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НАЧАЛО КОСМИЧЕСКОЙ ЭРЫ

SPACE:
THE FIRST STEP

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SCIENCE EDITOR *A.V. Zakharov*

EDITOR *V.S. Kornilenko*

Collection of essays devoted to the 50th Anniversary of First Artificial Earth Satellite — Sputnik launch. Prominent scientists, engineers, experts in space exploration, writers and public figures reflect upon the significance of Sputnik and it's consequences in different areas of society.

Articles and illustrations are provided by authors unless otherwise stated.

Reliability of the information in the articles are provided by authors.

Editorial Board may not be concordant with authors' opinion.

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INTRODUCTION

Right after completing the first revolution of the First artificial satellite TASS news agency announced **'...The first sputnik was successfully launched in the USSR** on **October 4, 1957. By preliminary data, the rocket vehicle has provided Sputnik with necessary orbital speed, about 8000 metres per second. Now Sputnik gyrates on elliptic trajectories round the Earth, and its flight can be observed at dawn and sunset by means of elementary optical instruments (field-glasses, telescopes, etc.)...'** It seemed that the entire world observed small bright point, floating in the night sky fifty years ago, listened to simple signals '*beep-beep*', knowing that those sounds were sent by a new celestial body. It was extremely amazing that this celestial body was artificial, that is created by hands of humans. Then, in the beginning of October, 1957 billions of people suddenly felt themselves a part of mankind, citizens of the planet Earth standing on the threshold of vast, but already becoming accessible Universe.

Not everybody understood then the implications of this event, but the feeling that something enormous was happening, an event of really 'cosmic' scale, stayed with the almost all the people on earth. Activity of the mankind always striving to new discoveries, conquering new frontiers developed 'new degree of freedom', 'new dimension'. This event enabled to create a new science — space research and to pave the way to unthinkable opportunities, i.e. to look behind dense curtain of terrestrial atmosphere and to reveal basic knowledge about the Universe, to send robots to the bodies of the Solar system, to take a walk on the surface of the Moon and to build feasible plans of manned flights to neighbor planet in the nearest decades. Undoubtedly and at the same time surprisingly enough the launch of Sputnik in the frame of International Geophysical Year 1957–1958 acquired great meaning not only for a limited community of scientists, but also, without exaggeration, for all mankind. That was the event which gave rise to new branches of industry and usage of space practically in all the fields of human activity. Surprising aspect of the Sputnik story was that space race of the Great Powers was a peaceful, 'cold' battle, giving confidence to the nations, involved in this confrontation, that the third world war was impossible. It took half a century after the first Sputnik — an instant from the historical point of view — for dozens of countries to become members of 'space club', and space exploration to become day-to-day routine.

So what was and still is the first Sputnik for all Earthlings and for each human in particular? Has the estimation of the event changed half a century later? These speculations served the basis of the concept of the book in front of you. Authors of the articles are 50 outstanding scientists, engineers, cosmonauts, writers, public figures from different countries whose life and work are connected with space. These articles are memoirs, impressions, reflections on the role of the first Sputnik, the place of space research in the modern world, the way event affected their personal destiny and the destiny of mankind. We did not confine the authors to specific form or style, so the articles are diverse, behind each of them is the author and his/her estimation of this outstanding event.

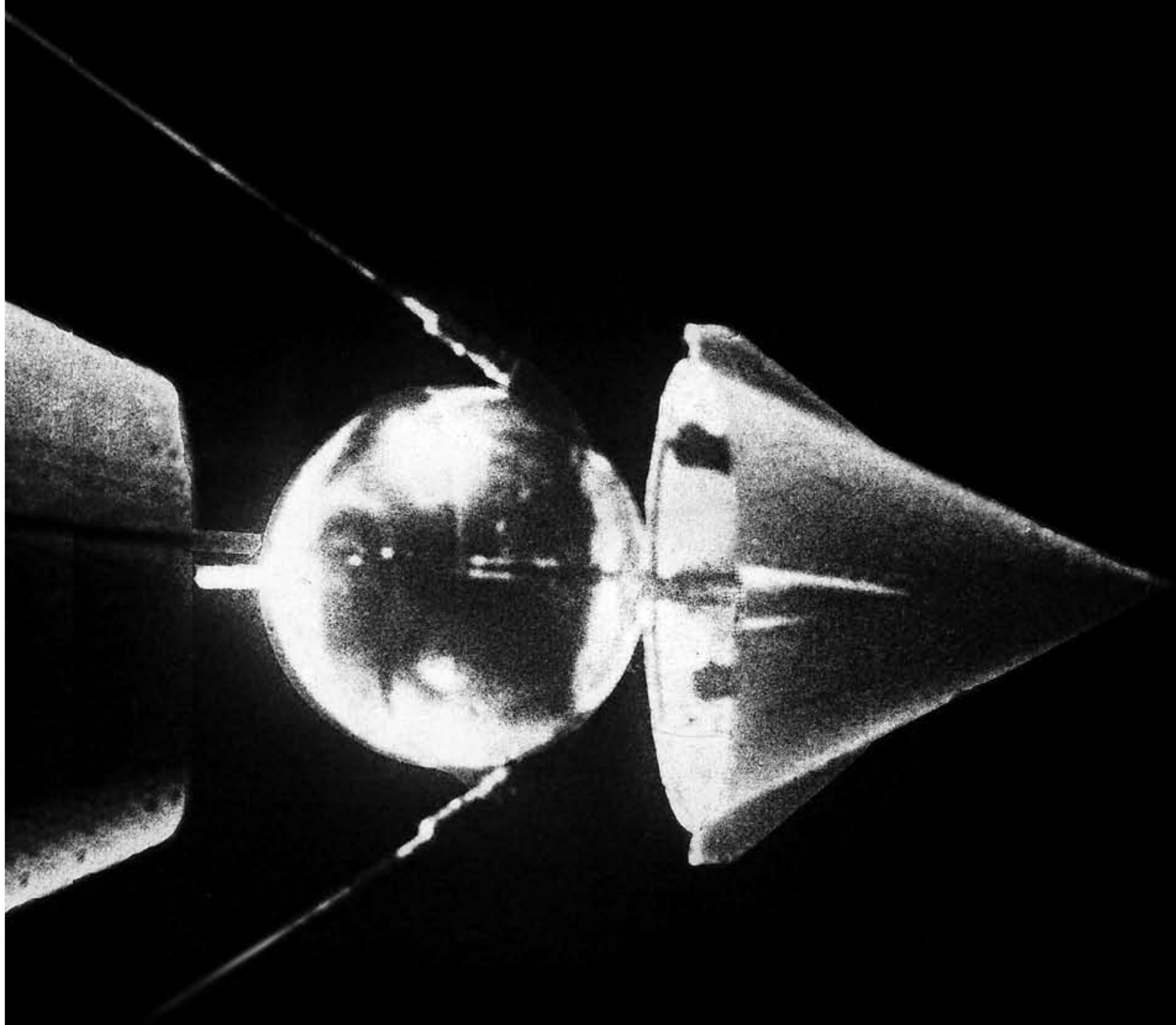
The Space Research Institute of the Russian Academy of Sciences has initiated the preparation of this book, and we are very grateful to the authors for their contribution to this collection. We hope it gives multidimensional representation of how the world and our notions of it changed throughout first 50 years of a space era.

Director Space Research Institute
Space Research Institute

Lev Zelenu

Chief Scientist
Space Research Institute

Alexander Zakharov



Separation of the last stage and the head of the rocket from AES-1. 1957 (modeling)

S.P. Korolev, I.V. Kurchatov, M.V. Keldysh, V.M. Mishin. Moscow, 1959

Participants of development of first intercontinental missile and AES-1.
Notions by G.Yu. Maximov

Ray BRADBURY
USA

Ray Bradbury (Raimond Douglas Bradbury) is a world-renowned author of science-fiction short stories, novels, screenplays, plays and also poetry. He has published more than 600 short stories over a period of sixty years.

He was born 1920, lives in Los-Angeles.

His best known works are *The Martian Chronicles*, *The Illustrated Man*, *Something Wicked This Way Comes*, and in its 50th anniversary year, *Fahrenheit 451*.

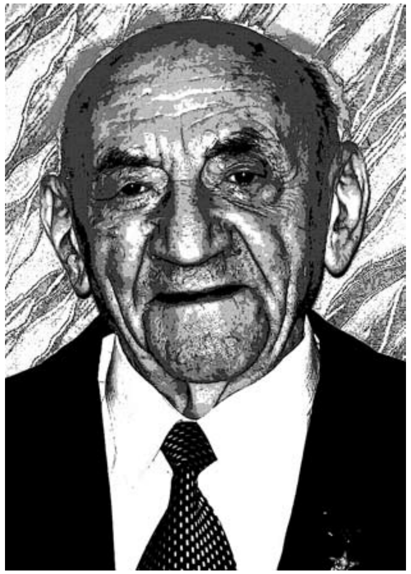
A new novel, *Farewell Summer*, which is the sequel to *Dandelion Wine*, was published in October 2006. 2007 will see the release of a double offering from Bradbury, *Somewhere a Band is Playing* and *Leviathan'99*.

In 2001 The National Book Award was given to Bradbury for his contribution to American literature and in 2004 he was awarded the National Medal of Arts by President Bush and the National Endowment for the Arts.

THE FIRST LIGHT OF IMMORTALITY…

I was out in Palm Desert, California, at a friends house the first night that Sputnik flew over in the sky. I looked up and thought that the future of mankind was ensured. That little light that swiftly passed from one direction to the other in the sky was the future of mankind because the Russians may very well have been leading the way, but I knew that we soon would follow and that we'd be ensured a place in the air and then on the Moon and finally on Mars. The immortality of mankind was ensured by that light in the sky. We couldn't stay on Earth because some day the Earth might die from cold or too much heat. Mankind was destined to become immortal and that light in the sky above me was the first light of immortality.

I blessed the Russians for their endeavor and I looked forward to President Eisenhower forming NASA shortly thereafter.



Boris CHERTOK

RUSSIA

Rocket and space technology engineer. Research fellow in the development of the first intercontinental ballistic missile R-7 and first interplanetary stations. Academician of Russian Academy of Sciences and International Academy of Astronautics. Teaching experience over 50 years.

Born in 1912 in Lodz, Poland. Graduated from Moscow Energy Institute in 1940. In 1974–1992 was the Deputy Chief Designer specialized in operation systems, in the NPO Energia. Science advisor to Chief Designer in the S.P. Korolev Rocket and Space Corporation Energia since 1993.

Hero of Socialist Labour. Was awarded Order of Lenin twice (1956, 1961), Order of October Revolution, Order of Red Star, Order of Red Banner of Labour, National Order (IV level) and Petrov gold medal of the Russian Academy of Sciences.

THE FIRST ARTIFICIAL SATELLITE OF THE EARTH

The first AES was launched in the Soviet Union on October 4, 1957 at 10:28:34 p.m. Moscow time.

For the first time in the history of mankind, hundreds of millions of people were able to observe an artificial star, created by human's rather than gods' hands, translating along the dark dome of the sky in the rays of the rising or setting sun.

The world community treated the appearance of the first in the world AES-Sputnic as a greatest scientific achievement. This was indeed a greatest engineering achievement from the viewpoint of its historical significance.

* * *

The history of creating the First Sputnic is the history of a rocket. The rocket engineering in the Soviet Union was of a German origin.

In view of the Versailles Treaty ban imposed on development of new types of artillery armament and construction of combat planes, the German military paid attention to the prospects of long-range missiles, since no ban was envisaged on them within the Versailles Treaty.

Particularly active work was initiated in Germany after 1933 when Hitler came into power. A small team of missile enthusiasts, led by a young gifted engineer Wernher von Braun, gained support from the army. Soon its activity became a high priority state program of armament.

In 1936, construction of a full-scale scientific, production and testing missile center Penemünde was undertaken in Germany. Six years after, in 1943, the first successful launch of a combat ballistic long-range missile A4 was performed, later popularized as V-2 (*Vergeltungswaffe*). It was the first unmanned automatically controlled ballistic long-range missile. The maximum shooting range amounted to 270... 300 km. The initial missile mass was up to 13 500 kg. The mass of the warhead was 1075 kg. The mass of the 'raw' missile structure amounted to 4030 kg. Liquid oxygen — an oxidizer and ethyl alcohol — a fuel were used as propellant components. The thrust of the propulsion system near the Earth was 27 000 kg.

A cannon barrel was used as an active section of flight. A stand-alone control system, using broadside radio correction, ensured a stable flight in this section.

The development of technology for batch production of powerful liquid-fuel rocket engines and flight control system were among the main achievements of German specialists. Ideas of Konstantin Tsiolkovsky, German Obert, Robert Goddard and other talented individualists were transformed into real-life engineering systems by teams of powerful world renowned companies of *Siemens*, *Telefunken*, *Lorenz* and others. The best universities carried research executing the tasks from Penemünde. In the Penemünde itself, hundreds of specialists combined these developments and created a unified missile system. By learning from the German expertise in Germany itself for a year and a half, we made sure that a missile is neither a shell nor a cannon, but a large and complicated system, requiring the use of the up-to-date achievements in the field of aerogasodynamics, radioelectronics, thermal engineering, material science and high production standards.

On May 13, 1946, J.V. Stalin signed a Decree to establish rocket science and industry in the Soviet Union. Following this Decree, Sergey Pavlovich Korolev was appointed to be the Chief Designer of long-range ballistic missiles in August, 1946.

Back in 1946, none of us anticipated that by collaborating with Korolev, we would become participants of the launch of the first in the world AES and, soon thereafter, of that of the first man.

The powerful support rendered by the state to the rocket industry, headed by remarkable scientists, being enthusiasts and organizers, using mobilization economy methods, was a prerequisite condition but still not a sufficient one for the first satellite to appear. Already during the cold war time, a tendency to arm missiles with a nuclear — atomic bomb rather than with a conventional explosive turned out to be a driving force for development of a missile capable of launching a satellite into space.

In the Soviet Union, the 'cold war' brought about an intensive acceleration of creation of a new weapon, i.e. long-range ballistic missiles.

After the surrender of Germany, I was among the organizers of restoration of the German missile engineering reconstructions on the territory of Germany itself. Already at that time, we made sure that there was no need for discovering any new physical laws to create powerful long-range missiles flying in the outer space. In 1947, by flight tests of missiles V-2, assembled in Germany, the work on actual implementation of missile engineering was begun in the USSR.

Missiles R-1, a replica of the German V-2, but manufactured using solely Russian materials, were tested on the first central missile range in Kapustin Yar in 1948.

In 1948, the government published decrees about the development and flight tests of the missile R-2 for a range of 600 km and the design of a missile for a range of 3000 km with the warhead mass of 3 tons.

In 1949, a series of experimental high-altitude launches of missiles R-1 was undertaken to explore the outer space.

