid is stored, the more gases it contains. Should such liquid be directed into ducts at high velocity, reduction of pressure and separation of gas particles would result according to the laws of hydrodynamics. For that reason, all dissolved gases have to be removed from rocket fuel on the ground. Cleansing of the fuel from gases in a vacuum chamber is not acceptable, since not only gaseous particles but also lighter fractions of the fuel would escape into the vacuum, thus changing the fuel's chemical consistency. On the other hand, if easily dissolved gases such as oxygen and nitrogen are removed from the fuel by flowing insoluble gas (such as helium) through it (the so-called deaeration method) the requirements of space are entirely met. Before fuel that has been subjected to such cleansing process is pumped into the tanks of a space vehicle, the tanks and the tubing of the entire system must be vacuumed carefully to rid it of gases.

The above complicated requirements were successfully met by Soviet constructors in the building of a new, unified engine system for the second generation orbital station "Salyut-6." On-board engines are used in space stations primarily to correct the orbit of the station, to stabilize the station's position, and to join up with other orbital systems. An independent system of engines was previously used for each of these tasks, and often they used different fuel components. This made the fueling of space vehicles difficult even on the cosmodrome, not to mettion resupply in orbit.

The two correction engines of the "Salyut-6" orbital station (with a force of 300 kgf each) and approximately 30 docking, orientation and stabilization engines (14 kgf each) have all been joined to a common fuel system. It consists of three cylindrical fuel and three oxidizer tanks. Each tank contains a hermetically sealed accordion bellows that separates the liquid from the part filled with pressurized gas. The pressurized gas consists of nitrogen that is stored in separate tanks under a 200 Atm pressure. The pressure of nitrogen forced into fuel tanks through reductors is 20 Atm. The action of the gas pressure forces the fuel components into the engine. For engine starting only a valve has to be opened, since the fuel consists of the above-mentioned spontaneously igniting components. During space refueling the pressurized nitrogen is pumped back into its container by a 1kW compressor.



As the above diagram shows, for a fuel supply to the engine valve (1) in front of reductor (3) and valves (4), (5), or (6) located in front of the fuel tanks must be opened. Then valves (7), (8), or (9) on the fuel lines of the respective tanks must be opened, and fuel is supplied to engine groups (14) and (15). The engine is started by opening starting valves (16) or (17). Directives for this procedure arrive together with the task to be accomplished from the direction and orientation control system.

For a resupply of fuel, valves (4), (5), or (6) and valve (10) are opened, and compressor (11) pumps the pressurized nitrogen from the respective tank back into container (2). Exertion of pressure in the tanks of the fuel supply ship "Progress" and with the opening of valves (12) and (7), (8), or (9) fuel is inserted into the tanks of the space vehicle. Gas mixture that has become useless can be expelled through valve (13) into open space in the course of cleaning of the fuel system. This was necessary on board "Salyut-6" when a leak in a bellows was discovered that had resulted in the entry of gas into the fuel. To avoid an entry of gas into the other tanks cosmonauts V. Lyakhov and V. Ryumin performed a complicated repair operation in the orbital station. The fuel in the defective tank was cleansed of gas particles by centrifugation (the orbital station was put into a revolution of .5 revolutions per minute), the tubing was cleaned, the tank filled with pure nitrogen, and then isolated from the remaining fuel system.

In the history of space travel liquid-fueled rockets have reigned supreme, although solid-fueled rocket engines have been used in isolated cases of space flight. Nuclear engines as well as electrical rockets engines could open new vistas for interplanetary travel especially. But more of them in a later issue.

9240
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CONTROL OF SPACE VEHICLES

Moscow UPRAVLENIYE KOSMICHESKIMI APPARATAMI in Russian 1978 (signed to press 14 Nov 78) pp 2-4, 191

[Annotation, introduction and table of contents from book "Control of Space Vehicles", by Gennadiy Dmitriyevich Smirnov, "Nauka i tekhnicheskiy progress" (Science and Technological Progress) series, USSR Academy of Sciences, Izdatel'stvo "Nauka", 17,500 copies, 192 pages, illustrated]

[Text] The development of space rocket technology made it necessary to develop intensively the methods, means and systems for control of different types of space vehicles. G. D. Smirnov, candidate of engineering sciences, tells about this new branch of technology in his book. It describes the time and space, and statistical characteristics of the space environment, defines the tasks referable to ground-based support of space flights, describes algorithms for analysis and decision making concerning the control of space vehicles.

Introduction

In our days, exploration of space is being deployed on an increasingly broad scale; the practical use of space technology is becoming increasingly diversified and effective. Near-earth and distant space is being traversed by various space vehicles, which are launched to solve many scientific and applied problems.

The intensive development of space technology is being stimulated by the fact that its use is becoming economically justified. Cosmonautics has already furnished some valuable results to, for example, geography, geology, meteorology, navigation, communications, ecology, forecasting natural disasters, planning transport networks and a number of other scientific and national economic directions. Studies of earth from space are of particular importance to comprehensive detection of natural resources and investigation of geophysical processes.

Much attention is devoted to problems of development and practical use of space technology for the nation's needs in the national economy in the proceedings of the 24th and 25th CPSU congresses. The 10th Five-Year Plan provides for further increase in the network of space television and communications, weather forecasting by means of meteorological satellites, as well as studies of natural resources of different parts of our country.

Proper operation of a space vehicle would be inconceivable without constant and reliable ground monitoring of its time-space and functional characteristics, consideration of which makes it possible to control them continuously and, consequently to perform the targeted tasks put to them. The territorially scattered "earth-space vehicle" system contains all of the elements of complex systems: hierarchy of organization, purposefulness [goal orientation] of operation, large number of elements, existence of information connections and interaction between elements.

Development of complex control systems of this type always involves some difficulties, since one must combine in one complex many branches of science and technology. In cosmonautics, this refers to rocket dynamics, ballistics, automatic regulation, information theory, radiophysics, radio engineering, electronics and others.

On the whole, theory of "earth-space vehicle" control systems is viewed as a branch of engineering cybernetics of the man-machine type, while the systems built on its basis are referable to automated control systems with direct and feedback communication channels for giving information and commands. The aggregate of elements of this complicated system forms a closed control circuit, which consists of informative and measuring, informative-computer subsystems and controls. This construction determined the contents and structure of our book. An attempt was made there to describe the entire complex [set] of elements in the "earth-space vehicle" control system, the correlations and operation thereof.

The author expresses his sincere appreciation to Z. S. Karamov, doctor of engineering sciences, whose numerous recommendations and advice were largely instrumental in improving the book.

Contents

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CSO: 1866/999

UDC 629.785:523.3

STUDY OF LUNAR SOIL

Moscow GRUNTOVEDENIYE LUNY in Russian 1979 (signed to press 18 Dec 79) pp 2-4, 232

/Annotation, foreword and table of contents from book "Soil Science on the Moon", by Igor' Ivanovich Cherkasov and Valentin Vladimirovich Shvarev, Institute of Physics of the Earth imeni O.Yu. Shmidt, USSR Academy of Sciences, Izdatel'stvo "Nauka", 1,300 copies, 232 pages/

/Text/ ANNOTATION

This book summarizes the results of a decade of investigation of the Moon's soil, considered as an object for human engineering activity. The primary attention is focused on the lunar regolith. The specific methods used in lunar soil science are described: direct and indirect, with optical and radiophysical tools and instruments, automatic units, telemechanics and space equipment designed to operate in the lunar environment.

The authors describe the research performed by the "Luna" and "Surveyor" stations, the traveling "Lunokhod" laboratories and the "Apollo" expeditions, as well as the investigations of samples of lunar soil that have been conducted in terrestrial laboratories. The results of all of these are systematized and correlated. Special attention is given to the use of terrestrial rocks and materials for modeling lunar soil. The authors discuss possible methods for improving the natural properties of regolith, as well as the newest data on the properties of other planets' soils.

This book is intended for the broad circle of readers who are interested in questions relating to the conquest of space and specialists working in the field of Moon and Earth soil studies.

FOREWORD

The delivery to Earth of the samples of lunar soil taken by the Soviet "Luna-24" automatic station in August 1976 marked the end of the first decade of direct investigation of the Moon's surface, which decade had begun with the soft landing of the "Luna-9" in February 1966. During this time, automatic lunar stations, the "Lunokhod" traveling laboratories (USSR) and the "Apollo" lunar expeditions (United States) conducted many variegated investigations of the surface layer of soil on the Moon, drilled to depths of up to 3 meters, and delivered hundreds of kilograms of samples to laboratories on Earth.

In connection with this, lunar soil science, which was born only 12 years ago, has now developed into an independent branch of general soil science that is worth of a summation of the results of its first stage.

As on Earth, soils on the Moon are any material that is available for human engineering activity. Primarily, this means lunar regolith, which is a dispersed soil that has been subjected to the effects of meteorites and solar and cosmic radiation.