The missiles R-2 for the range of flight of 600 km began to fly already in 1950 and were added to arsenal in 1951. The missiles R-1 and R-2 were those using the V-2 engineering to a great extent. The missile R-5 for the range of 1200 km marked the beginning of breaking away from the German heritage. Its flight tests began in 1953.

Joint research, undertaken together with atomic scientists, on the use of the R-5 missile as an atomic bomb carrier was initiated in 1953. Following the government decree, Chief Designer Korolev together with Chief Designer Khariton studied the option of installing an atomic bomb on the medium-range missile R-5M. The 'cold war' was started. The Soviet Union was surrounded by military bases of the US Air Force, from which planes carrying atomic bombs were capable of hitting chief political and economic centers of the country. Our planes carrying atomic bombs were not able to reach the USA territory. That was an undisputable advantage enjoyed by the Americans. The responsibility for developing an intercontinental missile carrier was imposed on missile specialists.

On February 13, 1953, the Chief Designers' Council initiated the first government decree, which made it obligatory to undertake the development of a two-stage intercontinental missile for the range of 7...8 thousand kilometers. It was anticipated that the missile would carry an atomic bomb of the same dimensions as that developed for the single-stage missile R-5M with the range of 1200 km. But nuclear engineering actively interfered into the missile engineering.

On August 12, 1953, the first thermonuclear bomb tests were carried out. Judging by top-secret hints made by atomic scientists, together with whom we arranged the warhead part of the missile R-5M for the atomic bomb, we, missile specialists, understood that the mass and overall dimensions of the thermonuclear bomb were so large that it would be unrealistic to develop a missile carrier for a hydrogen bomb in the nearest years.

The activities on combining the automatic system of an atomic bomb with a missile, development of multiple safety systems of interlocks, upgrade of the R-5M missile to substantially increase its reliability were very interesting. The development of a two-stage missile for the range of up to 8000 km was the more so fascinating. As calculated by the designers, its launching mass reached 180 tons. This required the use of a propulsion system with the thrust on the ground of no less than 250 tons. The figures themselves were striking. Finally, we would get rid of the German birthmarks.

In November, 1953, Korolev convened a top-secret meeting for his closest deputies. He said:

'I was unexpectedly visited by the Minister of the Medium Engineering Industry, also being the Deputy of the Chairman of the Council of Ministers, Vyacheslav Alexandrovich Malyshev. He flatly suggested that we 'forget about an atomic bomb for the intercontinental missile'. He said that the designers of the hydrogen bomb promised him to reduce its mass so that it would drop down to 3,5 tons for the missile option. Therefore, we must develop the intercontinental missile proceeding from the 'payload' of 3.5 tons, while retaining the range of 8000 km'.

Our Chief Project Developer, Sergey Kryukov, said that 'we must begin everything anew'.

THE BASIC SPUTNIK

A small project team was created, commissioned by Korolev to preliminarily develop the parameters of a new missile to be discussed at the Chief Designers' Council.

In January 1954, a historical conference of Chief Designers Korolev, Barmin, Glushko, Kuznetsov, Pilyugin, Ryazansky took place with the participation of chief deputies and chief developers of radio systems of monitoring and control, Konoplev, Borisenko and Bogomolov. The main decision of that meeting was a rejection of the use of a traditional launch pad. Young designers proposed to create a system of ground equipment with missile suspension on special rejection girders. This allowed the lower part of the missile not to be loaded and, thus, its mass to be decreased. The solution of setting up a missile of five units with unified propulsion systems was unconventional. The central unit played the part of the second stage. But the engines of all the units were activated on the ground simultaneously. The mass of the warhead with a hydrogen bomb was preliminarily estimated at 5500 kg. To ensure a preset accuracy of control in range, it was required to strictly regulate the engine aftereffect momentum. However, Chief Designer Glushko proved that the control specialists' requirements were unrealistic. For the first time, it was proposed to do without the gas-jet graphite steering wheels, which were traditional since the times of V-2, and to develop special missile control thrusters. The same thrusters were intended to 'hold out' the missile second stage to the required parameters in speed and coordinates during the last seconds of its flight. To decrease the propellant mass, it was proposed to develop a system regulating the discharge of tanks, measurement and control of apparent velocity.

Later it was decided to develop a new and more informative system of telemetry measurements.

A Government Decree about the design of a two-stage intercontinental missile R-7 was issued on May 20, 1954. And only a week later, on May 27, Korolev sent a memorandum to Ustinov, the Defense Industry Minister, which had been prepared by Tikhonravov about the development of an AES and its possible launch by the missile R-7 being designed.

It should be noted that, except Korolev himself, neither chief designers of the Chief Designers' Council nor Korolev's deputies treated his enthusiasm about the idea of launching the AES as a serious thing.

A preliminary design of a missile having a new unusual layout was developed and approved by the Council of Ministers of the USSR on November 20, 1954. The rocket design, approved by the Expert Commission, is now well-known to all the rocket specialists throughout the world. It consists of four similar side rocket units, which are fastened to the central unit. As far as their internal layout is concerned, the central and the side units are similar to the single-stage missiles with the oxidizer tank front location. Fuel tanks of all the units are bearing. The engines of all the units begin operating from the ground. When the stages get separated, the side engines shut down, while the central one continues to operate. A unified four-chamber liquid-fuel rocket engine, with the thrust regulated within the limits of 80-90 tons, was installed on each unit. The control equipment was located in the inter-tank section of the central unit. The control system included a stabilizer automatic unit, regulators of normal and lateral stabilization, apparent velocity regulation system, and a radio system for range control and correction in the lateral direction. The head part of the rockets entered the atmosphere at a speed of 7800 m/s. The total length of the separating warhead amounted to 7.3 m, with the mass of 5500 kg.

There were many new problems to be solved ASAP. The main problem were:

- To choose a location for a new test pad, to build a unique launching structure and to commission all the required services.
- To build and to commission a test benches for firing tests of the units and the package as a whole.
- To create test benches for the operation system verification, simulating the dynamics of motion with a large number of degrees of freedom, taking into account the structure resilience and liquid filling agent.
- To find and verify new thermal insulation materials to protect the head part integrity as it enters the atmosphere.
- To develop a new telemetry system: according to preliminary data, it was required to control up to 700 parameters at the first stage of flight tests.
- To create a new system of radio control and flight trajectory control.
- To build a command and measuring complex, comprising measuring stations, following a rocket and receiving telemetry data along the whole of the route up to the Pacific Ocean.

In 1955, designers generating the design and production documentation for manufacturing of the R-7 missile were joking that their drawing boards were smoking because of their round-the-clock work. Computer technology was non-existent at that time. 'Piping hot' drawings went directly to the workshops of the pilot plant.

But in 1955 Korolev was very enthusiastic about installation and flight tests of a missile on a submarine. In the fall of 1955, Korolev and I made an unforgettable cruise on the first submarine, equipped with ballistic missiles. We participated in a pilot launch of a missile from a diesel-engine submarine.

A Government Decree on the design of a non-oriented AES, secretly encoded as an 'Object 'D', was prepared during January, 1956 and signed on January 30. This Decree envisaged the design of a non-oriented AES (the 'Object 'D') in 1957–1958 and its launch by the R-7 missile, the AES mass amounting to 1000...1400 kg with the science payload mass of 200...300 kg.

The USSR Academy of Sciences was responsible for providing overall scientific leadership and hardware for scientific exploration of the outer space, while the Design Bureau OKB-1 of the Ministry of Defense Industry was to design the satellite itself, and the Ministry of Defense was to carry out the pilot launches.

When this Decree was signed, Korolev and his main deputies, including myself, were at the Kapustin Yar range. Together with atomic specialists we were preparing the missile R-5M with a real nuclear charge for testing.

The first in the world launch of a missile equipped with an atomic bomb was performed on February 2, 1956. Atomic explosion took place in an uninhibited steppe at a distance of 1200 km from the launch pad.

Soon the missile R-5M with the atomic warhead was added to the arsenal.

The draft design of the first AES was completed by July, 1956. A list of scientific tasks was specified, including measurements of space ion content, corpuscular radiation of the Sun, magnetic fields, space rays, thermal mode of the satellite, its deceleration in the upper layers of the atmosphere, duration of its orbit life, accuracy of determining the coordinates and parameters of the orbit, etc. Command radio link equipment, used to control instrumentation from the ground, was installed on the satellite, as well as an on board system of command processing for connecting the scientific equipment and down linking the measurement results via the telemetry channel.

THE BASIC SPUTNIK

A system of means ensuring receipt of information downlinked from the satellite was created on the ground. Provision was made for building 15 special scientific measurement ground stations on the territory of the USSR.

By the end of 1956, it became clear that the schedule for designing the satellite will be ruined because of difficulties encountered in manufacturing reliable scientific equipment for the satellite. Nevertheless, the 'Object 'D' project was approved by a special committee of the Council of Ministers.

In compliance with the Government Decree, dated February 12, 1955, construction of scientific-research and test range No. 5 was undertaken in a semi-desert, in the region of the Tyura-Tam station (since 1961, this place is called the Baikonur cosmodrome).

It was built by the military. General Shubnikov was the Chief Builder. After the Second World War he headed the construction of the well-known monument for the Treptow-Park Memorial in Berlin.

The manufacturing of the first engineering complex of the R-7 missile was completed and its tests were performed at the Leningrad Metal Works jointly with a real launch system during 1955–1956. Firing tests of individual units of the missile were undertaken at the firing test benches near the town of Zagorsk (Moscow regione).

Simulation and complex adjustment of the control system was performed at the scientific research institute of Chief Designer Pilyugin.

In 1956, together with the chief designers of autonomous and radio control systems, we carried out pilot launches of medium range missiles M5RD and R-5R at the Kapustin Yar range to verify the autonomous and radio control systems of the R-7 missile under real flight conditions.

The Council of Ministers of the USSR approved the program of flight tests of the R-7 missile on January 14, 1957. The first engineering 'pilot' missile was transported to Tyura-Tam to the launching pad already in January.

I spent many days and nights at the test facility of our plant. We performed stand-alone and integrated electric tests of the first flight missile R-7. At first, we tested it unit by unit, then assembled in a package and carried out integrated tests.

We found many mistakes in the documentation and complicated electrical schematic circuit diagrams. There were five propulsion systems instead of the usual one! Only steering jets numbered 12. That meant 12 steering engines. There were 20 main combustion chambers and 12 steering ones. The total of 32 chambers.

The missile looked like a fantastic structure standing in the assembly workshop of the plant. Korolev invited Nikita Khruschev to visit the plant. He came accompanied by the chief members of the Politburo. They were amazed by the missile. And they were not alone. Andrey Sakharov, being the main ideologist of our hydrogen bomb, wrote in his memoirs: 'We believed that we worked on a large scale but what we saw there was by an order of magnitude greater. We were amazed by great, megascopic engineering culture, coordinated work of hundreds of highly qualified people and their almost habitual but very business-like attitude to those fantastic things they dealt with...'

The first missile and after it the second one were prepared to be transported to the launching pad. Korolev, having made sure of the ruined manufacturing schedule for the first AES as a space laboratory, turned to the Government with an unexpected proposal.

‘There are news reports to the effect that the USA intend to launch a AES in 1958 in connection with the International Geophysical Year. We are running the risk of loosing priority. I suggest that the simplest satellite be launched into space instead of the complicated laboratory of the ‘Object ‘D’.

Korolev’s proposal was accepted and the Council of Ministers issued a Decree about manufacturing and launch of the simplest satellite ‘PS’* on February 15.

Korolev delegated me and other deputies, Voskresensky and Abramov, to the range to meet the first missile and to prepare for the launch.

In February, 1957 the upgrade of the launch pad was in full swing. Residential area was being built on the bank of the Syr-Darya River. The construction of the mounting and test facility for preparation of missiles was almost completed – it was an engineering pad. But the hugest structure – the launch pad No. 1 – was not finished yet.

A concrete road was being laid from the railroad station, a railroad branch line was under construction, high-voltage line towers were being installed. Lines of dump trucks loaded with liquid concrete, trucks with building materials, covered caravans with soldiers-builders were going to the builders working on the launch pad.

I recollected war roads in the nearest rear of the army before a full-scale offensive. There was the same heavy-work buzzing of hundreds of trucks, each hurrying with its own load. Here there was no rumbling of tanks and cannons but there were soldiers at the steering-wheels and in the bodies of all the vehicles.

Our automobile was also driven by a soldier. I expected to reside for a long time under those, as we believed, next-to-the front conditions. While I, other Korolev’s deputies, hundreds of civil and military specialists, who moved to the pad, were mounting, testing and preparing the first missile for launch, as well as dozens of complicated ground support systems, Korolev organized the design and subsequent manufacturing of the first simplest satellite at the design bureau OKB-1.

The first missile R-7 with the serial number M1-5 arrived to the engineering pad test facility at the beginning of March, 1957. That was the beginning of long-term tests of the units, corrections of found faults, upgrades of on-board and ground systems, verification of operational documentation. In April, fire tests of the units and the package as a whole were successfully completed at the test facility.

At the meeting of the State Commission, Korolev reported about the work done in preparation of the missile and the parameters of the first missile for flight tests.

The initial mass of the fully filled missile amounted to 280 tons. The mass of the head part with a payload simulator was 5.5 t. The mass of components to be filled — liquid oxygen, kerosene, hydrogen peroxide, compressed nitrogen — 253 t. The speed at the moment of second-stage engines shutdown was 6385 m/s in case of full-range firing. However, the launch was to be performed for the range of 6314 km to hit the firing ground on Kamchatka. One of the main tasks was to check the mutual dynamics of the missile and the launching facility, to check the stability of motion. The rated preset accuracy of ±8 km was not guaranteed for the first launches.

* PS — short for ‘prosteishy sputnik’ (‘the simplest satellite’). The word ‘prosteishy’ in Russian also has the meaning ‘protozoa’.

On May 5, 1957, the missile was rolled out to the launcher – pad No. 1. Taking into account its novelty, the work on preparation for the launch lasted one week. The filling began only on the 8th day.

The launch date was set on May 15. After the end of all the tests at the launcher, I descended into an underground shelter to the depth of 8 m at a distance of 200 m from the launch pad. The last operations and launch were controlled from the main control panel room, equipped with two sea periscopes. A separate large room was intended for the members of the State Commission and another one, for engineers-consultants — an ‘engineering emergency team’. One more room was used to house the monitoring equipment to control the filling, and launch mechanisms. Information about the status of the on-board systems was displayed on the indicators of the main control panel room and transmitted to the communication bunker from the tracking station IP-1, which received data from three on-board telemetry systems, installed on the missile. Leonid Voskresensky, Korolev’s deputy, and Lieutenant Colonel Evgeny Ostashov, the Head of the test department of the launch pad, were located next to the combat periscopes. Evgeny Ostashov was giving the last launch commands.

The launch took place at 7 p.m. local time. Judging by visual observations and subsequent processing of the telemetry data, the missile left the launch pad normally.

‘It was a stunning sight’, – was later said by those who observed the launch, hiding in the trenches at a distance of 1 km. The roar that reached the bunker was weakened considerably. The controlled flight continued up to the 98th second. Then the thrust of the lateral ‘D’ unit engine dropped and it separated from the missile without a command. The missile lost stability and at the 103rd second a command was generated to shut down all the engines because of large deviations. The missile fell at a distance of 300 km from the launch pad.

Korolev was congratulated that the launching system survived and that the stability of flight of the whole package was proved at the most crucial first section. But he was the most upset person out of all the participants of the first launch.

Procession of the telemetry data and investigation of the remaining unit remnants showed that the flight crash was caused by fire initiated by leaking high-pressure kerosene lines of the propulsion system.

The second missile R-7 No. 6L was prepared taking into account lessons learnt.

Multiple attempts at launching were made on June 10–11 but the automatic launch control system ‘reset the setup’ at the last seconds. The missile never left the launch pad. The reason for that was freezing of the main oxygen valve on the ‘C’ unit and an error in setting the valve of nitrogen purge. The components were drained; the missile was taken off from the launch pad and returned to the engineering pad.

The third missile No. M1-7 had already been waiting for its turn on the engineering pad for a month and the launch took place on July 12, 1957.

The missile was launched normally but began to deflect around the longitudinal axis, having exceeded the allowed 7˚. The automatic system performed an emergency shutdown of all the engines. The package disintegrated at the 32.9th second. The units fell and were burning out at a distance of 7 km from the launch pad.

As shown by analysis, it was caused by a contact-to-frame fault in a new device of the control system, which, as intended by dynamical ops specialists, was to improve the rotation stability. A false command was sent to the control missile engines, which 'twisted' the missile.

Finally, the fourth launch took place on August 21. The missile No. 8L operated normally throughout the trajectory active section. The external monitoring data showed that the head part reached the preset region of Kamchatka, entered the atmosphere but no traces of the missile were found on the ground. Thermal loads exceeded all expectations. The thermal blanket did not help.

Despite another failure, this time with the structure, intended to house the 5-megaton thermonuclear bomb, the TASS news agency of the USSR published an awesome statement.

'A super long-range intercontinental multi-stage ballistic missile has been launched in the Soviet Union. Missiles can be launched to any region of the globe'.

The next launch of the R-7 missile No. M1-9 took place on September 7, 1957. Throughout the active part, all the units operated nominally. But the head part burned again during the re-entry. This time a few burnt pieces of the head part structure were found with a great difficulty.

So, by results of the flight tests of five missiles, it was evident that this missile can fly but the head part needed radical upgrade. By optimistic estimates, this would require not less than half a year. The disintegration of the head parts allowed the simplest satellite to be launched, since there was no need for it to perform re-entry.

Korolev obtained N.S. Khrushchev's consent to use two missiles for a pilot launch of the simplest satellite.

On September 17, 1957, Sergey Korolev, an almost unknown Corresponding Member of the USSR Academy of Sciences, made a presentation at a ceremonial meeting devoted to the 100th anniversary of K.E. Tsiolkovsky. He said that pilot launches of artificial Earth satellites will be performed in the nearest future.

A missile carrier 8K71PS (a vehicle M1-PS) arrived to the launch pad on September 22.

It was made much lighter as compared with nominal missiles. The mockup head part was removed and replaced with an adapter 'fitted to suit a satellite'. All the radio control system equipment was removed from the central unit, since no accuracy was needed. One of the telemetry systems was also taken off. The central unit engine shutdown automatic system was simplified. It treated one of the components differently. As a result, the launching mass of the PS missile was made lighter by 7 tons, as compared with the first missiles.

The launch was performed on October 4, 10:28:34 p.m. Moscow time. The satellite and the central unit of the rocket launcher reached the orbit 295,4 s after the launch.

It was just the third successful launch of the R-7 missile designed for an intercontinental flight with a thermonuclear bomb.

For the first time the first orbital velocity calculated by Newton was achieved. For the first AES it amounted to 7780 m/s. The satellite orbit inclination amounted to 65,1°, the perigee height was 228 km, the apogee height — 947 km, the orbital period — 96,17 min.

After the first enthusiastic reactions, when the first '*beep-beep*' signals were received at the launch pad and after finally processing the telemetry data, it turned out that the missile launch was 'a narrow escape'.

The lateral 'D' unit engine was achieving the required mode with a delay. The time when the mode is achieved with a delay is very dangerous. The time of going over to the mode is strictly controlled by the automatic system. The 'D' unit achieved the required mode less than a second earlier than the time was out. Had it delayed more, the setup would have automatically performed a 'reset' and the launch would have been cancelled.

The tanks' dumping control system failed at the 16th second of flight. It resulted in an excessive consumption of kerosene and the central unit engine was shut down one second earlier than the rated value by an emergency signal initiated by rpm of the turbo-driven pump assembly. Had it happened slightly earlier, the orbital velocity might have been failed to achieve.

But victors need never explain!

The great event took place!

On October 5, the TASS announcement ended in the following:

'Artificial Earth satellites will pave the way to interplanetary voyages and, apparently, our contemporaries are destined to witness how a liberated and conscientious labor of people of the new socialist society will make the most daring dreams of mankind a reality'.

The first satellite functioned 92 days till January 4, 1958 and made 1440 orbits. The central unit lasted 60 days. It was observed by an unaided eye as a star of the first magnitude.

The political and public response displayed on the next day after the TASS announcement was issued was unexpected for us.

The world was literarily astounded! The world was boiling; it looked like the 'cold war' would go over into a hot one. The satellite changed the political alignment of forces. The USA Minister of Defense declared: 'It is no longer possible to win in the war with the USSR'.

Having replaced the thermonuclear hydrogen bomb with a small Sputnik, we have achieved an enormous political and public victory.

Georgy GRECHKO
RUSSIA

First-level space pilot, instructor. Doctor of Science. Spacecraft division crewmember since 1966. Awarded Hero of the Soviet Union twice (1975, 1978).

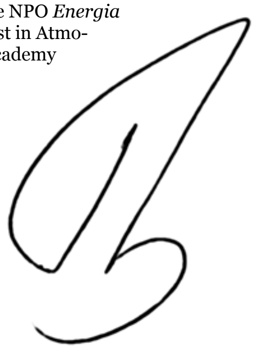
Made three space flights (1975, 1977–1978, 1985) to orbital space stations *Salyut-4*, *Salyut-6* and *Salyut-7*.

Full member of International Academy of Astronautics.

Born in 1931. Graduated from Military Mechanic Institute in Leningrad in 1955. Employed at the NPO *Energia* in 1966–1986. Chief Research Scientist in Atmosphere Physics Institute, Russian Academy of Sciences, in 1986–1997.

Awarded Order of Lenin (3 times), Kirty-Chakra Medal (India), Tsiolkovsky Golden Medal (1975).

From 1979 was Deputy Chairman of the Soviet Peace Committee.



THE FIRST SPUTNIK: INSERTION TO ORBIT

In 1955 I started to work as an engineer in OKB-1 (Development Design Office-1) headed by Sergey Pavlovich Korolev and merely a year or a year and a half later I was entrusted to calculate the insertion trajectory of the first Sputnik (Satellite). It was requested it particular, to develop the pitch and relative velocity control programs in such a way that the rocket would reach the Earth orbital velocity with zero inclination with respect to local horizon.

By that time Americans have already done, probably, two attempts to launch the first satellite. Though they turned out in failures, still, we realized that the third one will follow any time soon, and thus we had to rev up.

Directed by me, that program was calculated by the team of calculators — 'the girls' as we used to call them. Sure thing was that 'the girls' were about thirty and more years of age, but that was customary way to converse. The first shift of calculators was working nine to five, then, they handed over to the second shift and they were calculating from six in the evening till midnight. When all of them were gone home I could get to my rest. However, a fresh shift of calculators was to come again by nine in the morning, therefore, not to make far commuting ends, I stayed to sleep at the office: donned in my overcoat, stretching on the working table. New morning was bringing a new cycle.

Once an interesting thing happened in the course of our work. It is very difficult to sort out such specific pitch and relative velocity control programs that will direct the rocket with zero inclination to horizon in the given location point, so the rocket was flying over the horizon in our calculation either to plus side or to minus side, thus

we had to proceed by iterations or sequential approximations method. The machines we were using could not calculate trigonometrical functions. And than, of a sudden, the fact got revealed that while we were using trigonometrical functions from Bradis tables with four digits after decimal, trajectory calculations for insertion region specifically are considerably influenced by the fourth digit.

Thus I had to provide the girls with Khrenov tables where trigonometrical functions are shown with eight digits after decimal. In the beginning they raised a mutiny, how come, all our life through we were calculating with the use of Bradis, and now we'll have to shepherd eight digits back and forth...well, to cut the story short, it was at the trade-union meeting where the issue of the tables was decided, where it was explained to the calculators that all their life they were calculating combat missiles trajectories and there was no requirement to calculate the angles close to zero and thus trigonometrical functions were not 'jumping' so rushing.

Our last calculations we accomplished on the first Big Electronic Computing Machine* which had just emerged in the Soviet Union and was installed in Lebedev Institute of Physics on Leninsky Prospect.

The machine was mounted in a tremendous hall. It was a tubes and valves construction, and to preclude tubes overheat the windows in the hall were always open, even in the winter, and the fan was always on. To stay in winter overcoats was what was left to us. When a rookie happened to enter into the hall, his first reaction was to stretch up to switch off the fan, and above it was a plate hanging, saying: '*The fan is labor's friend, keep it running with no end*'.

Half of machine's working time, say, all through the day, was allocated to the atomists. Almost all the night time was given to us, the 'rocketmen'. When deep in the night we terminated our calculations the public transport was not working, and it goes without saying that we had no cars, thus we had only one way – to sleep at same spot. And, man, it was cold there, and to keep ourselves warm we had to invent different tricks. Even going to the extent of sleeping in the corridor, where carpets were laid, so we could roll ourselves into them and lay so wrapped till morning.

That very morning, when our computations were finished at length and we obtained the final first Sputnik insertion trajectory, got really branded on my memory. It was me who took the tape with its recording, and went out of the Institute, then I had to wait till 'Gastronom' grocery store across the street would get opened. It was a place were sausages were sold, and in Podlipky**, our place, there were no sausages sold. I bought the sausages and put them to a mesh bag along with that tape, and took the commuter train to Podlipky.

I made my way without adventures and was lucky this time not oversleep my station, as it did happen before pretty often. At the place that tape was immediately withdrawn by our security guys and was stamped 'classified', though it was clear that during the time I was riding to Podlipky I might have lost or copied it that many times I wanted. However they would not want to make their way to the place where we were doing our computations. That was the arrangement of our security system.

That trajectory was incorporated into calculation, and on its basis the pitch control program was created, guiding the rocket in a transition from a vertical flight to

* BESM, to pronounce in Russian.

** Place, where the Korolev's OKB-1 Design Bureau was situated.

a horizontal with respect to the local horizon, and into a relative velocity control program. When that job was done we made our way to Baikonur – a few weeks prior to the launch which was slated for October 6.

The assembled rocket was already through the course of testing at the launch site, and the task awarded to me was to verify the settings for launch and to monitor the propellant charge to the rocket. Moreover, I had to attend the launch process till the moment of oxygen tank venting complete: if you get the venting valve closed after filling, the tank will get exploded by the pressure, therefore is was required to release evaporation and continuously to refill with liquid oxygen to the needed level till the very start.

The Sputnik was also prepared by that time. The story of its creation was quite interesting: the truth is that our first Sputnik, that very one which was supposed to be the first, weighed one-and-a-half tones and was equipped with a lot of scientific hardware. But time was running short for its adjustment and check-out by the 6th of October, and therefore it was decided to lay it aside (it was launched later, running number three). And the first to get launched was PS-1, that is Simplest *Sputnik-1**. It contained battery cells and radio transmitter only – a sphere slightly exceeding 83 kilograms.

Naturally for us, vernal romantics, once we came to know about it, to start arguing with Korolev: How come that instead of a serious scientific device we are about to launch a simple transmitter? Wouldn't it be better to build-in a pressure sensor, say, a temperature sensor or...? Korolev explained that for the time being we couldn't afford these things (by the way, though they say that Korolev was very rugged man, he was very polite when he talked to us), because should we go for preparing these sensors to set up with the Sputnik, Americans, meanwhile, can do the third launch attempt, and what if that one will turn out successfully?

The launch date was shifted forward for the same reasons. At that time, early in October, International Astronautical Federation was holding its assembly in Barcelona, and, by the by, Soviet delegation from Academy of Sciences has also participated. Now, in one of those booklets, which used to be issued regularly, we do read that on the 5th of October the Americans are to present to the Assembly the report which is called *Satellite over the Planet*. That stroke a warning note to us: could that message be prepared in the wake of the satellite launched by the Americans? And us planning the launch on the 6th only.

We dashed to Korolev and shown that message to him. At once Korolev didn't say anything and left the room, and only, many years later I came to know that he got in contact with KGB, Committee for State Security, and asked if they had any information that the Americans are planning to make another attempt to launch their satellite on the 5th of October. The reply from the KGB, and I also came to know it many years thereafter, was the following: '*Negative. We do not possess the information that the Americans want to launch the satellite on that day*'. *And the second paragraph reading as: 'We do not possess any information that the Americans are not planning to launch a satellite on that day*'.

Korolev's direction was to shorten all preparatory activities: cancel some check-outs which might be not so critical, and get the launch date shifted to the 4th of October. It was a risk, certainly, and a serious risk it was, but he dared to take it.

* See p. 18.

And so came the day of the launch. My team was at the launch pad till half-an-hour readiness check-point verifying all the required parameters, and then, as we sing in our song: '*Let us, cronies, get aside*', we went behind the theodolite tower which became our viewing spot for the launch.

The rocket emerged from the flames. It was even a little bit funny to watch it as it looked somewhat awkward, with its 'native' original re-entry vehicle being very long compared to the fairing of the First Sputnik being exactly a short end cap.

By the way, before that moment I have seen the warhead or re-entry vehicle itself only as a figure, shown as a sketchy triangle. And then, fifty years later only, had I seen the authentic re-entry vehicle, jumbo piece rising to the ceiling — in Museum in Sarov.

Well, now, '*semyorka*'* went off flying, then was a separation, then went the commands, telemetry measurements... and then, all of a sudden — hoots and shouts: '*It is falling, falling!*' And we saw it rising over the horizon in the beginning and then it moved onto a horizon.