In this book, our basic discussion centers on the mechanical properties of lunar soils, which determine the conditions for landing and moving on the Moon and stipulate the possibility and methods for erecting various platforms, shelters and other structures. We describe the indirect -- astronomical and radioastronomical -- methods that have been used to study the Moon's soil and the work performed by automatic stations on its surface in areas where landings have been made and along the paths taken by self-propelled equipment, as well as lunar expeditions and automatic units that took samples for delivery to Earth. Special chapters are devoted to the study of samples in terrestrial laboratories and experiments with terrestrial analogs of lunar soils.

The instruments and methods that were first specially created for these investigations utilize the most recent achievements in machine building, automation, telemechanics and telemetry that have also opened new possibilities for the development of instruments used to study the soil of Earth. The use of these instruments and methods will make it possible to accelerate engineering-geological and soil science work and make it cheaper and more reliable, particularly in hard-to-reach areas of the Earth.

In connection with this, this book, which is intended primarily for readers who are interested in questions relating to the investigation of the Moon, will also be of interest for a much larger circle of people who are involved in soil science and the study of the Earth's soils.

At the end of the book we present data on the prospects for the artificial improvement of the engineering and physical properties of the Moon's soils by strengthening and compressing them, which may be of considerable practical importance in the future stages of its conquest by man. An appendix gives a brief summary of the first results of the investigation of the properties of soils on Mercury, Venus and Mars.

Numerous Soviet and foreign sources were used for this book. The reference data on the soils that are presented in it correspond to what had been published in the scientific press as of 31 December 1977.

In connection with their research and the publication of its results, the authors made use of the advice and support of Academicians A.P. Vinogradov and P.A. Rebinder, who have always been interested in questions relating to lunar soil science. The authors feel deep gratitude toward these scientists for their priceless assistance.

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SPACE APPLICATIONS

SATELLITE OCEANOGRAPHY

Leningrad UCHENYYE ZAPISKI LENINGRADSKOGO GOSUDARSTVENNOGO UNIVERSITETA IMENI A.A. ZHDANOVA, NO 403: SERIYA GEOGRAFICHESKIKH NAUK, VYPUSK 27: SPUTNIKOVAYA OKEANOLOGIYA in Russian No 2, 1980 (signed to press 16 Apr 80) pp 2, 163-167

/Annotation and abstracts from journal "Scientific Notes From Leningrad State University imeni A.A. Zhdanov, No 403: Geographic Sciences Series, Issue 27: Satellite Oceanography", edited by V.Kh. Buynitskiy, Izdatel'stvo Leningradskogo universiteta, 559 copies, 167 pages/

/Text/ ANNOTATION

This collection of works (No 1 was published in 1975) contains new data on the circulation of seawater and ice in the southern polar area of the world ocean that were obtained as the result of special processing and analysis of satellite observations. There are also discussions of questions relating to the determination of the temperature field and dynamics of oceanological fronts and the possibility of using satellite information for the operational support of commercial sea activities. Finally, there are explanations of new methods of analyzing satellite photographs and processing them automatically, as well as making cartographic measurements on satellite photographs.

This collection is intended for oceanographic specialists, as well as graduate students and undergraduates at universities and hydrometeorological institutes.

ABSTRACTS

UDC 551.456.1+551.456.7

NEW DATA ON THE CIRCULATION OF SEAWATER AND ICE IN THE SOUTHERN POLAR AREA OF THE WORLD OCEAN

/Abstract of article by Buynitskiy, V.Kh., Dmitrash, Zh.A., and Kuptsova, L.N./

/Text/ As the result of an analysis of satellite photographs, the authors demonstrate that the concept of stationary cyclones as a characteristic feature of atmospheric circulation in the southern polar area and the previously accepted plan of geostrophic surface water currents do not correspond to reality. They also present new data on special features of the movement of surface waters and sea ice in the southern polar area of the world ocean. Figures 10; references 15.

UDC 551.456.1+551.456.7

EXPERIMENT IN THE STATISTICAL ANALYSIS OF THE BRIGHTNESS FIELD IN AN INFRARED PHOTOGRAPH OF THE GULF STREAM REGION

/Abstract of article by Grigorkina, R.G., Likhachev, I.V., and Chistyakov, Yu.A./

/Text/ A system has been developed for processing satellite information on a digital computer that provides for the conversion of an analog signal into digital form, its entry in the computer's memory, and primary processing. With the help of the theory of nonstationary random functions, the authors have obtained data on the spatial nonuniformity of the Gulf Stream region's brightness field. Calculation of the current spatial spectral characteristics of the brightness field makes it possible to investigate the statistical structure of the surface water's temperature field. Figures 5; references 5.

UDC 551.515.2

NON-STEADY-STATE MODEL OF THE EKMAN BOUNDARY LAYER OF THE ATMOSPHERE IN THE TYPHOON ZONE OVER THE OCEAN

/Abstract of article by Fuks, V.R./

/Text/ In order to determine the tangential wind pressure in the lowest layer of the atmosphere over the ocean in the typhoon zone, the author realizes a non-steady-state model of the Ekman boundary layer with an approximation of the pressure field in the form of a bell-shaped function. The approximation parameters can be determined with the help of television and infrared satellite information. References 7.

UDC 551.561.7(268+261)

ANALYSIS OF THE THREE-DIMENSIONAL THERMAL STRUCTURE OF GULF STEAM WATERS FROM INFRARED IMAGES OBTAINED BY AN ARTIFICIAL EARTH SATELLITE

/Abstract of article by Andreyev, I.N., and Guber, P.K./

/Text/ Using infrared images obtained by an artificial Earth satellite, the authors analyze the temperature field of the Gulf Stream's surface waters. It has been established that water temperature data obtained by a satellite that corresponds to the results of actual temperature measurements also contains more detailed information on the water's thermal structure than the actual measurements do. Figures 6; references 3.

UDC 551.461.7

IDENTIFICATION OF THE UPWELLING ZONE NEAR THE NORTHWESTERN COAST OF AFRICA ON THE BASIS OF DATA FROM AN ARTIFICIAL EARTH SATELLITE

/Abstract of article by Sokolov, B.I./

/Text/ On the basis of the results of a comparison of data on cloud cover obtained by an artificial Earth satellite with data obtained during full-scale oceanological observations, the authors demonstrate the possibility of using satellite information to detect cold-water upwelling zones on the ocean's surface. Figures 2; references 5.

UDC 551.465

ON THE PROBLEM OF MEASURING THE OCEAN SURFACE'S TEMPERATURE FROM AN ARTIFICIAL EARTH SATELLITE

/Abstract of article by Staritsyn, D.K./

/Text/ The author discusses the problems involved in relating sea surface temperature as measured with a radiometer to the temperature obtained by the normal contact method. He gives a brief review of experimental observations of the difference in temperature between the boundary molecular layer and the ocean's surface. He also analyzes the special features of the thermal interaction of the sea's boundary layers and presents a method for calculating the difference in temperature between the "cold film" and the surface. On the basis of an analysis of data obtained in the Sea of Japan with a radiometer operating in the 8.0-12.5 m band and quick-response thermoresistors submerged to a depth of 2-3 cm, he derives a regression equation between the radiation and kinetic temperatures. Figures 4; references 17.

UDC 551.461.7(265)

VORTEX STRUCTURE OF THE SUBARCTIC FRONT IN THE NORTHWESTERN PART OF THE PACIFIC OCEAN

/Abstract of article by Bulatov, N.V./

/Text/ Using infrared images and the results of surface observations, the author investigated the vortex structure of the thermal field in the area of the sub-Arctic front in the northwestern part of the Pacific Ocean. He also presents new data on the dimensions of the vortices and their development and collapse. Figures 2; references 17.

UDC 551.46.07/08

INTERPRETING OCEANOLOGICAL FRONTS AND CURRENTS ON TELEVISION IMAGES ON THE BASIS OF CLOUD INDICATORS

/Abstract of article by Sokolov, B.I./

/Text/ The author makes recommendations for interpreting oceanological fronts and currents on the basis of an analysis of television images of cloud cover that have been obtained by an artificial Earth satellite. The interpretation methods are illustrated by examples. Figures 7; references 9.

UDC 551.461.7(265)

ON RELATING OPTIMUM REGIONS FOR LONG-LINE TUNA FISHING IN THE PACIFIC OCEAN TO THE DYNAMICS OF THE NORTHERN TROPICAL CONVERGENCE

/Abstract of article by Bulatov, N.V., and Sokolov, B.I./

/Text/ The authors investigate the relationship between tuna catches and the dynamics of the northern tropical convergence. Analytical data enable them to explain a number of special features in the variability of catches in the regions where commercial fishing is conducted. Satellite information was used to describe the location of the convergence zone. Figures 10; references 7.

UDC 621.391.837.2

ON THE FEASIBILITY OF UNIDIMENSIONAL FILTRATION OF TELEVISION AND TWO-DIMENSIONAL SATELLITE DOT IMAGES

/Abstract of article by Movchan, B.N., and Derevyanko, V.G./

/Text/ The authors discuss and evalute the form and magnitude of the distortions that are characteristic of dot images. They evaluate the effect of spacecraft stabilization errors on the degree of distortion of a dot image. They suggest unidimensional filtration of dot images instead of two-dimensional filtration in order to determine the structural features of an image. Figures 2; references 3.