Those days, indeed, the rockets were falling quite often, as we were just at stage of development tests of '*semyorka*', and that why all hearts stopped beating. But in reality the rocket at that moment was 'falling' only with respect to us, that is, with respect to the launch horizon. It ought to be driven to a zero inclination hundreds kilometers from the starting point, therefore, we were bound to see it going down in order to 'lay' to the local horizon later. So I say: '*Well, no, guys, the thing are going OK, it is just flying a different trajectory...*' However the people with no experience of seeing satellites launch got frightened.

Later on the information about the rocket and Sputnik was received from telemetry. It has shown that the booster impulse was corresponding to the estimations and the velocity was as planned. But to be on safer side, we had waited till Sputnik has flown overhead so that we could receive its signals and that happened in about an hour. We started to disband only when it was finally clear that it was on orbit. It was dead in the night by the local time.

Using special communication assets Korolev has reported about the launch and then he came out to us — the whole event was taking place in kind of barracks, people got crowded in the corridor, — and he said: '*Comrades, I do thank you. Now you can go and have a drink*'.

To have a better understanding of how it may have sounded in those circumstances, you'll have to envision Baikonur in the year of 1957. As a matter of fact, Baikonur Cosmodrome as such was not existent at that time. Huge constructions like launch pad, assembly and testing complex and others were collectively called '*polygon*'**, and it was located by the side of the Tyura-Tam railway station. There was a song with a line saying: '*Tyura-Tam, Tyura-Tam, here is a fine place for only a donkey*'.

Now it takes them a few hours to prepare a rocket. At that time it took them two weeks to assembly from the moment they would get a delivery in separate blocks, and months — would it take till the launch event itself. And all through that lapse of time 'prohibition law' was enforced at the site: neither wine, nor beer, nor vodka. And there was not even a place to buy it, Tyura-Tam was a railway station with a little built-up area of a dozen houses and not a single shop. When they built the range it

* Russian word 'seven', colloquially used for R-7 rocket.

** Range.

was serviced by the military unit, there were some shops there but no alcohol beverages sold.

People, of course, were 'finding some ways from the situation', and though you could not find wine at the site, but there was always pure alcohol available. It was used for cleaning the glass surfaces and connectors. Biggest supply of alcohol was at telemetry specialists disposal because all the data was recorded to motion picture film strips, and to expedite acquisition of data the developed film strips were dried by pure alcohol. Well, one could drink that stuff after the drying process.

Far and by, the situation was quite constrained. Well, and under such circumstances, here is Korolev saying: '*Now you can go and... have a drink...*' He was person with an actor at heart and thus he made an appropriate pause and then added: 'of a cup of tea'.

As I have just started to work at the launch site and was simple-hearted, there I go out and say: '*Well, I happen to have a bottle of wine*'.

Korolev's smiling face just a moment before got frowned as it was not allowed to bring in alcohol to the Cosmodrom.

He said: '*Give away the bottle to the superintendent*'.

I say: '*The bottle proper — yes, I will surrender*'.

He laughed and asked: '*What are you? An engineer? Will be promoted to a Senior Engineer*'.

It was an end of a scene, and down the road was a celebration of course.

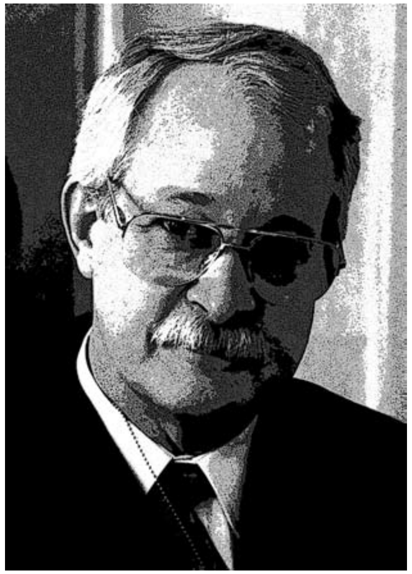
There is yet one more interesting thing: Though it was us who have launched Sputnik, and the text of the message for TASS* was also written by us, we did not disperse till we heard it on the air read out by Levitan.

The wording of the message was prepared in a somewhat reserved spirit and apart from the other things we have written that, perhaps, now this event may be left unnoticed, but years will pass and our contemporaries will truly appreciate its importance in the future. Levitan, in his turn, made a mistake while casting his words on the radio, and instead of the word 'contemporaries' pronounced the word 'compatriots' and it sounded like this event will be important through many years to our compatriots only.

As a result, the next day's, October 5 *Pravda* newspaper was published as a routine issue with a tiny article somewhere it the bottom corner stating that Earth satellite was launched in the Soviet Union with some several figures that followed. The front page news of the world newspapers were dedicated to the launch of Sputnik with color illustrations, opinions and comments... The foreign papers made us understand, what was that deed that we accomplished in reality. One day later *Pravda* newspaper had joined to the choir and published illustrations, articles and scientists' interviews, and later on they started to publish schedules showing where and over what town and city you could see that little star – the First Sputnik.

Eventually Korolev was awarded with Lenin Prize for participation in this work. My Director, to the extent of my memory, received Badge of Merit. I have received a medal For Labor Achievements — the smallest civilian medal. I am still keeping it as treasure because I have received it for the First Sputnik.

* Telegraph Agency of Soviet Union, the main Information Agency of USSR.



Wesley T. HUNTRESS, Jr.
USA

Director of the Geophysical Laboratory of the Carnegie Institution of Washington, President of the Planetary Society, an Academician in the International Academy of Astronautics, a Lifetime Associate of the National Academies, an Associate of the Royal Astronomical Society and a Distinguished Visiting Scientist at Jet Propulsion Laboratory.

He received his Ph.D. (1968) from Stanford University, then started in 1968 at Caltech's JPL. From 1993 to 1998 he was Associate Administrator for Space Science at NASA Headquarters. At the Carnegie Institution, today he is a spokesman and strategist for the scientific exploration of space.

His awards include NASA's Distinguished Service Medal, the US Presidential Distinguished Executive Award, the Robert Goddard Award from NASA, the Carl Sagan Award from the American Astronautical Society, a National Endowment for the Arts/Federal Design Achievement award for the Mars Pathfinder mission.

Asteroid 7225 has been named after him.

A DATE THAT WILL LIVE IN FAME

October 4, 1957, a date that will live in fame for all of human history. This was the day on which the Space Age began. This is the date dividing the history of humans bound to the earth from the history of humans moving off the earth. It will forever be remembered. Those of us privileged to be alive and aware on this date will remember always where we were and what we were doing.

"All the News That's Fit to Print"

The New York Times.

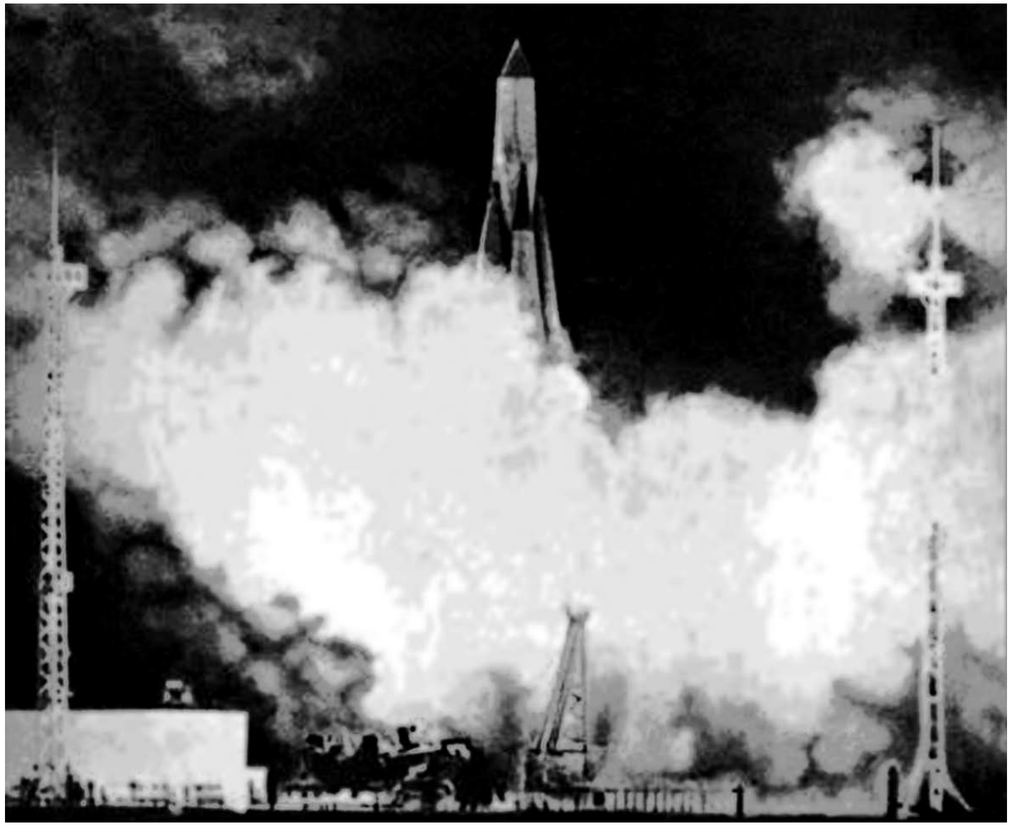
LATE CITY EDITION

SOVIET FIRES EARTH SATELLITE INTO SPACE;
IT IS CIRCLING THE GLOBE AT 18,000 M. P. H.;
SPHERE TRACKED IN 4 CROSSINGS OVER U. S.

And what do I remember of it? I was a 15-year-old schoolboy living in a suburb of Washington, DC, and getting ready for school when the morning newspaper arrived with an extremely large headline announcing that the USSR had launched the world's first artificial satellite. The printed story below the headlines tried to relate the facts as well as they were known, but the words conveyed awe and surprise. A second article described America's plans for orbiting a satellite but seemed weak and apologetic. Nothing could subvert the realization that this was a monumental moment in

American dreams — *Collier's* magazine covers in 1952 and 1954 illustrating Wernher von Braun's dreams of space flight. Paintings by Chesley Bonestell

THE BASIC SPUTNIK



Russian reality — Launch of *Sputnik* October 4, 1957

modern history; no matter whose achievement it was. I was filled with a feeling that I would later recognize many times in the years to come following similar events in the space race between the USSR and the US, an exotic mixture of excitement and fear — excitement over visions of new worlds beyond the earth and fear for the darker motives behind the achievement.

In America in the 1950's, it was taken for granted that the US would be the leader in space exploration. As a young child, I was excited about the visions of space exploration that filled our magazines and television screens. These were all about Wernher von Braun and his fabulous dreams. We heard nothing, absolutely nothing, about any such advances in the Soviet Union. Nor were we to learn until decades later that Wernher had a rival behind the Iron Curtain, Sergey Korolev. The shame is that the two never met — what a team that would have been.

In the early and mid 1950's, before the rise of television news and near instantaneous world wide coverage, Americans got their information about what was happening in the world from newspapers and magazines. The newspapers gave us the daily news, and the magazines gave us lengthy articles on what was happening around the world. Among the largest of these magazines were the weekly *Saturday Evening Post*, *Collier's monthly*, and *Life* magazine — a monthly magazine famous for its picture essays. Almost every household in America subscribed to one or more of these.

In 1952, *Collier's* magazine began a series of articles about Wernher von Braun and his dreams for putting a space station in orbit around the Earth, and using it as an assembly point to send spaceships first to the Moon and then to Mars. These articles were filled with fabulous paintings of how all of this would be done. I was ten years old and a fan of science fiction. This was science fiction brought to reality. We might actually be able to do this! Maybe even in my lifetime. The articles were thrilling. And shortly afterwards, Walt Disney, who had an immensely popular weekly show on television with stories and cartoons for kids, made animated movies based on the *Collier's* articles that brought it all to life. There on television was the famous Wernher von Braun with all of his spaceship models and illustrated explanations of how we were going to the Moon and Mars. It is hard to explain how wonderful all of that was to a young, impressionable child filled with dreams of his own future. There was no doubt that I was going to be a scientist and a space explorer. I knew at the age of ten years what I wanted to do in my life.

And then came *Sputnik*. Not the first step into space we expected from America, but wholly unexpected from behind the Iron Curtain. Not even the leaders of the Soviet Union predicted the worldwide shock and awe resulting from the 'shot heard around the world' — they were caught as much by surprise with all the acclaim as everyone else.

The reaction to the launch of *Sputnik* was immense in America. There is some truth to the notion that *Sputnik* forced more revolutionary changes in the US than any course correction it might have influenced in the USSR. *Sputnik* changed the whole direction of American education, science and technology development, military policy and international politics. In the following decade, US schools graduated more scientists and engineers than at any time in its history. Young people were very attracted to the excitement of exploring space. The reaction to *Sputnik* awoke the leadership in both the US and the USSR to the power of civilian space achievement. The US established and funded a whole new Federal agency charged with civilian space exploration, NASA. Inside the USSR, Korolev became a state hero (although incognito) and was given great latitude by the leadership to carry out his long-cherished ideas for civil space exploration.

Sputnik changed the world as well. It made achievement in space exploration the mark of an advanced nation, a prestige still sought after by many nations today besides Russia and the United States. Europe and Japan followed in the 1960's and 1970's, establishing fledgling civil space programs that have since matured into competitive enterprises. And eventually China followed suit. China is now the third nation in the world to develop the independent ability to launch men and women into space. China is a member of an exclusive 'club' that carries with it enormous respect and prestige in the world.

Sputnik was initially not at all about peaceful uses of outer space. It was a test flight of Russia's first intercontinental ballistic missile (ICBM). It was the fifth test flight, and only the third success. Just as in the US where Wernher von Braun was developing military missiles with the hope of being able to use them to explore space, so was Sergey Korolev developing military missiles in the Soviet Union with the same dream in mind. The military objected to his proposals to test his rocket by orbiting a satellite. He overcame these objections by using his persuasive powers with the government in Moscow. It was only after the powerful and unexpected affect *Sputnik* had on the West was Krushchev fully convinced that a strong civil space program was in the best interest of the USSR *Sputnik* also convinced the reluctant government check

writers in the US that there were more powerful and essential motives for civil space than just science, and the money began to flow.

The achievements of both Soviet and American civil space programs that followed *Sputnik* were the single best results that issued from the missile arms race between them. These military missiles enabled civilian space. Without them, it would have taken far longer for a civil space program to develop. Without the military incentive we might still be dreaming about sending spacecraft to the Moon, Mars and beyond. The idea of scientific space exploration was not a sufficient incentive for building such expensive launch vehicles. Witness the puny size of the built-for-science US *Vanguard* missile, developed exclusively to launch the first US scientific satellite weighing little more than 8 kg, compared to the *Atlas* missile developed as an ICBM but capable of launching a manned spacecraft into orbit.