UDC 551.46.07/08

CONCEPTUAL DIAGRAM FOR THE AUTOMATIC PROCESSING OF INFRARED SATELLITE INFORMATION

/Abstract of article by Staritsyn, D.K./

/Text/ A model of the automatic processing of results of artificial Earth satellite measurements of outgoing radiation has been developed in the Oceanography Department of Leningrad State University, and the author proposes that it be used to compile surface temperature charts. In contrast to existing models, the plan for this model contains a unit that allows for the effect of the "cold film" and a unit that makes it possible to produce a temperature gradient chart as well as representing a temperature field in the form of statistical gradients. Figures 1; references 4.

UDC 551.46.07/08

EXPERIMENT IN THE MACHINE PROCESSING OF SATELLITE OCEANOLOGICAL INFORMATION REGISTERED IN THE DIRECT TRANSMISSION MODE

/Abstract of article by Vinogradov, V.V., Likhachev, I.V., and Staritsyn, D.K./

/Text/ The authors discuss the results of the processing of satellite infrared information obtained from artificial Earth satellites in the direct transmission mode. In the processing they used data obtained by satellites in the "NOAA-2" series (United States) during their period of operation over the test range for the International Tropical Experiment ATEP-74. The results of the processing are obtained as radiation temperatures, profiles and temperature charts of the ocean. The authors compare these results with synchronous data obtained by radiation measurements made from an IL-18 airplane and surface measurements made from scientific research ships. Figures 4; references 11.

UDC 528.235

CARTOGRAPHY WITH SATELLITE SURVEYING MATERIALS

/Abstract of article by Zvonarev, K.A./

/Text/ This article has two parts. In the first, the author reviews the cartographic projections used in the practice of oceanography and meteorology, to which maps the contents of space photographs are transferred. These projections include Mercator, stereographic, equidistant azimuthal (Postel') and conformal conical. The author discusses questions relating to the transfer of the contents of geographically correlated (as was described in a preceding collection of articles) space photographs to maps using these projections. In the second part, he describes the determination of directions (azimuths), distances and areas on maps using these projections. The second part also contains auxiliary tables. Figures 19; references 14.

11746
CSO: 1866/106

UDC 629.7.014.18

'SOYUZ-22' STUDIES EARTH

Moscow 'SOYUZ-22' ISSLEDUYET ZEMLYU in Russian 1980 (signed to press 25 Sep 79) pp 15-19, 230-231

[Introduction and table of contents from book "'Soyuz-22' Investigates the Earth", joint publication of the USSR Academy of Sciences and the GDR Academy of Sciences, Izdatel'stvo "Nauka", 231 pages]

[Text] Introduction. The capacity for studying different phenomena and processes while at a great distance from the investigated object was for a long time the monopoly of astronomy. Everything which we knew until recently about the celestial bodies, large and small, close and distant, was obtained by the measurement and analysis of the electromagnetic radiation reaching us from these objects.

At first astronomers registered only the visible radiation of celestial objects: planets, stars and galaxies. Radioastronomy was born later. New directions in astronomical investigations developed as space technology was developed: submillimeter, infrared, ultraviolet, X-ray and gamma astronomy. The possibility of carrying out direct experiments appeared -- investigation of the composition and structure of planetary atmospheres with instruments carried aboard spacecraft. Then it was possible to take samples of lunar ground and deliver them to the earth. Finally came direct photography and the transmission to earth of panoramas of the landing sites of the descent modules of Soviet automatic stations and the investigations carried out by the "Vikings" on the Martian surface.

It would seem that such a logical line -- transition from remote to direct investigation -- will also in the future predominate in space investigations. But in actuality it is not all that simple. It appears that in the coming decades space vehicles will be able to carry out direct investigations only at the surfaces of the most accessible planets of the solar system. As before, the remote method will play the predominant role.

During recent years the remote method has come into use in a field of knowledge very distant from astronomy -- in investigations of what goes on around us, on the earth. It was found that by observing our planet from a distance, from the orbits of artificial satellites, it is possible to obtain information on terrestrial processes transpiring in the biosphere and atmosphere, information which is necessary to geology, agriculture, meteorology, etc.

Among specialists in the earth sciences the first to use remote methods were the meteorologists. By regularly receiving images of the cloud cover from aboard a satellite it is possible to draw conclusions concerning atmospheric dynamics. The usefulness of such information is obvious.

The results of analysis of space photographs of the earth are used effectively in geology. In particular, on the basis of observations from space it has been possible to discover new major faults in the territory of Kazakhstan and the Altay, which made it possible to compile a map of dislocations of this region and classify them with respect to their ore content. On the basis of the results a general plan was drawn up for carrying out mineral exploration work.

A geological analysis of space information is used in a study of structure of the earth's crust. It unquestionably will lead to a qualitative jump in the investigation of the patterns of structure of the earth's deep layers and mineral exploration.

Equally important is the information received from orbit on the contamination of rivers and the coastal regions of the seas and oceans and also the changes transpiring in the atmosphere of our planet. For example, atmospheric concentrations of aerosol particles were discovered on images of the earth obtained at a distance of hundreds of kilometers from its surface. It was possible to evaluate the nature of atmospheric contamination by aerosol, which is exceptionally important. Under conditions of intensive growth of the productive-economic activity of man there is not only an increase in dust content, but also a change in the gas composition of the atmosphere on which life itself on our planet is dependent. In order to prevent any such shift, much less undesirable consequences on a global scale, it is necessary to register it in its initial stages. How to do this? The "Salyut-4" station carried a spectrometer which was used in registering solar spectra through the atmosphere at the times of sunrise and sunset. Such measurements make it possible to monitor small aerosol impurities in the atmosphere and the dynamics of its gas composition.

Observations from space made it possible to obtain data which are helpful not only in the search for minerals and preservation of the environment, but also to solve a number of problems in agriculture and forestry, power production, etc. It is known that in arid and semidesert regions the development of agricultural production is held back by the shortage of fresh water. However, this shortage in some cases is only apparent. For example, the processing of photographs of the Mangyshlak Peninsula in the Caspian Sea indicated that within the limits of the studied territory there is a sector with a total area of about 2,000 km^2 where the ground water lies at a shallow depth. The exploitable reserves of fresh water there are estimated at approximately 3,500-4,000 million cubic meters.

Remote methods make it possible to determine the moisture reserves in the soil, which must be known for the planning of sowing work and determining the optimum variety of agricultural crops. The use of remote methods is also extremely effective in making observations of the course of field work, stages in the maturing of crops, timely detection of regions of damage to sown fields by predators, the degree of lodging of grains, etc.

In forestry space observations even now are being used for detecting centers of forest fires, sectors of damage of the forest by predators and diseases, and also for inventorying forest resources.

The basis for investigations of the earth from space was methods for measuring characteristic and reflected electromagnetic radiations. Naturally, it is necessary to take into account the degree of transparency of the earth's atmosphere for waves of different length and their interaction with terrestrial features.

The nature of reflected solar radiation is very sensitive to such physicochemical and biological parameters of terrestrial features as the chlorophyll content in the green mass of plants, temperature, moisture content and composition of soils, water salinity and its contamination by chemical substances and mechanical suspensions, its concentration of phytoplankton, etc.

However, a survey in the visible range can be carried out only during the daytime. In addition cloud cover in many cases completely covers some sector of the earth's surface. Accordingly, an entirely predictable solution of this problem was a broadening of the range of investigations in the infrared, submillimeter and microwave spectral regions up to the decameter wavelengths.

The region of thermal IR radiation makes it possible to detect variations in the physicochemical characteristics of natural features on the basis of their temperature changes. In particular, using IR instruments it was possible to detect sectors of vegetation damaged by diseases and having a higher temperature, detect outflows of geothermal waters, deep faults in the earth's crust and much else. The most important merit of the thermal IR range is the possibility to "see" during both daytime and nighttime.

Radio waves carry less information than the IR and visible rays. On the other hand, they are capable of penetrating through great thicknesses of terrestrial surface materials and ice and are very sensitive to the geometrical characteristics of the surfaces, and also to the moisture content in the soil.

The most complete data can be obtained by combining the information registered in different ranges, as was the case, for example, in astrophysics, in the study of the sun. What are the principal methods for obtaining and representing space information concerning the earth, taking into account the properties of different ranges of electromagnetic waves and their statistics?

The stochastic nature of the characteristic and reflected radiations of the earth and the normal distribution of probabilities of the received electromagnetic oscillations make it possible to assert that an exhaustive characteristic of such a process is its energy spectrum or any other function proportional to it (spectral brightness coefficient, spectral albedo, etc.). In this case it appears that there is no need to register the intensity of the received radiation in the entire spectrum; it is sufficient to use only several spectral zones selected in a definite way. The latter circumstance has also become the principal prerequisite for the appearance of the so-called multizonal method for investigating the earth from space.

In the optical range this method is realized by the use of multiobjective, synchronously operating cameras supplied with different light filters and films and scanning optical-electronic systems.