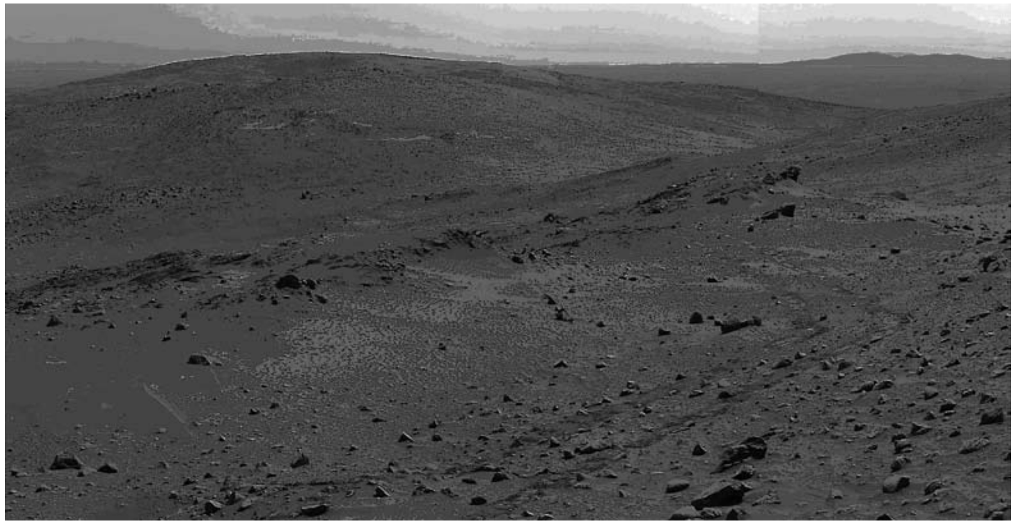
You can imagine the chagrin of US missile developers when the USSR demonstrated the capability to orbit the 80 kg *Sputnik*, 10 times more massive than the *Vanguard* satellite, followed almost immediately by *Sputnik-2* weighing more than 500 kg! It became abundantly clear that Soviet missile technology was far ahead of American efforts. The ability to orbit a satellite signaled the ability to send a missile from the Soviet Union to anywhere in the United States, and the unexpected massive size of Soviet rockets was clearly more than adequate to carry a large nuclear warhead. Americans were terrorized by such a prospect. I remember civil defense drills in which all school children hid under their desks in mock air raids, as much good as it would have done in a missile attack. After *Sputnik*, America sped up the development of military rockets and warheads. Without a Russian missile test as open and public as *Sputnik*, America may not have mobilized so early to match its missile arsenal with Russian capabilities and to begin a competitive civil space program.

These very same military missiles developed in the 1950's and 1960's are still launching most civilian spacecraft today. Korolev's venerable R-7 '*Semyorka*' ICBM, the rocket that launched *Sputnik* and the Space Age, is still the staple of Russia's civil space program today, now upgraded as various versions of the *Soyuz* launcher. The US still uses the *Atlas* in its stable of civilian launches, and in one of the great ironies of history the current *Atlas* uses rocket engines developed by the USSR for its own nuclear missiles in the 1960's. The legacy of *Sputnik* has indeed changed the world in ways that could not have been imagined in 1957.

Sputnik also changed the way we thought about exploring space. Prior to *Sputnik*, no one imagined the first space explorers as robots. No one was writing about autonomous landers on the Moon, or robotic rovers on Mars. Pre-Sputnik visions were all about human beings going to the Moon, Mars and beyond. Wernher von Braun was driven by dreams of human space travel to the Moon and Mars. Sergei Korolev thought in the same way. Sergei's orbiting satellite was simply a test in the path to building the piloted spacecraft he was already designing in his mind. But with *Sputnik* came the realization that we could send robotic spacecraft to these faraway places much more easily than humans. And of course, the Moon was the first place to go. The USSR led the way with robotic missions being the first to fly past the Moon, first to impact the Moon, first to photograph the lunar far side, first to land and photograph the surface, first to orbit the Moon, first to land a rover on the Moon, and first to return samples from the surface robotically.

As a result of the explosion in robotic exploration of the Solar system initiated by the earth-orbital flight of *Sputnik* in 1957, we have leapt off the surface of our home planet

Sputnik opened the door to planetary exploration: on the surface of Venus from the USSR's *Venera-13* in 1981 (left); on the surface of Titan from ESA's Huygens Probe (right)



On the surface of Mars from the USA's *Spirit* rover

and sent robotic extensions of our eyes, ears, nose, arms and legs to the far reaches of the Solar system. Robotic spacecraft have surveyed the Solar system from Mercury to beyond Pluto, orbited Venus, Mars, Jupiter and Saturn, and landed on Venus, Mars and Titan to show us the bizarre surfaces of exotic new worlds.

In 1957 these places could only be imagined, and traveling to them was the realm of science fiction. Today, the Solar system has become humankind's new backyard.

We can thank *Sputnik* for getting all this started. *Sputnik* initiated a renaissance in understanding our Solar system and the Universe. It also opened up the era of Earth remote sensing, to understand our planet as an entire system including the natural and anthropogenic changes that can affect our life here.

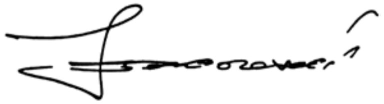
Sputnik signaled the beginning of world-wide satellite communications that have shrunk the planet and will hopefully someday bring out the best instincts in humanity towards understanding of our fellow human beings instead of the fear and hatred that have characterized much of human history. Observations of our planet from orbiting spacecraft born of *Sputnik's* first flight may help us to protect ourselves and our planet from self-inflicted damage in a world different from 1957 yet still dangerous — threatened by global climate change and by continuing human violence. *Sputnik* flew around a world without boundaries, standing as an icon for knitting together the disparate cultures of our planet. And let's hope that is its best long-term legacy.

Georgy USPENSKY
RUSSIA

Chairman of the System Engineering of Scientific and Socioeconomic Complexes Department, TsNIIMASH (Central Research Institute of Machine Building). Doctor of Science. Professor. Born in 1932. Graduated from the Bauman Moscow High School of Technology in 1955, a diploma in mechanical engineering. Worked in the Tikhonravov Artillery Academy in 1955–1958.

A TsNIIMASH employee since 1958.

Honoured worker of science.



THE SPUTNIK: TWO DAYS BEFORE THE LAUNCH

...The mission control room was buzzing with pre-launch commotion. The officers were checking on the phone about the functionality of measurement and communication systems and reported readiness to their superiors. Various troubles and arguments would break out and be settled as by the true military officers based on the Charter and a loud voice.

Excited colonels and lieutenant colonels were buzzing between the desks, pushing each other away and not caring for any apologies. The generals were monumental in their stature, graciously listening to the reports and giving instructions, some crucial, some even more so.

The civilians were more sincere in their emotions and actions. They were more excited by the event itself, it's importance and historical value. Enthusiasm and curiosity were written on their faces.

At about eight o'clock, Lieutenant colonel Grigory Levin showed in the doorway and declared with the voice of a Jericho pipe: 'Marshal Nedelin!'

The room fell silent and froze, as if in a still frame. The officers froze at their desks and bowed their heads gingerly squinting at the door. The civilians turned towards the shouting Levin with obvious curiosity on their faces.

Nedelin entered the room, not paying any attention to the people inside and realizing how significant his appearance here is for the common ranks. General Sokolov escorted him respectfully but without a trace of complaisance.

They went to the end of the rectangular room where there was a working desk for Marshal. Then escort of a few generals showed up in the doors. They followed their leader in a group at a 10 m distance.

Nedelin came to the chair, stopped and looked at the room. His brick-red marshal's face expressed the peace and infallibility. His whole appearance radiated with power and magnitude. He glanced at the crowd of officers frozen over the green desks and his lips formed an ironic and condescending smile.

The escort crowded at about 5 meters from his chair and were staring the Marshal awestruck. Only Sokolov, being the host here, dared to stand by his side and give explanations.

Finally, Nedelin sat in his chair with his side to the others in the room and went deep in his marshal's thoughts. Maybe he imagined the first stages of launch site construction in bare desert near Tyura-Tam, the life in rail cars under merciless southern sun, initiation of the intercontinental missiles project, arguments and doubts of its fast completion, the successful launch – and here it is – the Sputnik. This smart intellectual did a lot to organize and launch this historical event, and, maybe this was the reason why he could realize how significant this event was.

Wearing the marshal's uniform, the exercised his commander's function in a massive and somewhat scenic way and thus ensured all his subordinates were up and doing. With all his exterior austerity and perfection his face sometimes revealed sparks of self-irony, which the others personalized. Such caution instinctively protected them against potential misunderstandings, and Marshal had a chance to free his emotions without any harm to his troops.

Little by little the marshal induced shock was waning away; the busy rustle was setting in. People's voices were growing louder, and the rattle was increasing. Finally, Nedelin, who has been sitting quietly up until now deep in his commander's thoughts, slowly raised his heavy head and, as if passingly, said: 'It's getting too loud.'

Lieutenant colonel Levin stepped off the escort group, made three steps towards the Marshal, stopped, assumed an official ceremonial stand, and shouted in a thick bass voice: 'Stop the noise!'

The command shot through like a shock wave from an antitank shell over the excited people's heads and everything went quiet instantly.

The planned launch time was approaching. Nedelin leaned in his chair with slow grace and with a wide gesture removed large silver watch on a long thick chain out of his pocket. Holding it in his left half-extended hand, he opened the lid on the watch by quickly pressing on the watch knob and started watching the dial. Everyone froze anticipating the events. Sokolov and Levin quietly approached the Marshal – just in case.

'Any news from the launch site?' Nedelin asked in a smooth voice.

'Nothing so far', Sokolov answered.

This breathless silence of anticipation was on for about an hour. Finally, there was a call in one of the comm booths in the other end of the room and in a few moments the comm officer, whose all appearance revealed the importance of what he was doing, half ran to Nedelin. Escort generals intercepted him on his way; they heard the report and Sokolov then quietly reported to the Marshal. After that, Nedelin stood up and headed for the exit.

Everyone in the room realized there would be no launch today, something did not set straight there on the launch site, — or it could have been a simple drill of which only the commanders were aware of.

The room became empty, the commotion died away, but the operational group led by Jatsunsky remained at their work stations. What if there happened a miracle and the launch would still be 'go'? That is why, complaining about the decisive role of the contingencies and the lack of any valid information, people decided against going home but to spend the night at work. Igor Marianovich Yatsunsky considered it normal to stay overtime after his work in the evening, especially in case there were some issues with the estimates. He justified it by the tedious commuting home and back to work again.

It was really a full scale journey from the Institute across the field to the train station, then by electric train to Moscow, then metro and tram. About two hours in total. Whereas here everything is so simple: you lie down on the desk, a pile of books under your head, cover with overcoat, and hardly you have time to close your eyes, as your colleagues show up at your door and say tell you there is morning already.

...Although being a true intelligent, Igor Marianovich, or simply 'Marianych', was not choosy about the conveniences and life comfort, but did not spare himself. He was extremely polite and kind everyone around, and the major's rank did not associate well with his appearance. But he would become close friends to people very seldom and slowly: he could not stand dishonesty, insincerity and indifference towards work.

Whatever Igor Marianovich did, he always managed to find original ways and unique decisions. People would first view them as complicated and bizarre, but they were very efficient upon closer examination.

Thus, he was a pioneer of researching a way to perform reconnaissance from space back in 1954 and in 1956 he started developing a method to estimate the orbit based on the observations of the sunlit satellite against stellar sky made by the amateur astronomers.

The guitar was Marianych's secret passion. He played from music classical sketches and plays by Sor, Julliani and Carcassi. He worshipped guitar. He took it very tenderly in his hands, ceremonially put it on his laps, and played focused and inspired. It was complete ritual, another part of his personality, just like the work...

* * *

The whole thing happened the next day, just like in a play at a theater: Nedelin's appearance, the characters, their arrangement in the room, the postures and facial expressions, all in accordance with their rank in the hierarchy.

'There is a draft in the room. Somebody feels hot?' Nedelin said in a thick throaty voice, hardly heard by the people standing close to him and without turning his head.

'Close the window!' Roared lieutenant colonel Levin who was standing three meters away from the Marshal.

The people in the room, hypnotized dead still until then by the Marshal, suddenly shuddered and the room was humming with inquiring shouts: 'Where? What? Who? How?' Lieutenant colonel Narimanov was the fastest to react. With all his heavy build and external steadiness, he unexpectedly dashed to the window, closed it and equally dashed back to Nedelin. Everyone was stunned, watching the maneuvers of the smart lieutenant colonel.

Narimanov slowed down the pace as he approached Nedelin, his movements revealed the military bearing, and, finally, having approached at a distance of 5 meters, he stood still and reported: 'Comrade Marshal of the Soviet Union! The source of the draft was neutralized! Lieutenant colonel Narimanov.' Heavily built Marshal, leaning in his chair, raised his head, smiled ironically and nodded.

Thus, we have been waiting for the launch to commence for about half an hour. Captains and majors would sprang regularly out from the communication booths and approach the escort, report something, the escort would listen intently, someone from the escort would approach the Marshal and tell him something quietly. Suddenly, the door on one of the booths banged open, a communication officer sprang out of it and dashed towards the Marshal. He stood at attention and thundered: 'The rocket has been launched, Comrade Marshal!'

The communication officers started running even more briskly between their booths and the escort reporting the rocket flight status at the active trajectory. Finally, there was the report: 'Rocket thrusters were disabled at the estimate time!'

The commotion in the room was gaining momentum. The military officers and the civilians took their nominal positions, ran through estimate forms and tables, getting ready to determine the satellite period. Numerous guests, mainly the generals of every rank and academicians from the Academy of Sciences would get in corporate groups and excitedly exchanged their views.

Everyone was waiting intensely when Sputnik would be first tracked anti-ballistic missile defense. If the launch was successful, then the Sputnik would show up from the south-west in about ninety minutes. Communications officers started shouting in the phones in an hour after the launch: 'Report the status! Do not miss it!' Although the phones were in six booths behind closed doors, everyone in the room heard bursting voices of the military officers bleeding in a shouting oratory. Finally, there was a cry of joy and wonder:

'What, we have tracked it? Are you sure? Who is reporting?' Then there was a brief pause, everyone went calm. 'What, what? Pushkin? What are these jokes?! I will report the Marshal and disrank you!'

Another pause. It changed to perplexity.

'What, your name is really Pushkin? Give me your superior' A pause. 'Do you confirm the satellite has been spotted? You take full responsibility for that'.

After the confirmation the captain, flushing with excitement, rushed towards Nedelin. All the heads turned to the captain. Having come up at a run, stood at a halt, stood at attention and shouted: 'Comrade Marshal of the Soviet Union, we have spotted Sputnik!'

Nedelin stood up, looked at his watch, swept his eyes triumphantly over the room, and turned to Sokolov and the generals standing further away. The generals took this as an invitation gesture, approached closer and started exchanging ideas about how valid was the report about spotting Sputnik and not some airplane or some other object. People's faces expressed jubilation and anticipation of an epic event.

Another report followed in a few minutes that Sputnik was detected by another ground site, then more and more ground sites reported. It was clear that the event had happened, and the room started humming with jubilation. People were running to and fro. They hurried to report to ballisticians about the time, location and the azimuth of the detection. Common rank generals stood up and watched the happening with increasing curiosity.

The focus in the room shifted from Nedelin to Sputnik. You could see that Nedelin realized this, and he began to loose his scenic posture and become an ordinary military officer. Having discussed the status with his escort, marshal decided to personally confirm the event and meet the people in the flight control room.

Nedelin went from one desk to another. Sokolov accompanied him by his side, Levin followed behind and then the escort generals. They stopped by each participant and listened to officers shouting their status reports. Marshal nodded patronizingly, and the escort generals smiled reverently. Finally, they approached the desk where Eliasberg, Yatsunsky and Narimanov had been working. This is where the Sputnik orbital period was estimated. Excited, each of them, independently from each other, exponentiated with slide-rules, multiplied and divided, added and deleted with *Felix* calculating machine to find out later that the period was 98 minutes.

Nedelin stood by the desk and watched the busy fuss with an apparent curiosity. For some reason, no one would spring up or shout in a roaring voice to report to Comrade Marshal of the Soviet Union. Everyone had his nose in his papers, people were red and perspirated with excitement, calculated and recorded something jerkily. Marshal was silent and no one of his escort dared to break this silence.

Narimanov was the first to see Nedelin. He stood up deftly, and was about to start shouting out his report, when Marshal gestured him not to disturb his colleagues. Yatsunsky also began to get up from the desk, checking the buttons on his uniform in a confused manner. Pavel Ephimovich kept on writing, mumbling something, throwing the remaining hair from one side of his bold head to the other. This was the climax of the dumb show: everyone is standing at attention, Sokolov was looking gloomy, the escort froze anticipating the unfortunate Lieutenant Colonel would be taken to task, and Marshal gave an ironic smile.

Narimanov was the first to break the silence. He said quietly to Eliasberg: ‘Pavel Ephimovich, Marshal Nedelin...’ Pavel Ephimovich did not bother to raise his head, waved away and said vexedly: ‘Leave me alone!’ And went back in his work again, stooping over his papers. Then he suddenly limpened, stopped, raised his eyes, saw Nedelin, smiled embarrassedly, and started arranging himself slowly: fastening upper buttons on his uniform with one hand and searching for the cap on the desk with the other. He stood up awkwardly and tried to compose his mind figuring out what he should say and do.

Nedelin cleared the air.

‘So, what do you have here?’ He asked in what appeared as a friendly tone.

‘The period is about 98 minutes, Comrade Marshal’, said Eliasberg in an embarrassed voice.

‘It this too much or too little?’ Nedelin asked.

‘It’s normal’, concluded Eliasberg.

The short answers and routine tone of the dialogue between Eliasberg and Marshal as peers shocked the people. Marshal took this gently. He realized that there is no need to stimulate the enthusiasm in the scientist standing in front of him, and disciplining him would be useless and wrong.

To break this abnormal situation, Narimanov started explaining how the period is estimated, but Marshal could not care less. Having listened for a while, he asked suddenly: ‘How can you be sure that the spotting we received from the anti-ballistic missile defense is not a mistake or worse, a provocation from the potential enemy?’

A dumb show again, but now everyone watched Nedelin not without a slight sarcasm. Marshal realized his question was odd and he managed to find a way out from the confusion:

‘Yes, I believe you are not a person to answer this question. Keep on working.’

Pleased with himself, Marshal headed towards the exit from the flight control room.

By the next morning Sputnik has made three orbits, and now everyone realized that the epic event has happened. Information from the observers was forwarded to the flight control room, was processed, orbital evolution and Sputnik life span were forecasted. Nedelin’s appearance was not shocking to the inhabitants of the room anymore. Marshal would sit calmly in his chair and listen to Sokolov’s and Narimanov’s reports.

...It was about 10 in the morning. The door burst open and Sergey Pavlovich Korolev showed up. He did not stop and went straight to Nedelin. His face expressed satisfaction and concentration.

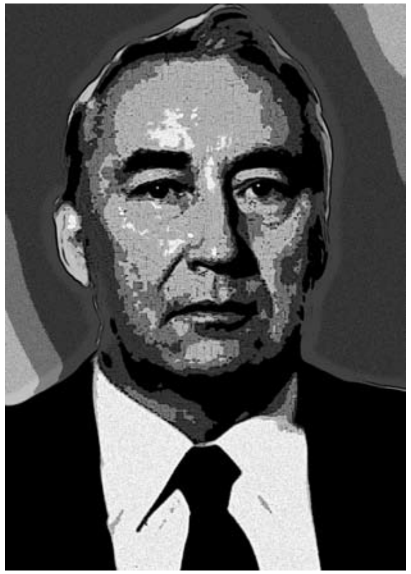
Ryabikov was also here. Small in stature, lean and fit, he was walking next to Korolev to Marshal.

Vasiliy Pavlovich Mishin followed them. His smiling face radiated happiness and he, a good deal taller than his Leader, transmitted jubilation to all in the room. The feeling of boyish happiness was even further amplified by standing out ears of the deputy Chief Designer.

Upon seeing Korolev, Nedelin stood up from his chair and greeted and congratulated Glavny as a peer with a handshake. Nedelin, Korolev and Ryabikov started a discussion. Korolev, slightly stooping, was smiling modestly. Nedelin was open and complacent. Ryabikov looked focused, inappropriately resolute and ready for action.

Mishin was viewing the room with curiosity. The room was viewing Mishin. The joy he radiated was transmitting to the people in the flight control room, reflected back and made Vasily Pavlovich shine even more.

After a brief exchange Korolev, Nedelin and Ryabikov headed for the exit. The escort rolled after them at an appropriate distance.



Viktor FAVORSKy
RUSSIA
Lieutenant General.

Born in 1924 in Moscow. Joined the Red Army voluntarily in 1924. In 1942 graduated from Artillery College in Leningrad (express course). In 1943 transferred to the High Military School of Air Defence Forces. From 1946 to 1951 was a student at the Jet Propulsion Department of Dzerzhinsky Military Academy. Served as the senior engineer in the number of projects by the Ministry of Defence. Took part it testing P-5 and P-5M missiles. Appointed to the Central Office of Space Devices in 1967.

In 1986–1989, Commander of Main Office of Armament, then Deputy Commander on Space Devices of the Ministry of Defence. Adviser in the representation of the Ministry of Defence on quality and reliability in the Space Research Institute of the Russian Academy of Sciences since 1989.

Hero of socialist labor. Awarded the State Prize of Russia, 5 orders of the USSR and medals.

Honorable member of Tsiolkovsky Academy of Cosmonautics.

THE BEGINNING OF SPACE ERA: EVENTS, RESULTS, AND PROSPECTS

The Soviet period in the development of cosmonautics became history, going farther away from us into the past. It was a period when in a short period of time under the 'cold war' conditions on the basis of overstressed military economy outstanding success was achieved in this country, turning the USSR into a leading world power. We owe this to talented scientists, designers, industrial managers and their efficient work management in the field of cosmonautics.

Lately, Russia has lost this position. It is evident that basic change in the work management is the main reason for that. However, we still retain extensive experience, scientific-engineering groundwork laid for the future, and, to a lesser degree, industrial and test facilities and engineering human resources. It is important to study the experience gained in the work management in the past to build a new structure of the retained industrial potential and to develop the most efficient way of using it under the conditions of market economy.

...This past time can be visualized in memory as bright, happy days of post-war years, as colorful, unforgettable pictures of youth, as a constant pursuit for the future.

Many years of research work and experiments performed in a number of countries, development of first missiles in the pre-war period, then the development and use

THE BASIC SPUTNIK

of the first military missiles by Germany during the Second World War, as well as a post-war decade, when intensive efforts were undertaken in our country and the USA to develop ballistic missiles, — all that preceded the beginning of immediate work in the field of space engineering.

During the post-war period, responsibility for the development of missile technology was shared by eight defense ministries in the Soviet Union. The Ministry of Armament, headed by D.F. Ustinov, was the leading one. A dedicated Committee on Missile Technology reporting to the Council of Ministers (CM) coordinated the work. This organization retained some traits of the war time period but, being a product of progressive-mobilization economy, it still needed certain changes to be made during peacetime. It was also required to strengthen new trends of research in the fields of nuclear engineering, rocketry and radioelectronic engineering. I remember this whole process only too well, since in 1951, having graduated from the Dzerzhinsky Military Academy, I was assigned to serve at the military representative office of the Chief Artillery Department at the NII-88 Scientific-Research Institute, being the leading institution in the development of rocketry at that time.

The power created by the first developed single-stage missiles, without being outfitted with the second stage, was not enough for them to enter into space. The access into space could be open only for a missile with greater power capabilities, available for a promising intercontinental-range R-7 missile with a cluster configuration. Proactive research, studying possible launch of an artificial Earth satellite (AES), performed by M.K. Tikhonravov's team at the NII-4 Scientific-Research Institute of the Defense Ministry, preceded the creation of such a missile. However, this activity did not go smoothly, since such a research did not follow the lines of a military institution engaged in development of ballistic missiles.

Nevertheless, it was a report delivered by M.K. Tikhonravov at a plenary meeting of a scientific-research conference, held by the Department of Applied Mathematics of the USSR Academy of Sciences on March 15, 1950, that laid the beginning of establishment of applied cosmonautics, gave the initial momentum to the rise and subsequent development of space engineering. In that report a conclusion was made public that the problem of creating an AES could be practically solved in the near future. The report was based on the scientific-engineering report called *Composite Liquid-Fuel Long-Range Missils*, *Artificial Earth Satellites*. Its conclusions were developed in the period of 1950–1953 within the framework of scientific-research work, entitled *Research into the Problem of Creation of an AES*, and laid the basis for writing a letter with a proposal to carry out a practical implementation of the AES, signed by S.P. Korolev, the Head of the OKB-1 Design Bureau, and addressed to the Central Committee of the Communist Party of the Soviet Union (the CC of the CPSU), as well as to the CM of the USSR, on May 26, 1954. By that time, a study (the N-3 Project) of schematics for building extra-long-range missiles with different types of engines and control systems was performed at the OKB-1 Design Bureau, which indicated that it was feasible to implement such a proposal, and a pre-design analysis of the R-7 rocket was undertaken. Before that, at a Peace Conference, held in Vienna, A.N. Nesmeyanov, President of the USSR Academy of Sciences, announced on November 27, 1953 that the AES development is quite feasible. In 1955, in order to exceed the AES development, a part of staff members of M.K. Tikhonravov's team, namely: K.P. Feoktistov, I.K. Bazhinov, G.Yu. Maximov, A.V. Soldatova — were delegated from the NII-4 Institute to work at the OKB-1 Design Bureau. And in 1956, M.K. Tikhonravov also went to work with S.P. Korolev.

However, more than a year and a half had passed until, on January 30, 1956, a decision was made by the CC of the CPSU and the CM of the USSR to begin practical implementation of the AES. The OKB-1, headed by S.P. Korolev, was assigned to be the leading organization responsible for the development and building of the satellite. Team workers of chief designers V.P. Glushko, N.A. Pilyugin, M.S. Ryazansky, V.P. Barmin, and V.I. Kuznetsov were engaged to participate in the activities on the launch preparation. The OKB-1 Design Bureau presented a conceptual design of the AES, while on September 3 of the same year a Government Decree was issued about the development of the satellite and all the ground support facilities, which specified cooperation between scientific-research institutes and design bureaus. The NII-4 Institute, dealing with ballistic support, conceptual design and development of a command and measurement complex, substantiation of options for using the AES for resolving military tasks, as well as the 5th scientific-research range, dealing with preparation of the satellite and launch booster for the launch, were engaged in this work within the framework of the Defense Ministry.

Following the Government Decree, as of May 30, 1954, it was anticipated to launch the satellite by using an intercontinental ballistic R-7 missile. In fact, the work on R-7 was being carried out since 1953, and a conceptual design was already developed in July 1954. That missile was basically different from other missiles by its booster performance and design schematics. Therefore, to complete its development on a short-term basis was a big engineering problem. It took merely three years to build a dedicated launch pad for its flight testing by May 1957, namely, the NIIP-5 range with special flight range facilities and a test range for warheads to fall in Kamchatka.

The launch due dates were specified by the fact that on September 11, 1956, a Soviet representative (Academician L.I. Sedov) announced at a session of a special committee on the International Geophysical Year (July 1, 1957 – December 31, 1958), held in Barcelona, that the USSR plans to launch a AES during the upcoming geophysical year. One can judge S.P. Korolev's confidence about the implementation of this idea by his presentation delivered at a jubilee session of the Bauman Moscow Higt School of Technology (now Bauman State Technical University), celebrating its 125th anniversary back on September 25, 1955. While reporting on the results of using rockets for studying the upper atmosphere, Sergey Pavlovich concluded by saying that in view of the current state of development of the Soviet engineering and, in particular, of rocket engineering, and with the use of the most powerful fuels out of those known and employed at that time, the tasks of the AES development and missile flight from the Earth to the Moon were quite feasible engineering tasks. He also informed about potential characteristics of future AES. Moreover, he stated: 'Our goal is for the Soviet missiles to fly higher and earlier than it would be done anywhere else. Our goal is to create a new type of hypervelocity transportation for passengers and cargoes, i.e. to create rocket vehicles. Our goal is that a Soviet-made AES, created by Soviet people, should be the first AES, and that Soviet missiles and rocket vehicles should be the first to fly into boundless space of the Universe'.

At the same time, the conceptual design showed that a considerable amount of time would be required to develop avionics if the satellite mass amounted to 1200 kg. Therefore, there were great doubts about the tentative launch date in the summer of 1957.

Besides the Soviet Union, the USA also announced a launch of an AES within the period of the International Geophysical Year. Therefore, it became of primary importance to adhere to the planned launch date.

The accelerated launch of the satellite was promoted by a decision taken at the stage of design optimization. At the end of 1956, M.K. Tikhonravov, taking into account the tight schedule of the launch preparation, all of a sudden proposed to make it simpler than it was planned initially: with a mass of 83 kg and a minimum instrumentation. This could make it possible to obtain experience in launching a satellite into an orbit, to confirm the possibility of establishing communication with the satellite, and to develop the command and measurement complex. The proposal was immediately approved, and urgent development of such a satellite was undertaken at the beginning of 1957.