The exposed films are delivered to the earth; the results of measurements with the scanning systems are transmitted through a radio channel and are registered in a digital form. On the earth these digital records are decoded, after which they are transformed into black-and-white images of the surface for each of the spectral zones. Then using these photographs, assigning to each spectral zone its arbitrary color, it is possible to synthesize color photographs. What are the essence and merits of the method for the synthesis of color images? The method of synthesis of images in arbitrary colors is a logical result of the multizonal method for obtaining space videoinformation, the method for representing the results of a multizonal survey. With the matching (synthesis) of several images obtained in different spectral zones, and especially those in which the intensity variations are orthogonal, the spectral dependence of the reflective and emissive characteristics of natural features is manifested most completely. The effectiveness of such a representation of multizonal videoinformation is enhanced by the capacity of the human eye to react more sensitively to color contrasts than to black-and-white contrasts. In the opinion of specialists in the earth sciences, the interpretation of synthesized images makes it possible to detect additional, frequently extremely important information concerning the studied features in comparison with ordinary black-and-white and color images.

A key stage in remote investigations of the earth from space, carried out using scanning systems, is the stage of processing of the collected information. Here, first of all, it is necessary to contend with two very important problems: reception and registry of gigantic flows of information, on the one hand, and the need for its rapid processing, on the other. For example, modern multizonal scanning systems ensure the output of videoinformation at a rate exceeding 1, and sometimes even tens of megabits per second. In addition, in many cases it is necessary to have an extremely operational output of data from remote observations to users at virtually a real time scale. Evidently, solution of these problems is possible only on the basis of automated computer processing of information, taking into account the presence of corresponding mathematical and technical support.

The mathematical support includes the development of specialized programs and algorithms for the processing of multizonal information on the basis of the cluster and divergent analysis methods, the maximum similarity method and other methods in the theory of statistical solutions, and also a number of standard transformations, for example, of the Fourier multidimensional transform type.

Technical support includes, first and foremost, high-speed processors and external devices for the operational, magnetic and photographic registry of videoinformation.

A comparison of the speed and productivity parameters of modern computers with the volumes of space videoinformation reveals that they cannot be used in constructing systems for the processing of data at a real time scale on their basis. The need therefore arises for a specialization of electronic computers applicable to the specific peculiarities of such information. This specialization applies for the most part to the external devices of the computers. Their make-up must be supplemented by devices for the input and output of images and means for operational "man-machine" communication of the type of displays with half-tone and color images.

The processing of space information is based on the same schematic diagram which is well developed and widely used in astronomy. This is the conventional separation of stars into a finite number of classes on the basis of the characteristics of their spectral radiation. However, there is also a definite scheme for the processing of space videoinformation concerning the earth, related to the diversity of types and states of the studied terrestrial features and phenomena, on the basis of measurements of their spectral characteristics.

The processing of space videoinformation on the earth can be broken down into preliminary and specialized. In the course of preliminary processing express information is extracted, for example, information for the purpose of warning about various catastrophic phenomena; distortions and interference in the image are eliminated; the data are represented in a form convenient for further processing. Specialized processing, carried out in the interests of different branches of science and the national economy, involves primarily the identification (interpretation) and classification of natural features on the basis of their spectral criterion, similar to the classification of stars. The final product of this processing is specialized maps: geological, geobotanical, soils, etc. We will illustrate the methods for the interpretation of space videoinformation in several specific examples.

The interpretation of space photographs, for example, for agricultural purposes, is carried out in the following way. Sectors of the territory which are sown with a definite crop are selected. The spectra of reflected and emitted radiation are registered in each stage of its maturing. Such surveys are carried out directly from the earth and from aircraft. The spectrum characterizing a particular crop is stored in the computer memory.

A similar procedure is also carried out with other agricultural crops, forests, water bodies, etc. An extensive "archives" of spectral images is accumulated in the computer memory. A photograph of the earth's surface transmitted from a satellite is analyzed by the electronic computer. The latter finds the elements of one and the same spectral type, outlines them, reckoning the areas, and then makes a comparison with the spectral information present in the memory and communicates to users data on the state of the studied object and its dynamics. For example, this can be information on the stage of maturing of crops, possible damage to them by predators or lodging, course of harvesting work, etc.

The interpretation of information in the interests of geology and the search for minerals is carried out in a similar way. It is well known that deposits of different materials usually are adjacent to definite geological structures, for example, tectonic faults. For example, at the margins of arched uplifts petroleum deposits are usually situated alongside faults. Typical examples of geological relief are subjected to a multizonal survey, the results of which are stored in the computer memory as keys. The geological structures discriminated on the images obtained from space for the investigated regions are compared with examples stored in the computer memory. Those which appear to be close to some key are regarded as promising for mineral exploration. The final checking is carried out by geological prospecting parties.

True, one difficulty is encountered here. Extensive sectors of the earth's surface are almost completely covered by vegetation masking the geological structures. It is no accident that at the present time the most valuable results from space geological prospecting have been obtained in desert and semidesert regions. However, it is entirely possible to overcome this difficulty. The fact is that different geological formations correspond to a specific landscape which is characterized by a very definite type of vegetation. This is especially conspicuous on small-scale space photographs. Thus, the vegetation itself can serve as a sort of indirect indicator of the presence of various natural features of interest to geologists. Accordingly, a geological analysis of "overgrown" sectors of the earth's surface is carried out in two stages, one might say: the nature of the vegetation is used in determining the characteristics of the landscape, and these are used in judging the presence or absence of minerals. Thus, here, as in most other fields of application of space methods for studying the natural resources of our planet, the progress of investigations is determined by the storage in the computer memory of a larger and larger "archives" of spectral images.

The situation is somewhat different with respect to the interpretation of space information in the interests of the fishing industry. In this case the users are extremely interested in indirect indicators of regions where fish are probably present, specifically: the boundaries of areas of marked upwelling of deep oceanic waters, the presence of fatty spots left by the fish at the surface, the concentration of phyto- and zooplankton, water temperature, etc. By discriminating on multizonal images of the sea surface the regions which are characterized by one indicator or another or a group of indicators, it is possible to give recommendations to fishing ships on the optimum organization of the fishing enterprise.

Finally, several words concerning the development of the methods for the interpretation of space videoinformation. In order to solve this problem in the territory of the most representative regions it is the practice to select test polygons with different standard sectors whose characteristics are well known. Then in these sectors a "multistage" survey of their spectral characteristics is carried out from surface towers, helicopters, aircraft and space vehicles. The result of such surveys is a study of the influence of the atmosphere on remote measurements and the creation of a so-called "archives" of spectral images characteristic for the particular regions.

For investigations carried out in different geographical regions and in the interests of different branches of science and practice it may be necessary to use different regions of the spectrum, different spatial, energy and spectral resolutions. In the future it will be possible to create specialized survey instruments and satellites for special purposes -- some for geology, others for agriculture, etc. Now, however, there is a need for optimizing the requirements on the technical means for investigating the earth from space in order to create a unified space complex which to the greatest degree will satisfy all the needs of users for information concerning the earth's resources and concerning the environment.

What has been said here is evidence that the problem of study of the earth from space has two principal components: physicotechnical and geointerpretation. The first is related to solution of the problems involved in the optimum synthesis of on-board data-measuring complexes operative under the real conditions of solar radiation, reflected radiations of the earth's surface and the influence of atmospheric factors. Within the scope of the physicotechnical component of the problem there are special problems in the processing of data along both technical and mathematical lines, together ensuring solution of the problems of conversion from the totality of remotely measured parameters to the physical characteristics of the investigated objects. Geointerpretation is a concept bringing together a complex of problems related to the use of space information in the interests of scientific and practical problems of study of the earth.

Space measurement complexes for the investigation of the earth's natural resources and monitoring of the state of the environment can be divided into two groups. The first includes instrumentation for the optical and radio ranges of electromagnetic waves, information from which is transmitted to the earth through radio channels and which must be processed automatically on the basis of the extensive use of computers. On-board instrument complexes of this type are carried aboard the "Meteor" satellites (USSR), "Landsat" satellites (United States) and others. They are used in the solution of problems requiring the routine collection, processing and use of information concerning the earth.

The second group includes means for photographing the earth's surface from orbital altitudes. In this case the exposed films are delivered to the earth and after development are processed for the most part by visual-instrumental methods on the basis of the broad use of optical photometric and photogrammetric equipment. The photoapparatus makes it possible, in the visible and near-IR spectral regions, to obtain images characterized by the highest detail and accuracy of representation of the shapes and sizes of terrestrial features. This predetermines the desirability of using space photoinformation concerning the earth for solving a broad range of scientific and practical problems where there are no requirements for the operational collection and use of data. Space photoinformation makes it possible to revise topographic maps and compile different special maps. For the latter, in particular, it is effective to use multizonal photographs from satellites.

The flight of the "Soyuz-22" spaceship and the "Raduga" experiment carried out on the basis of this flight were devoted to the perfecting of methods and equipment for photographing the earth from space. This experiment in its physicotechnical aspects was based on multizonal photography, and in its geointerpretation aspect -- on the visual-instrumental interpretation of images of the earth's surface employing color images obtained by the optical-photographic synthesis of multizonal space photographs. The MKF-6 multizonal space camera carried aboard the "Soyuz-22" was used in obtaining thousands of photographs of the territory of the USSR and the German Democratic Republic.

A special feature of the "Raduga" experiment was that in addition to perfecting the methods of multizonal space photography it pursued the goal of creating standard apparatus for regular investigations of the earth's natural resources using space technology and by means of carrying out a complex of surveys of extensive territories in the interests of solution of specific problems in the national economy.

This book convincingly demonstrates that the flight of the "Soyuz-22" spaceship has successfully completed an important stage in cooperation under the "Intercosmos" program on the part of scientists and specialists of the USSR and the GDR in the field of development of means and methods for making photographic investigations of the earth's natural resources.

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AEROSPACE METHODS OF STUDYING SOILS

Moscow AEROKOSMICHESKIYE METODY IZUCHENIYA POCHV in Russian 1979 (signed to press 14 Dec 79) pp 3-6, 279-280

/Foreword, introduction and table of contents from book "Aerospace Methods of Studying Soils", by Valeriy L'vovich Andronikov, Soil Institute imeni V.V. Dokuchayev, All-Union Academy of Agricultural Sciences imeni V.I. Lenin, Izdatel'stvo "Kolos", 3,400 copies, 280 pages/

/Text/ FOREWORD

This book, which is presented to the reader's attention, is the first experiment in monographic correlation of materials for studying soils that were obtained by aerospace surveying. In connection with the rapid development of space methods for doing research in the USSR, the United States and other countries, there have arisen a number of new fields in this area: space meteorology, aerospace geology, space cartography, space geography and others that have as their goal the further investigation of our planet's resources.

Materials provided by automated artificial satellites, manned spacecraft and orbital stations play a substantial role in the investigation of land resources. At the present time we have developed a whole spectrum of photographic and television systems and methods for surveying the Earth's surface with the help of aerial and space equipment, with subsequent visual-instrumental and opticoelectronic processing of the materials that are obtained.

By using remote aerospace methods, in the near future we may be able to solve many problems relating to the quantitative and qualitative accounting for and studying of the USSR's soil resources. This monograph will be of assistance in solving these problems. It contains an analysis of the methods used to study the soil cover from the experimental "Meteor" satellites, the "Soyuz" spacecraft and the "Salyut" orbital stations. The capabilities of multizonal surveys with the MKF-6 camera (the "Raduga" experiment) are demonstrated from the aerospace viewpoint.

The author presents the results of many years of research in using black-and-white, spectrozonal, multizonal and multispectral aerial and space photographs to study the soil cover, as well as data from infrared, radiothermal and radar surveys for soil and agricultural purposes.

Academician V.V. Yegorov, VASKhNIL /All-Union Academy of Agricultural Sciences imeni V.I. Lenin/, and Doctor of Geographic and Agricultural Sciences Yu.A. Liverovskiy

INTRODUCTION

At the present time, the use of aerospace materials for studying soil cover is attracting the attention of Soviet and foreign investigators.

In the "Basic Directions for the Development of the USSR's National Economy for 1976-1980," the necessity of expanding research in the use of space facilities for studying the Earth's natural resources is pointed out. Remote aerospace methods involve objective, high-speed, automated systems for collecting and processing information about the state of soils and agricultural lands and crops. Control of agricultural production can be organized more efficiently on this basis.

One of the new fields in the area of utilizing aerospace methods to study soils and plantings of agricultural crops is the development of multizonal and multispectral aerial and space surveying. The essence of this is that the same section of land surface is photographed simultaneously in several narrow bands of the spectrum. As a result, pictures are obtained that carry the most information about the soil cover and agricultural crops.

Infrared photographic, photoelectronic and radar surveying are promising for use in agriculture, to study the soil cover and plantings. The latter can function in the absence of visibility (through clouds and even at night). Radar pictures can be used to determine moisture, some structural elements and the complexity of the soil cover, the composition of the soil's upper levels, and types of agricultural crops.

In comparison with aerial surveying, surveying of the soil cover and plantings of agricultural crops from space makes it possible for the first time to see, both objectively and simultaneously, soils and agricultural crops over large territories, along with separate mountain systems and the vertical zonality of the soil and vegetative cover, and the nature of irrigation and drainage systems as a whole. Another important feature of space surveying is that in space photographs there is an objective generalization of the soil cover and, in addition, these photographs make it possible to interpret the soil cover in separate regions that are frequently hard to reach. The utilization of space materials will help us conduct a more thorough and objective study of soils.

One of the basic and principle features of surveying from space is the timeliness with which we obtain information about the state of the soil cover, the nature of the snow melt, the development of erosion processes, and the state of agricultural crops on a countrywide scale. Yet another special feature of space surveying is the possibility of a rapid repetition of a survey. This is especially important studying rapidly developing, dynamic soil and agricultural processes taking place on the Earth's surface.

On the one hand, aerospace (remote) methods using the appropriate receivers installed in flying (both aerial and space) craft register the reflection of sunlight from soils and vegetation and, on the other hand, intercept the intrinsic radiation from the soil and vegetative cover on the Earth's surface.

The use of aerospace methods is based on the fact that the absorption, radiation, scattering and reflection of electromagnetic energy by different soils and plants is selective and specific for each type of soil and agricultural crop.

The soil cover is "decoded" according to its image in aerial and space photographs, including multizonal ones. In connecting with this, we are studying decipherability and the possibility of using aerospace photographs obtained in different bands of the electromagnetic spectrum to investigate the soil cover, and are working out determinants for decoding soils.

Research in soil decoding has been conducted in the steppe, dry-steppe and desert areas of our country.

Research in decoding the soil cover, agricultural crops and virgin vegetation has been conducted using black-and-white, color and spectrozonal aerial photographs, multizonal aerial photographs (green, red and infrared bands) obtained with the AFA-39M complex during surveys in 1973-1975, multispectral aerial photographs obtained with a scanner, black-and-white space photographs taken from the "Soyuz-9", "Salyut-1" and "Salyut-4," and multizonal space photographs taken from the "Soyuz-12," "Salyut-4," "Soyuz-22" and the experimental "Meteor" satellites.

In this work we also analyzed foreign black-and-white and color space photographs taken from the "Gemini" and "Apollo" ships and multispectral space photographs in four spectral bands taken from the "Landsat" ERTS satellite over the territory of the USSR and other countries.

The combined use of aerial and space photographs is the most optimum variant for interpreting soil cover and vegetation images. In connection with this, the interpretation of aerial photographs is used most successfully in key sections to study elements of the soil cover's structure, since in the interpretation of space photographs soil scientists run into a generalized image of the soil's surface. The investigation and interpretation of aerial and space photographs begins with a preliminary period of lab work, the value of which increases with the use of multizonal photographs and stereoscopic, opticoelectronic and photometric equipment for processing the photographs and films.

The interpretation of aerospace photographs includes terrestrial field work to examine the soil cover and plantings of agricultural crops and check the results of lab interpretation. In this work, materials from the book on the fields' history, allowing for productivity data, are used. In addition to the field investigation data, in both the lab and field interpretations the researchers use existing soil and topographic maps on various scales, plans for the allocation of agricultural crops and materials available in the literature.

The stereoscopic investigation method, with a stereoscope and an interpretoscope, is used to analyze aerospace materials. The spectral reflective capacity of soils is measured by an SF-10 spectrophotometer, using air-dried samples. An MF-4 microphotometer and the quantitative visual-instrumental method of decoding, using a modern "Kvantimet-720" electronic-optical image analyzing instrument, are utilized in the investigation of aerospace photographs. Chemical analyses of soils are performed in the Soil Institute's Mass Analysis Laboratory. In addition to the experimental surveys performed by the Soil Institute, extensive use has been made of materials from experimental multizonal flights made by the USSR Academy of Sciences' Institute of Space Research. A significant part of the space photographs were obtained from the "Priroda" State Center of the Main Administration of Geodesy and Cartography of the USSR Council of Ministers and the GosNITsIPR of the USSR State Committee for Hydrometeorology and Monitoring of the Environment.

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11746
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USING AEROSPACE INFORMATION TO INVESTIGATE LAND WATERS

Leningrad TRUDY GOSUDARSTVENNOGO ORDENA TRUDOVOGO KRASNOGO ZNAMENI GIDROLOGICHESKOGO INSTITUTA: ISPOL'ZOVANIYE AEROKOSMICHESKOY INFORMATSII V ISSLEDOVANIYAKH VOD SUSHI in Russian No 276, 1980 (signed to press 8 Aug 80) pp 2, 130

/Annotation and table of contents from journal "Works of the Order-of-the-Labor-Red-Banner State Hydrological Institute: Using Aerospace Information in Investigations of Land Waters", edited by V.V. Kupriyanova, Gidrometeoizdat, 650 copies, 131 pages/

/Text/ ANNOTATION

Various authors present different aspects of the use of information obtained by artificial Earth satellites in hydrological investigations related to the determination of the characteristics of snow and ice covers, in addition to explaining questions concerning the investigation of land waters with the help of aerial photographic surveying and radar studies of the Earth's surface.