It became possible to carry out a large scope of work due to precise operation of all the divisions of the OKB-1 Design Bureau and of the pilot plant, experienced management on the part of S.P. Korolev's closest teammates: V.P. Mishin, S.O. Okhapkin, K.D. Bushuev, S.S. Kryukov, B.E. Chertok, L.A. Voskresensky, B.V. Shabarov, M.S. Khomyakov. Another important circumstance, which specified the due dates of the first satellite launch readiness, was the completion of the missile launch booster development.

The first launch of the missile was performed on May 15, 1957. It was abortive due to a leak in the missile propellant lines. The second attempt at launching on June 9 also failed. Due to a faulty valve assembly in the central unit booster, the missile was taken from the launch pad and returned to the manufacturing plant. The launch on July 12 was also abortive due to a contact-to-frame fault of control loops in one of the instruments during the missile flight.

Three abortive launches gave many people rise to concern about the destiny of the R-7 missile. However, S.P. Korolev displayed certainty that the first intercontinental R-7 missile would fly. Moreover, he already insisted at the CC that two missiles should be allocated to launch the AES, reminding about the readiness of the USA to launch their first AES. It was crucial to prove by a successful launch that the difficulties in ensuring the R-7 missile reliability had been overcome.

After measures taken to increase reliability and careful preparation at the launch pad, the launch undertaken on August 21 turned out to be successful. On August 27, 1957, a special TASS message was published in all the papers: 'Recently, a launch of an ultralong-range intercontinental multistage ballistic missile has been carried out. The tests were successful. They fully confirmed correctness of calculations and selected design. The flight was taking place at a very high altitude, not available until now. Having covered a huge distance in a short time, the missile fell within a specified region'. The country obtained a means to deliver a warhead to the territory of a potential enemy, who already had that opportunity, using military bases arranged around the borders of the USSR. However, there was no anticipated reaction of the world mass media to this news. In the USA nobody believed it and treated it as a hoax. Then, in order to cool the 'war hawks', who proposed to implement a plan of unanswered atomic attack of the towns/cities of the USSR, as well as taking into account the positive results of the recent R-7 missile launch, performed on September 7, at a session of the State Commission, S.P. Korolev proposed to accelerate preparation of the missile launch to bring an artificial Earth satellite onto an orbit. By that time, judging by the status of work on the satellite development and preparation of test facilities, the launch could be performed in one-two months, according to the estimates of the Chief Designer. That proposal was accepted, the more so that in the USA an AES launch was being prepared within the *Vanguard* Project, following a very tight schedule. A plan for the launch preparation was approved. The final stage of work began.

Work at the Design Bureau (KB) and Plant continued on a 24-h basis, 7 days a week. The program of the launch booster avionics operation was changed due to a new flight trajectory. The satellite separation and activation of its instrumentation took place after deactivation of the second stage engine. All the problems were being resolved promptly, immediately on the spot by the KB staff members. S.P. Korolev personally supervised the progress of work, appeared in the plant shops and at the KB at any time of the day, maintaining its quick progress by his insistence on high standards.

The second satellite was being prepared with a month shift to the right. It was intended for biological studies and was already well equipped with scientific payload. It had a separate pressurized cabin, housing a test animal — a dog named Laika. The satellite mass already amounted to 508,3 kg. The third satellite was also under construction. It was intended to explore the near-earth space.

Readiness to carry out the first satellite launch was confirmed by progress made in preparation of the launch pad and measuring instruments. Provision was made at the missile pre-launch area for locations equipped for testing of avionics and for validation of the satellite and warhead separation from the missile on the ground. The tests were successful. The satellite and fairing were docked to the missile and installed on the test facility. The work was supervised by L.A. Voskresensky on behalf of the OKB-1 Design Bureau.

At that time, a formal ceremonial session was held in Moscow in the Hall of Columns of the House of Unions, dedicated to the 100th Anniversary of K.E. Tsiolkovsky. S.P. Korolev took the floor. Speaking about practical importance of research work done by Tsiolkovsky, he indicated that the AES launch was an event of the nearest future. Only a few people out of all those present knew that it was possible to count days till the launch of the first satellite. On September 19, just two days after that, S.P. Korolev arrived to the range.

At the beginning of October, the missile with the satellite were rolled out to the launch pad for pre-launch preparation. At night from October 3 to October 4, its final stage was initiated, i.e. fuelling of the missile with propellant components. The pre-launch preparation went to schedule. Joint crews of launch pad test engineers were at their work places, headed by A.I. Nosov, the launch pad Deputy Head, while L.A. Voskresensky and E.I. Ostashov, the Head of the Division, were at the periscopes.

...Commands were issued to perform launch operations, the automatic equipment was activated. The launch boosters were ignited. The concrete bunker was shuddering with roar and the missiles launched.

It happened on October 4, 1957, at 10:28 p.m. Moscow time. In 315 seconds of flight the telemetry data recorded separation of the satellite from the missile and its entering the orbit at a specified time.

The launch participants congratulated one another but they were far away from fully comprehending the importance of this event...

The whole world was applauding the Soviet scientists and designers. Soviet and foreign newspapers published numerous responses of prominent scientists and political leaders to this event. The Russian word ‘Sputnik’ immediately entered the languages

of the world nations. Hopes were expressed that the new achievement would be used for peaceful rather than for military purposes. At the same time, in Washington, the news about the satellite launch was equal to an exploded bomb effect. Those Pentagon specialists who favored the strategy of ‘balancing on the war edge’, were shocked by a universally evident fact that a multistage intercontinental missile was created in the Soviet Union, against which an air-raid defense system was helpless, rather than by scientific importance of the satellite flight.

But the main result of the first artificial Earth satellite launch was the beginning of the space era, acknowledged by the whole world. Leading countries got involved in the development of space hardware, space research and utilization. During the first ten years of the space era, already eight countries began to develop their national space vehicles, while a much greater number of countries participated in space exploration. Manned flights into space, which were began in 1961 by Yu.A. Gagarin’s launch, continued actively in the USSR and the USA.

The USA and USSR ambitions for world leadership in the field of space exploration translated the ‘cold war’ into the sphere of space research, the so-called ‘moon race’ was waged, space militarization within the framework of flexible response strategy was launched, active development of military space facilities was undertaken.

In the USSR, space hardware development was actively supported by the government. Having originated from missile engineering, space facilities were successfully developed during the first years precisely due to engineering similarity of these two trends, practically within the same design institutions, under one and the same management, headed at that time by K.N. Rudnev, L.V. Smirnov, and S.A. Zverev. All the time, the OKB-1 Design Bureau remained the leading organization, initiating first developments, which was headed by S.P. Korolev, the founder of applied cosmonautics.

During the subsequent years, development of Soviet cosmonautics encompassed a number of large and complicated programs: scientific research, manned space stations, satellites for national economy needs and military purposes (at that, only the USA had programs similar to the Soviet ones). In 1965, the Ministry of General Engineering (Minister A.S. Afanasyev) was established and corresponding scientific-research institutes and design bureaus were founded for their implementation. Among them, first of all, one should name the principal institutions, headed by experienced experts, as a rule, from the OKB-1 Design Bureau. At first, they functioned as affiliations of S.P. Korolev’s Design Bureau. Then, having mastered stand-alone novel trends of space engineering, they turned into head design bureaus and scientific research institutes: the TsSKB Central Specialized Design Bureau on Means of Surveillance (headed by D.I. Kozlov), the KBPM Design Bureau of Applied Mechanics on Communication and Navigation Means (headed by M.F. Reshetnev), the Design Bureau of the S.A. Lavochkin’s Plant on Lunar and Planetary Systems (headed by G.N. Babakin), the KBYu Design Bureau on Meteorological, Scientific Satellites and Radiotechnical Surveillance (headed by V.M. Kovtunenko), the TsKB Central Design Bureau of Engineering on Orbital Stations (headed by V.N. Chelomey), the Design Bureau of the *Arsenal* Plant on Space Systems for the Navy (headed by Yu.F. Valov). On the whole, already about 80 enterprises were engaged in space projects within the Minobschemash (the Ministry of General Engineering) in 1965, with their number amounting to about 100 by the 1980’s. Cooperation between enterprises belonging to other ministries was even more significant.

Summarizing the development of work in the field of space exploration and research, one can state with much confidence:

1. In the first years of space era, the leadership of the USSR over the USA was ensured in the main fields. In the subsequent years, parity was established on the whole. At that, the USSR surpassed the USA in the manned program, while the USA outran in the research of far-away planets, launching expeditions to the Moon, and development of the multiple-use *Space Shuttle* system.

2. In executing the programs for development of space facilities intended for defense purposes, the USA was enjoying the leadership throughout all those years, which complied with their state policy. In the 1960's, the USSR lagged behind in this area by 6 to 7 years. It was explained by the fact that in this country, cosmonautics began to be developed in a new, defense field only after the Government Decrees *On the Work Schedule for 1960–1967*, dated June 23, 1960, and *On Deployment of Work on Defense-Purpose Space Facilities*, dated October 30, 1962, were issued. By the end of the 1960's, this gap was eliminated, except that in the field of operating surveillance, which remained as it was until 1982.

3. Practically, there had always been parity between the USSR and the USA throughout all those years, as far as the number of operational space military systems and facilities is concerned. As for the number of launches of space craft's, the USA somewhat outdid the USSR at the initial period. Beginning from the 1960's, the number of launches of space craft's per year in the USSR considerably exceeded that in the USA, which was explained by more intensive work in the field of space exploration and the beginning of utilization of continuously operating space systems. It was required to permanently re-supply these systems, since the active service life of our space vehicles was considerably less than that of the USA space craft's.

4. As for the orbit injection means, the capabilities of the USSR and USA turned out to be similar, but our rocket launchers boosters still display higher ratings in reliability of operation.

For the 50 years of the space era, achievements in space engineering left a noticeable trace in the history of mankind and the role played by our country is enormous. How was it possible to achieve such high work efficiency in space industry in the USSR? It was possible due to the progressive-mobilization economy, assisted by timely financing, development of industrial and test facilities, scientific support and sustaining engineering, with a continuous caring attention paid by the government of our country, by the agencies, placing their orders, due to the long-term planning of work at all the levels, introduction of standard documentation and continuous quality control. Under those conditions, all the people, participating in the development, production, testing and operation of space hardware, worked with dedication and displayed heroism.

Recently, 10...15 years after the breakdown of the Soviet Union, the pace of development of Russian cosmonautics has decreased considerably, while it is scientifically predicted that there would appear still new promising trends, further promoting the mankind development. Time has come to shape a planetary culture. In the 21st century, mankind enters a new phase of its development, mastering of space secrets and energies, raises it to a higher intellectual level and make it possible to replenish the already depleted Earth resources from space. One of the incentives for that is, undoubtedly, the adoption and further development of scientific and engineering

THE BASIC SPUTNIK

hypotheses for the sake of overcoming real crisis situations menacing the Earth – first of all, the energy crisis. Above all, it has to do with young people – soon they will have to enter the battlefield to rescue civilization on the Earth. Today, circumstances are favorable for the efforts of scientists all over the world to be united in order to collectively confront global threats, that mankind faces. There appeared a real possibility to increase the accumulated experience of international cooperation in this field. Those projects that are particularly complicated and expensive should be organized under the auspices of the UN.

Igor BAZHINOV
RUSSIA

Senior Research Fellow in TsNIIMASH (Central Research Institute for Machine Building).

Born in 1928 in Rostov-upon-Don. Graduated from the Ordzhonikidze Moscow Aviation Institute in 1951. Served in the Soviet Army in 1951–1960, was employed in the Research Institute-4. Took part in research projects of designation of ballistic missiles and artificial Earth satellites.

Since 1960 worked in the Research Institute-88 (now TsNIIMASH). Led the study of ballistics and navigation of prospective spacecraft vehicles, was Head of ballistic and navigation service in control of automated and manned spacecraft. In 1985–1992 he coordinated work on creating facilities for mathematical simulation modeling of complex mechanical systems in TsNIIMASH. Since 1993, leader of research for Russian automated ground-based flight control complex for robotics and manned spacecraft for scientific and social purposes.

Awarded Lenin Prize, State Award of the USSR, the Red Banner and several medals of the USSR.

THE EARLY WORKS ON THE STUDY OF PRACTICAL PROBLEMS IN THE DEVELOPMENT OF BALLISTIC ROCKETS AND THE ARTIFICIAL EARTH SATELLITES

The first artificial Earth satellite (AES) was developed and launched on October 4, 1957 under the direction of S.P. Korolev. The road toward this event in our country was not simple and easy one, having made steep zigzags and loops at times.

The first and the main factor which determines the possibility of the satellite launch is the presence of a rocket able to provide the satellite with the orbital velocity (about 7.8 km/s). The works on the problem study and the practical rocket development have already started in our country in the beginning of the 20th century. In 1921 the laboratory in Moscow created with the state funding began the operations studying the issues of building the solid fuel rockets, with N.I. Tikhomirov becoming the head of laboratory. It was relocated to Leningrad in 1925 and called Gas-Dynamics Laboratory (GDL) since 1928. In 1931 the sector (later the department) of the liquid fuel rockets was formed (head — V.P. Glushko). At GDL serious advances were achieved in the development of liquid propellant engines. Liquid fuel systems with a propulsive power up to 300 kgf were designed and built.

In 1931 in Moscow by Osoaviakhim the group of jet propulsion studies (GIRD) was established directed by F.A. Tsander and then by Sergey Pavlovich Korolev. The GIRD team headed by M.K. Tikhonravov has created and launched on August 16, 1933 the first rocket in USSR (GIRD-09) with an engine operating on liquid oxygen and paste gasoline. The rocket reached the altitude about 500 m*.

On the basis of GDL and GIRD the Jet Propulsion Scientific Research Institute (RNII) was created in 1934 in Moscow by the Government, with I.T. Kleymenov becoming its director. After GIRD-09 the GIRD and RNII staff has developed and launched a number of liquid fuel rockets reaching the kilometer heights during the tests. But during the pre-war and war years the works on creating the long-range rockets were frozen. Many leading specialists in rocketry (S.P. Korolev, V.P. Glushko, I.T. Kleymenov et al.) were repressed. The priority was given to the works on the design of tactical solid fuel rockets**.

In Germany, as it became clear later, under the deep secret the works on the liquid fuel rockets design have got the priority, and the German scientists under the auspices of Wernher von Braun have built the V-2 rocket capable of providing the 900-kg military payload with the 1.5 km/s velocity and delivering it to the distance of about 300 km. The wide-range utilization of this type of rockets has begun in 1944. The messages about it, as well as the Winston Churchill's letters to Iosif Vissarionovich Stalin about V-2 rockets have strongly changed the attitude of the country leaders towards these rockets.