This collection is intended for hydrologists and specialists in allied fields who utilize aerospace information in their research.

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11746
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UDC: 911.2:629.78+528.94

DEVICE FOR DYNAMIC ANALYSIS OF MULTIZONAL IMAGES

Moscow ISSLEDOVANIYE ZEMLI IZ KOSMOSA in Russian No 3, May-Jun 81 pp 113-114.

[Article by Yu. L. Kravchenko, G. M. Mamontov and G. F. Sitnikov, Special Design Office for Scientific Instrument Building, Siberian Department of the USSR Academy of Sciences, Novosibirsk, submitted 11 Feb 80]

[Text] The Synthesizer, a device for dynamic analysis of multizonal photos, is being developed in the Special Design Office for Scientific Instrument Building, Siberian Department of the USSR Academy of Sciences, and it will become part of the equipment of the Geophysical Data Processing Center of the Computer Center in the Siberian Department of the USSR Academy of Sciences. The Synthesizer makes it possible to analyze the color image obtained from three multizonal photos, sorting various transformation combinations, examining the result and making dynamic corrections when necessary. The controls of the Synthesizer enable the operator to rapidly select the required conversion and make the necessary measurements. The feasibility of altering numerous parameters and instant observation of the result on the synthesized image makes it possible to distinguish even images with minimal contrast, for example, to distinguish species of trees in a forest.

The photographs are placed on ground glass, which is lighted from the bottom by an illumination system. The photos are superimposed according to reference points using mechanical alignment devices with precision of 0.05%. Three objectives with variable focal distance transfer the images of multizonal photos to the targets of video camera vidicons [photoconductive camera tubes]. Use of objectives with variable focus distance operating synchronously makes it possible to dynamically alter the conversion scale by 4 times. This permits viewing both the entire image and fragments thereof. The location of all photos on one moving carriage permits processing an enlarged fragment of any section in the working field of the photo.

In the video camera, which operates in the standard television mode, the optical image is transformed into an electrical video signal. After preamplification, video signals from three video cameras pass into the control unit of the video cameras, then through coaxial cables to the input of an analog processor.

The analog processor permits processing in two main modes: synthesis of the color image from three multizonal photos and pseudocoloring of the overall signal from three, two or one video camera.

In the first mode, the output video signals U_R, U_G and U_B (input video signals for color monitor) are described by the following equations:

$$U_R = K_r(K_{1r}U_1+K_{2r}U_2+K_{3r}U_3) + U_{r\ bv}$$

$$U_G = K_g(K_{1g}U_1+K_{2g}U_2+K_{3g}U_3) + U_{g\ bv}$$

$$U_B = K_b(K_{1b}U_1+K_{2b}U_2+K_{3b}U_3) + U_{b\ bv}$$

where U_1, U_2, U_3 are video signals from the first, second and third video cameras, K_r, K_g, K_b, K_{ir}, K_{ig}, K_{ib} are coefficients of summation of video signals (i--video camera number), $U_{r\ bv}$, $U_{g\ bv}$ and $U_{b\ bv}$ refer to bias voltage.
Any of the coefficients of the matrix can have either a positive or negative value from 0 to 1.5. By altering the coefficients, the researcher is able to synthesize the color image, examine the result on a real-time scale and distinguish information in the analyzed image in the best manner.

In the second mode, voltage U_Σ is analyzed:

$$U_\Sigma = K_1U_1+K_2U_2+K_3U_3$$

Coefficients K_1, K_2 and K_3 can also change from 0 to 1.5 and have either negative or positive values. The video signal of U_Σ can be flashed on the monitor screen in black and white or artificial colors. When showing U_Σ in artificial colors, the video signal is pseudocolored on eight levels. The size and position of each level can be changed by the operator. The area of image section on any of the eight levels of the video signal can be measured with a digital gauge contained in the analog processor.

Processing of images and measurement of area can be confined to a rectangular "window." The position and size of the "window" are set by the operator.

The linear dimensions of the object can be measured with a controllable cursor. The cursor is displayed on the screen in the form of a horizontal and a vertical line, the position of each of which can be measured with a digital gauge.

The analog processor permits measurement of the U_Σ videosignal at the point shown by the cursor and formation on the monitor screen of the section of U_Σ video signal along vertical line of the cursor.

Multizonal photos taken with an MKF-6 camera and scanning equipment can be processed on the Synthesizer.

There is a mode of synchronization of the Synthesizer for plugging in to other devices for processing images and self-contained operation.

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SPACE POLICY & ADMINISTRATION

'AIR & COSMOS' ON POSSIBLE SOVIET LUNAR PROGRAM FOR 1980'S

Paris AIR & COSMOS in French No 848, 21 Feb 81 pp 37-38,40

[Article by Albert Ducrocq: "Soviet Program for This Decade: Approach to Manned Lunar Missions"; passages enclosed in slantlines in boldface]

[Text] Paralleling the pursuit of their Salyut program, the Soviets will very likely make a dash, during the 1980's, along the road to outer space: We must expect to see their manned space vehicles making incursions into the lunar domain...

We base this presumption on several considerations, the first being the possession by the Russians--with their Soyuz T--of the appropriately maneuverable vehicle to enable them to carry out the operations they had to abandon at the time of the Zond spacecraft. It is reasonable to expect that the Soviets, armed now with the Soyuz, will seek their revenge: They were compelled to remain virtually earthbound while the Americans carried out their Apollo program. The Soviet thrust is all the more to be expected in that in the coming years it is the Americans who will find themselves compelled to remain in near circumterrestrial space. Certain statements by Soviet leaders moreover appear to us entirely characteristic: They make clear, in a manner totally devoid of ambiguity, the Soviet intention to travel far from the bounds of earth.

To effect what operations?

Therein lies the question. A program of manned lunar flights would not fail to make momentary headlines. But disappointment would set in very rapidly if the Russians showed themselves capable only of effecting, 12 years later, a mere part of the feats accomplished by the Americans long ago.

Soviet astronautics officials are of course the first to have understood this, and we can therefore wager that their lunar program will in no way resemble the Apollo missions, the psychological considerations we have mentioned being compounded by technological imperatives.

We must understand, actually, that in its time the Apollo program represented an impressive technological breakthrough in terms of the means used to carry it out--the Americans having committed their entire avant garde industrial potential to enable their astronauts to go for a walk on lunar soil--as well as a specifically spatial breakthrough. For its Apollo program, NASA did not hesitate to build a rocket capable of placing in orbit payloads /10 times greater/ than those that had long been satisfactory for other programs; nor, generally speaking, did it hesitate to put into production specially designed equipment for the moon landing.

Relentless Progressivity

The Russians show no such intent. They build rockets having a certain capacity and spacecraft having certain maneuverability characteristics, and their space policy consists of doing what they can with the two. The means are not designed to a specific end; the end is chosen according to available means, so that to each generation of means there corresponds a certain category of missions. And this has the imprint of a relentless progressivity. At this point in time, although the Soviets are currently able to orbit the moon, we doubt that they could contemplate landing manned spacecraft on its surface. A lunar walk requires a powerful additional impulse. It demands a leap in the size of launchers and involves moreover "razor-edge precision work" that is conceivable only after a profound mastery of the maneuvers, a mastery the Russians are only now in the process of acquiring.

We must add: From a purely scientific viewpoint, new lunar walks do not appear to be a near-future necessity. The astronauts installed five ALSEP stations on the lunar surface, 23 of whose apparatuses continued transmitting, until 1977, a vast amount of information; it was /voluntarily/ that an end was put to further reception from them, because the specialists estimated they already had too much information to evaluate. Moreover, only a small fraction of the lunar samples being kept at Houston has been utilized. A new edition of the Apollo missions could hardly be justified...

But this only lends greater interest to the question: What, then, will the Russians do if they are not even contemplating a lunar walk?

Well, there are many interesting things to be done. And these become evident if we consider the "pinpoint" nature of the Apollo program. With the equipment at their disposal, the Americans could have done an enormous number of things, and they had indeed contemplated doing them: Let us recall the Apollo Applications program, which the United States abandoned to finally settle for /one/ use to be made of their equipment, unquestionably the most outstanding of its possible uses and at the same time the use for which that equipment was indispensable. But in doing this, they deprived themselves of the opportunity to carry out a very large number of operations for which incomparably less sophisticated equipment would have sufficed.

This means that the Americans have left many firsts up to the Soviets. And the latter will also not fail to make the best possible use of the trump card they now hold: /endurance/.

The Apollo missions, it will be recalled, were actually of short duration. They were designed not to exceed the limits of the timeframe involved in an earth-moon-earth flight, allowing for some tens of hours to be spent on lunar soil. And in any case, the medical studies conducted in the United States prior to the Apollo missions had not been approached from the standpoint of long flights in space: The record was the Gemini 7's 15-hour flight by Lovell and Borman. It was only thereafter, with the Skylab flights, that this situation changed. The Russians, on the other hand, now enter their lunar-missions phase straightaway after having effected flights of even over 6 months duration, armed with all the experience these flights have given them.

Initially, of course, the Soviet long-distance flights will be of short duration: They will essentially be testing the techniques of flying over long distances and returning. But it is reasonable to suppose that the Russians will very quickly seek to benefit from this asset bestowed on them by their Salyut program, and that their long-distance missions will be designed around their endurance capability.

A priori, within the dimensions of the lunar domain, the endurance characteristic can be exploited in two ways.

Selenostationary Points

To begin with, it is possible to contemplate sending manned spacecraft for earth to benchmarks in the earth-lunar system and /having them remain there for a certain time/.

During the first years of the space age, attention was drawn to these benchmarks. But strangely, they were soon somewhat forgotten. We expect them to be brought out again to the foreground of coming events. These benchmarks, which celestial mechanics specialists prefer to call Lagrangian points, are four in number:

Point 1, the best-known, located between the earth and the moon, is the so-called point of equilibrium at which the gravitations of the two spatial bodies neutralize each other. This takes place /not/ at 346,000 km from the earth (and at 38,000 km from the moon, for a configuration involving a total distance of 384,000 km between the two bodies) as was thought by Jules Verne, but rather slightly closer to the earth. Actually, the point cannot be reckoned as one of static equilibrium, but rather as one of dynamic equilibrium, since the point in question, situated in the earth-moon segment, revolves around the earth as does the moon. Thus, the equilibrium under consideration is between:

--on the one hand, the earth's gravitation, and

--on the other, the moon's gravitation augmented by the centrifugal force generated during one rotation around the earth.

The point of dynamic equilibrium thus defined is at 325,000 km from the center of the earth and at 59,000 km from the center of the moon, that is, a some 57,000 km from the moon's surface. It is a /selenostationary point/ straight above or below the center of the visible side of the moon, and is thus the ideal point from which to observe constantly the visible side of our satellite. Such observation, however, is being carried out today from the surface of the earth, using considerable equipment and facilities, so that Lagrangian Point #1 is to some extent the least interesting of the four.

Lagrangian Point #2 is straight above or below the center of the dark side of the moon. It is the point, at 470,000 km from the earth, at which there is equilibrium between:

--on the one hand, the gravitations of the earth and the moon, and

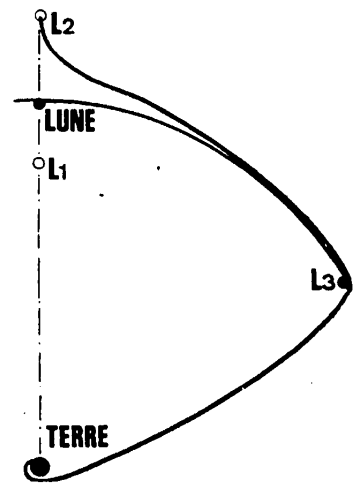
--on the other, the centrifugal force developed by the rotation around the earth.

This Lagrangian Point #2 is extremely interesting, in that it enables a study of the dark side of the moon (about which much less is known than about the visible side). Above all, a spacecraft situated at this point would be the specifically indicated command post for unmanned spacecraft (second-generation Lunokhod) by means of which a broad reconnaissance of the dark side of the moon could be carried out.

A conceivable operation would consist of generating, from a low earth orbit, an impulse of 3 km/s to transfer a manned spacecraft into a 280/470,000-km orbit, at the apogee of which an impulse of 1 km/s would anchor the spacecraft at Lagrangian Point #2, where it would remain for weeks, if not months, directing the work of the robots on the dark side of the moon. Its return to earth would be accomplished inversely, starting with a 1-km/s impulse. This means that the total cost of the operation would add up to 5 km/s. A 7-ton spacecraft would have to be associated with a module of some 20 tons. This operation would be very interesting, spectacular, relatively low-cost and risk-free.

Lagrangian Point #3 is situated on the moon's orbit 60° behind it. It would be slightly less costly to reach than Point #2. Its interest would be from another standpoint: that of studying the fossil substances that may have accumulated in this gravitational recess.

Lagrangian Point #4 is located on the moon's orbit 60° behind, symmetrically about the earth-moon axis with respect to Point #3. Obviously, it could be used to carry out the same studies as from Point #3. It is found, moreover, that these Lagrangian points (even taking into account the slight displacements to which they are subjected with variations in the earth-lunar distance) could provide the nodes of an interferometric lattice for experiments in radio astronomy. It will be noted that a "milk run," starting from earth, would enable a visit to be made cheaply to Points 3, 2 and 4 successively.



This "milk run" diagram indicates how the three Lagrangian points of most interest could be explored during a single mission. The earth-moon flight would require an initial impulse of 10.9 km/s, followed by a 0.81-km/s impulse at 484,000 km. After remaining at L3 a certain length of time, the flight from L3 to L2 could be effected very economically over a period of 1 month at a cost of 0.09 km/s. And the return would be effected systematically in accordance with the L2-earth trajectory (via L4, the symmetrical of L3 with respect to the earth-moon axis), so that the total cost of the operation would come to 12.7 km/s, or approximately the cost of putting a satellite into geostationary orbit.

Figure-8 Orbit

The endurance factor will be exploited in another way if we assume the placement of a spacecraft in an earth-moon orbit and allowing it to effect a certain number of revolutions, /which has not yet been done/. An earth-moon orbit would have a spacecraft orbiting both the earth and the moon; it would describe a curve which, in a frame of reference that takes into consideration inert space, would be a rosette. Or, it could be conceived as a curve in the form of a figure 8, whose loops would contain the earth and the moon respectively. Such figure-8 orbits can be can be perfectly stable (we have such examples in the asteroids on the scale of the solar system). They are especially economical (from a low earth orbit, they require an impulse of only 3 km/s) and obviously they can be maintained as long as desired, making it possible to carry out a number of experiments exploiting the large variations in velocity with respect to the moon and with respect to the earth.

These figure-8 orbits would of course enable studies of the earth and the moon. But their real interest is another, in that, to begin with, such an orbit could, if it describes a purely ballistic motion, constitute an /ultrasensitive gravitational-variations indicator/ whose motional irregularities would bring out in fine detail all the components of the earth-moon system, provided, of course, the flight involved a sufficient number of revolutions (each lasting on the order of 1 week); hence the interest in flights of long duration...

Once the scientists have acquired a certain experience with such ballistic motions, it will be necessary to apply, at given times, path corrections to enable fine-tuned exploitation of all the earth-moon system's gravitational resources and the possibility of learning how to escape from it in a precise and less costly manner. Let us consider the launching of a weight attached to a string: First, one wields it in the manner of a sling, waiting then to release it at the precise moment one senses the proper motion has been reached.

Similarly, manned planetary missions could conceivably be prepared by first putting a spacecraft into earth-moon orbit for a period long enough to check all equipment and ensure that the injection of the craft into the solar system will take place precisely as planned.

Be that as it may, this brings us to the subject of our next article: In the minds of the Soviets, planetary missions and moon missions must be intimately linked together in any program of flights into deep space...

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'AIR & COSMOS' ON POSSIBILITY OF SOVIET MARS-VENUS FLIGHTS

Paris AIR & COSMOS in French No 849, 28 Feb 81 pp 44-45

[Text] Ever since it was first decided to leave the earth behind, planetary and lunar missions have been closely linked in Soviet thinking.

Indeed, we know the cost of missions within the earth-moon system: they require starting from low earth orbit, the creation of impetus of 3 to 5 km per second. Now that is already enough to effectuate very nice trips in the solar system, if duration is not a problem, and it will not be for the Russians. We have continued to emphasize this: unlike the Americans, who went to the moon before having conquered the time barrier--we mean before having achieved long piloted flights--the Soviets are going to undertake exploration of the earth-moon system with the advantage of duration. And, to start, the first Russian mission through the solar system should follow shortly on that exploration...

What mission?

Our faithful readers, who have followed us, will not fail to recall No 427 AIR & COSMOS. It was 18 March 1972. At the time, some news was making a great stir: the academician Vasiliy Pavlovich Mishin (director of the Central Institute for Scientific Research on Medium Machine Building) had just been given responsibility for a space program which, one was given to understand, was intended to prepare for an overflight of Mars by piloted vehicles. Mishin was responsible, it was said, for recruiting a team of engineers and technicians to develop a module for a voyage in the solar system, and also to head the training of cosmonauts for such a mission.

Equitemporal Orbit

At that time we speculated that the Russians would try to exploit the possiblities offered by "equitemporal orbit." The principle is simple: it exploits Kepler's third law, by the terms of which the orbital period of a body revolving around a gravitational center depends solely on the major axis of its orbit. Thus the earth describes a very weak eccentric orbit around the sun, the major axis being 299 million km. That being the case, let us imagine that a rocket leaving the earth is placed on a solar orbit. Whatever its eccentricity, the orbital period will be 1 year if its major axis is 299 million km, and that is to say at the end of 1 year, there will automatically be a rendezvous between the rocket and the earth. The rocket and the earth will in the meantime have each have followed its own path, but they will meet again at the same place at the same time.

Now this property of the equitemporal orbit certainly seems to be what the Soviets have had in mind for their first missions outside the earth-moon system. One must therefore summarize the scheme, but simply change the dates. In 1972, it was thought that an overflight of Mars was plausible in 1978. Today one must be content to envisage the operation sometime in the next decade or so. But it is remarkable that one always continues to envisage it in the same way. And that is completely characteristic of one Soviet trait: they persevere. For a long time they endured disappointments in their planetary experiments with unmanned rockets: they studied all aspects of the problem, until they arrived, with respect to Venus, at the success which we all know. On the other hand, they had many problems in developing their Soyuz: in 1981 they have the vehicle they had hoped to start using in 1966, but the fact is that it is the very vehicle that they proposed to build. Their delay was considerable, but they reached their goal, with no concessions, and particularly without resort to the easy solution which would simply have consisted of enlarging the cabin. It is the same with their planned piloted planetary missions. At the present time all the information in our possession leads us to think that they are still trying to fulfill the 1972 plan, a plan which in the meantime has been, needless to say, studied in depth and optimized with all the ingenuity of which the Soviets are masters, the preparation of these piloted planetary missions taking place in hopes that they can follow the long-duration exploration within the earth-moon system.

Starting Point

The starting point could be placement of a piloted vehicle in an orbit very close to that of the earth.

The mission would be very economical, to the extent that the cost of placement in such a solar orbit is low on the scale in terms of impetus: starting from low earth orbit only some 3 km/sec. is required. If a vehicle starts from an earth-moon orbit, it is enough to create 0.1 km/sec. when it is flying over the earth to transfer it into an almost terrestrial solar orbit. In such an orbit our rocket will not diverge in the course of a year by a distance of more than a few million kilometers. That is not much on the scale of the solar system, but it is impressive in itself. For the first time men would have detached themselves from the terrestial domain: in fact this has never been done, because the moon is a part of the terrestrial domain. And such a departure would have the advantage of permitting, in case circumstances required it, a premature return.

By consequence, it will only be a question of impulsion--that is to say, modules to be added to the space train which constitutes the vehicle--so that the eccentricity of our solar orbit can be whatever one chooses and so that an overflight of Mars can be envisaged.

We are saying that since 1972, the Soviets have had all the time in the world to imagine the various scenarios leading to such a journey. Some are extremely subtle, requiring gravitational reactions at the time of the Mars overflight. Under certain unusual conditions, it is indeed conceivable, within the framework of an annual solar orbit, to overfly Venus and Mars in turn, and as it turns out, that would be the most advantageous order, because the larger mass of Venus translates into greater potential for gravitational reaction. Certainly, even if the Soviets do not turn their plans over to us, we too have the time to use computers as they do, to find the same solutions, and to imagine those which they will find the most profitable.

Without going into the detail of these fine points, we would only like to summarize in detail the program for one such flight in an annual solar orbit.

One preliminary observation will require attention. If one intends to overfly Mars, it is necessary that the aphelion of that annual solar orbit permit reaching the red planet.

That being the case, we know that the distance between Mars and the sun varied between 205 and 349 million km. That distance alone is deemed considerable under the formulas of conventional flight. It assumes considerable importance with the annual orbit, this latter only being conceivable if one can reach Mars when the planet is in the neighborhood of its perihelion: this is in fact when the eccentricity of our solar orbit is minimal. Now the cost of transfer of a rocket from the earth to an annual orbit is obviously greater when the eccentricity of this orbit is to be larger.

Earth-Venus-Mars-Earth

Let us therefore consider the configuration of the solar system which the diagram on page 44, shows us, a diagram in which M stands for the planet Mars at its perihelion, while T stands for the position of the earth at the time of the rocket launching (or more precisely its injection into solar orbit). The earth may be considered, as a first approximation, as describing a circle (C) of radius ST, S being the sun.

The annual orbit which our rocket will follow is an ellipse (E) with focus at S having MP for its major axis, the value of MP being defined as 299 million km. Its minor axis is TB, T and B being the two points common to the earth orbit and the annual orbit which we are giving to our rocket. The flight unfolds like this:

1--Injection of the rocket into the ellipse (E) requires, beyond the stage of its escape from earth, a supplement of 11.5 km/sec. in a direction forming an angle of some 11.1 degrees with the segment TS.

Near the earth, the creation of a speed of 15.9 km/sec. is sufficient (the sum of the square of 11.5 and 11 is in fact the square of 15.9), and this is to say if a rocket were in a low circular orbit (thus already having some 8 km/sec), 7.9 km/sec. must still be created. This is a considerable amount (it requires a mass ratio of 12 to 40 depending upon the fuels used): that is not unusual. If one has already placed the vehicle in an earth-moon orbit some 5 km/sec. will suffice, but in any case the total expenditure will have been the same.

2--In its ellipse (E), our rocket requires 69 days to negotiate the segment TP which takes it to the perihelion of its solar orbit at 97 million (km distance) from the day star, that is to say inside the orbit of Venus. This circumstance explains to us how one can hope to take advantage of a schedule that will permit (before or after the passage of point P) an overflight, close or distant, of Venus. In the present scenario, we are not taking into account this overflight and the gravitational reactions to which it would give rise.

When our vehicle is at P, the earth is found at T-1: it is far behind for it is slow by comparison with the rocket which has gained speed because it has been approaching the sun.

3--A period of 69 days is also necessary for our vehicle to traverse the arc PB of its ellipse (E). At B, 138 days after its departure it regains earth orbit, but not the earth itself, which at that time is at T-2.

4--The traversal of the arc BM requires 113.5 days. The rocket is really quite slow as it approaches its perihelion, the asymmetry of the velocities being large because of the eccentricity of the trajectory.

At M comes the overflight of Mars at rather small relative velocity (a velocity which will have been lowered as a result of a gravitational reaction judiciously chosen during the overflight of Venus). At the moment of that overflight the earth is at T-3: one sees that it has begun to catch up with the rocket.

5--Traversal of the segment MT requires the same time as BM, or 113.5 days, during which the earth is displaced from T-3 to T. In other words, it is at the rendezvous point to welcome back the vehicle after the latter has completed its 365 days of voyaging.

Conditions on arrival are obviously those at the start, we mean that our vehicle enters into the terrestrial domain with a relative velocity of 11.5 km/sec, and it is at the speed of 15.9 km/sec. that it encounters the dense layers of earth's atmosphere, an aerodynamic brake being possible if the crew module has been designed to that end.

Frequent Windows

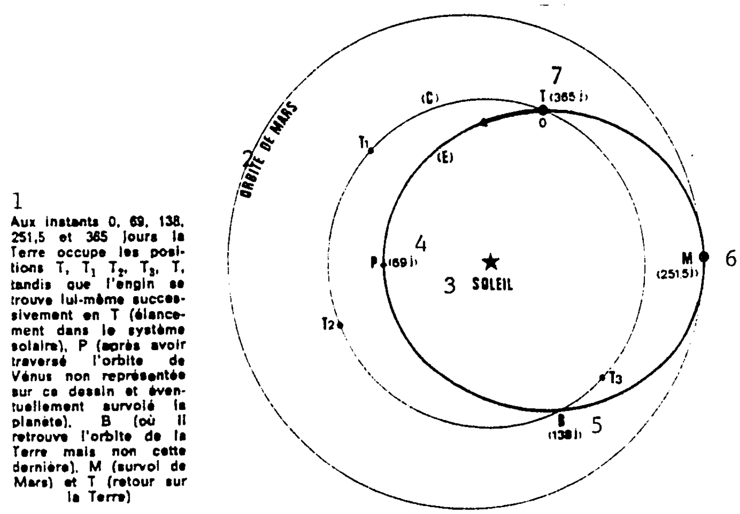
Such a mission requires, naturally, absolute mastery of the techniques of maneuvering and navigation in the solar system. This being the case, for whoever possess this mastery, let us understand that it is achievable with the means which astronautics is building today and will have at its disposal tomorrow. It is interesting in that:

--two departure opportunities (from T or from B) open up at each Martian window, so that in practice one could count on one launching possibility per year.

--approximately one window out of three can be adapted to a program that will involve a flight over both Venus and Mars.

In other words, the planets are already at our disposal. They have been waiting since 1978 for the cosmonauts who will fly over them. How much longer will the waiting continue? The time may be shorter than one imagines. In any case, the Soviet program between now and year 2000 seems to us to be sketched out very well, with construction of low-orbit stations, platforms, and space trains destined to fly both within the earth-moon system and within the inner solar system.

DIAGRAM



Key:

1. At the points 0, 69, 251.5 and 365 days, the earth occupies in turn the positions T, T-1, T-2, T-3, and T, while the rocket finds itself successively at T (launching into the solar system), P (after having traversed the orbit of Venus, not shown in this diagram, and eventually overflown the planet), B (where it regains earth orbit but not the earth itself, M (overflight of Mars) and T (return to the earth).
2. Orbit of Mars
3. Sun
4. 69 days
5. 138 days
6. 251.5 days
7. 365 days

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- END -