In the end of war and during the postwar years the Soviet government started urgently sending the groups of prominent rocket specialists to the liberated regions for collecting and studying the information on V-2 rocket. S.P. Korolev, V.P. Glushko and other specialists who survived the repression were set free. In February, 1946 the operation of all groups pointed at the study of V-2 rockets was combined within the *Nordhausen* Institute created in Germany, with General L.M. Gaidukov appointed its director and S.P. Korolev — his deputy, General Engineer. The Institute was operating in Germany until March, 1947. During this time the drawings of V-2 were restored, nonutilized spare rocket parts were found. Using them made possible to assemble some amount of rockets.

All the documents were delivered to Moscow for the following study and testing the assembled rockets. By this time on the basis of ordnance factory in Podlipki*** the Scientific Research Institute on Rocketry (NII-88) was established. S.P. Korolev was assigned the Head of Department No. 3. The design bureau, computational divisions, experimental production, testing subdivisions and others were created within the department. August 26, 1946 is considered to be the birthday of the Korolev's OKB-1****, when the department structure was approved. The above mentioned Decree also established the cooperation of industry factories which were given a task of studying and developing the basic rocket components.

* The world's first liquid fuel rocket was launched in USA in 1926 by Robert Goddard, having reached the altitude about 15 m.

** Those works have resulted in the creation of *Katyusha* missile launcher which played the huge role in the fights of the World War II.

*** Moscow region.

**** S.P. Korolev's Rocket-Space Corporation 'Energia', 1996, BBK 39.62 I90. UDK 629.78:658.5 (091).

The S.P. Korolev's Department together with newly established cooperation was entrusted to complete the study of V-2 as soon as possible and to carry out its flight test. For this goal the test range was built in Astrakhan region near Kapustin Yar village. The tests of assembled rockets started in 1947.

The Government of USSR with the approval by I.V. Stalin has also charged the Korolev's department with the cooperation to create the rocket similar to V-2 and to arrange its production on the native factories from the native parts and materials. It has got the R-1 index, and S.P. Korolev was appointed its Chief Designer which he remained to be during all following developments of rockets and spacecraft carried out at OKB-1. The flight test of R-1 started at Kapustin Yar in September, 1948.

Despite the hard work, the development of a more powerful rocket R-2 started at OKB-1 in 1947 which was accelerating the military payload about 1 ton heavy up to 2,2 km/s velocity and delivering it to the distance up to 600 km. The project of the rocket with the flight range of about 1000 km (so called 'thousand' rocket) was also under study. Research and development of the yet more powerful and long-range rockets was then (in 1948) beyond Korolev's and his colleagues abilities, and the practical possibility of creating rockets like that was not considered by almost anybody, especially in the military community.

The prospects and problems of building the rockets flying for many thousand kilometers were then thought of by M.K. Tikhonravov who was appointed in 1946 the deputy head of just created NII-4 at the Academy of Artillery (later NII-4 of the USSR Defense Department). Tikhonravov was sent to NII-4 from RNII together with a group of colleagues which included P.I. Ivanov, N.G. Chernyshev, V.N. Galkovsky, G.M. Moskalenko et al. In 1947 group was also joined by the young military land-surveyor I.M. Yatsunsky. On the basis of the group members, the department was created at NII-4 headed by P.I. Ivanov.

Mikhail Klavdievich, perfectly knowing the works of K.E. Tsiolkovsky who developed the idea of 'rocket trains', decided to investigate the principal possibility of achieving the long range of flight by the staged rockets obtained by packeting one-stage rockets already under development at OKB-1.

Rocket packet – cluster of rockets arranged in parallel with all their engines starting and burning simultaneously. Rockets in packet are divided into two-three (or more) parts, with their propellant lines connected to each other. First the engines of all rockets in the pack are working from the fuel stored within the rockets of the first part. Upon running out of the fuel empty rockets are thrown away. The rest with the full tanks continue the flight using the fuel from the rockets of the second part of the assembly. The emptied second part rockets are also thrown off and the third full part is performing the flight, and so on. The last part of the pack is providing the payload with the largest velocity. We will call the packets like this packs with the fuel transfer. Moving further along the required trajectory by inertia, the payload performs the flight for the necessary distance.

M.K. Tikhonravov entrusted I.M. Yatsunsky to develop the necessary methods and to perform the calculations on the estimates of packet capabilities. In early 1948 I.M. Yatsunsky has received a number of interesting results. It turned out, for example, that the packet made of five R-1 rockets is able to accelerate the military payload of 1 ton up to ~3.5 km/s velocity and to transfer it by the distance up to 1300 km. Packet of five rockets each of them flying for 1000 km range is boosting the payload up to ~5.5 km/s velocity and delivers it to the 4500 km distance; packet of 10 rockets like this boosts the payload up to 6.5 km/s, as a result it flies for 7000 km. Increasing the number of 'thousand' rockets one can reach the orbital velocity of flight — deliver the artificial Earth satellite into orbit.

The performed calculations have shown the principal possibility of achieving any range of flight for military payloads and even that of delivering the artificial Earth satellites into orbit using the packs of rockets developed at the technology level available at OKB-1 by 1948.

M.K. Tikhonravov has set a high value on the results obtained. He has reported them to S.P. Korolev who understood their principal importance and supported the intention of Mikhail Klavdievich to give a talk on this topic at the scientific council of NII-4. The presentation was given in the beginning of summer 1948 in the presence of specialists and scientists from other institutions. Unfortunately, the large majority of the meeting participants didn't appreciate the novelty of the presented work and the principal value of the results obtained. There were many impetuous emotional negative speeches, sometimes even acid-tongued ones and insulting for Mikhail Klavdievich. Criticized were mostly particular, non-principal questions which were, of course, little elaborated by the time. For instance, the construction difficulties of assembling the rockets in the pack were pointed at; it was stated that the increased air resistance during the flight of the pack in the atmosphere will 'eat up' all the packet advantages; operation difficulties were mentioned and so on. As the future research has shown, all these problems of building the packets were overcomable.

Despite the critics, M.K. Tikhonravov has repeated his presentation on July 14, 1948 at the Annual meeting of the Academy of Artillery. Many high-level managers, a number of military specialists of the generals rank were present here. The talk was listened to with a great attention, however the reaction of the most meeting participants was similar to that of NII-4 scientific council members*.

But still the novelty of ideas and the obtained results, feasibility of the constructive and technical parameters taken as the input data have aroused the scientific and engineering thought having caused the more wide and detailed study of the problem of creating the staged rockets. Works like this started developing soon, especially at OKB-1.

One of the consequences of M.K. Tikhonravov's talk was the fact that the higher military commandment closed down the P.I. Ivanov's department at NII-4 as dealing with non-topical problems, and M.K. Tikhonravov himself was removed from the position of Deputy Head of Institute and appointed the scientific consultant. It was only after the strong request from Mikhail Klavdievich that I.M. Yatsunsky alone was permitted to stay for continuing the study of problems of staged rockets design. Wider works on the staged rockets, and especially on the issues of satellite creation were strictly prohibited at NII-4. However, M.K. Tikhonravov's report was published in the journals *Academy of Artillery Reports* and *Rocketry***.

* *Yatsunsky I.M.* Justification by M.K. Tikhonravov of the idea of staged rocket with packet scheme (to the 30-th anniversary of M.K. Tikhonravov's talk) // In the collected works *From the history of aviation and cosmonautics*. M.: USSR Acad. of Sci., Scientific Committee on the history and philosophy of science. 1979. V. 36. P. 185.

** *Tikhonravov M.K.*, engineer. Ways of providing the long firing distances by the rockets. // *Rocketry*. 1949. No. 3.

After R-2 rocket OKB-1 has developed the project of one-staged rocket R-3 boosting the military payload of 3 tons weight up to ~4.5 km/s velocity and delivering it to 3000 km distance. On the basis of R-3 project by recommendation of NII-88 scientific and technical council a new war missile was designed (R-5) able to accelerate the military payload to 3.2 km/s velocity and deliver it to the distance up to 1200 km. R-5 rocket was built, its flight test having started in May, 1953. R-3 rocket development didn't go beyond the drawing phase, but the obtained results have made a large influence on the progress of following works on rocket space technology at OKB-1.

In 1949, taking into account the results contained in M.K. Tikhonravov's report at the Annual meeting of Academy of Artillery in 1948, S.P. Korolev has formulated the proposal to the Government of USSR on opening the new research topic which was suggested to perform at OKB-1 together with allied institutions the preliminary studies of the possibility to create rockets delivering military payloads to 5000...10 000 km distances. In 1950 Korolev's proposal was accepted by the Soviet Government, and N-3 research topic was started.

This was assisted not only by the successes achieved at OKB-1 but also by the geopolitical situation. The territory of USSR was surrounded by the more and more dense ring of USA military bases facilitating the access of US air force to the major strategical areas of USSR. The possibility of strike-back by the USSR aviation turned out to be much more difficult since USA were residing far away. Thus the creation of hard-to-intercept military rockets reaching the territory of USA and their main allies became of the special value for the USSR Government.

After closing down P.I. Ivanov's department at NII-4, S.P. Korolev has given the NII-4 the official order on the future studies of the staged ballistic rockets within the planned N-3 research topic to support M.K. Tikhonravov. Mikhail Klavdievich has got again the possibility to staff his group and develop the works on creation of staged rockets, and – under cover – on the issues of creating the artificial Earth satellite. In December, 1949 Tikhonravov succeeded in involving the young engineers G.Yu. Maksimov, L.N. Soldatova, Ya.I. Koltunov and A.V. Brykov to work. In 1950 G.M. Moskalenko was again involved into group, B.S. Razumikhin also came in. It was the same year when O.V. Gurko and the author of this article were ordered to the group for preparing diploma and the forthcoming work. In 1953 V.N. Galkovsky returned to the group. The mentioned collaborators have made up the basic staff of M.K. Tikhonravov's group at NII-4*.

In elaboration of his ideas M.K. Tikhonravov has decided to carry out the research of the staged rockets of a wider class within the framework of S.P. Korolev's order. He has proposed to consider the packets consisting not only of the identical developed or planned rockets but also the packets of different rockets which can be created based on the experience gained at OKB-1. Tikhonravov has also decided to analyze the power characteristics of staged rockets with the serial operation (engines of such a rocket work in series: first stage; then, after throwing off the first stage, second stage engines are fired and so on), as well as combined schemes of staged rockets (for instance, first and second stage — packet scheme, with the third one being fired after throwing off the first two used stages).

* *Yatsunsky I.M.* On the activity of M.K. Tikhonravov during the period of 1947–1953 in justification of the possibility of creating the staged rockets. // In the works *From the history of aviation and cosmonautics*. M., USSR Acad. of Sci., Soviet national union of historians of natural sciences and technology. 1980. V. 42. P. 31–39.

The so called simplest two-stage rockets were also considered which consist of the central rocket (second stage) and two-four attachable side rockets. Fuel lines of rockets are not connected to each other. The effect of combined rocket is achieved by means of producing a larger acceleration on the side rockets compared to the central one. This is made at the cost of reducing the fuel capacity in any of the side rockets (and hence of their launch masses) and increasing it in the central rocket, supposing meanwhile that all rockets are utilizing the same engines. By optimizing the fuel loads one can achieve the maximum efficiency.

Besides the analysis of power characteristics, a number of other issues of building the staged rockets was also considered at M.K. Tikhonravov's group.

Ballistic capabilities of staged rockets of different kinds were studied, possible schemes and tools of joining the stages of combined rockets. Ballistic research computations of various kinds of rockets were carried out. The goal of the research was to find out the optimal values of the basic parameters of the staged rockets providing the minimum initial mass with the given payload and flight range. Issues of flight stability of the rocket pack in the atmosphere were studied, as well as providing the required accuracy of trajectory realization during the engines operation. Problems of creating the launch sites of combined rockets were considered*.

Problems of protecting the heads of intercontinental rockets from the aerodynamic heating during their motion in atmosphere at the descending part of the trajectory were studied. Different methods of rocket operation and its engines cut-off moment were investigated.

G.Yu. Maksimov in 1950 was investigating in secret the conditions of delivering the artificial Earth satellites into the circular orbits of different height and has shown that it is effective to deliver the satellites into the orbits higher than 300 km in two phases. At first the rocket is delivering it to the perigee of the initial orbit, then at the apogee it is given an additional impulse for the transfer to the circular orbit with the height equal to the apogee height of the transfer ellipse which was later called Hohmann ellipse.

In March, 1950 the scientific and technical conference on the rocketry was held at NII-4. In the report *Rocket packs and the prospects of their development* M.K. Tikhonravov has elaborated the ideas outlined in the previous speeches, completed them with the new results and for the first time clearly spoken about the nearest perspectives of creating the artificial Earth satellites, up to the human flights on them. By the time the two-stage packet of three R-3 rockets was considered in the group on the technical order by S.P. Korolev and it was shown to be able after the necessary modifications to provide not only the transfer of heavy military payload to any range, but also the satellite orbit insertion.

The Tikhonravov's talk was listened to attentively, but mistrustful and satirical speeches were still prevailing. S.P. Korolev with one of his deputies was present at the conference.

The developments of the pack with three R-3 rockets were included by S.P. Korolev into the drawings of R-3**. That analysis was perhaps the first attempt of investigating

* In 1951 the developments of the latter problem together with Yan Ivanovich Koltunov were passed on to another subdivision of NII-4. See *Yatsunsky I.M.* // Ibid.

** The creative legacy of Academician S.P. Korolev. M.: Nauka, 1980. P. 300.

the issue of creating the AES based on real project developments of one-stage rockets of Korolev's OKB.

Works on studying the problems of building the staged rockets were continuing in Tikhonravov's group until 1953. The results of research were regularly presented in the form of scientific-technical reports and sent to OKB-1. It is little known that in the early 50's the group has prepared and M.K. Tikhonravov has presented to the USSR Government two report notes which were argumentatively pointing at the possibility of creating in the nearest future the staged ballistic rockets able to deliver the military payloads to intercontinental distances. Probably these letters have played a definite role in adopting the resolution of Government on creating the staged R-7 rocket.

Of course, M.K. Tikhonravov's reports in 1948 and the follow-up works of his group collaborators have not determined the project outlook of the future first Soviet staged R-7 rocket, that required the huge work of the OKB-1 staff and its allied factories. But that research have shown the possibility of creating the staged rockets and the ways of solving a number of major problems. Thanks to it S.P. Korolev already in the very beginning of the project developments had the basis for making a number of principal decisions: choice of ballistic rockets for delivering the payloads to the intercontinental distances instead of the winged ones which were also considered at the time; packet scheme of the staged rocket for future development and so on.

In 1953 S.P. Korolev has made the major project decisions on the intercontinental ballistic rocket R-7, in 1954 the Decree of USSR Government was issued on the creation of R-7 at OKB-1 and establishing the corresponding collaboration of allied institutions. In this respect an issue arose on arranging the flight development tests of R-7. The solution of this issue was ordered by the same governmental Decree to NII-4 of the USSR Defense Ministry together with the related cooperation of factories. The test range built earlier near Kapustin Yar village was not suitable for R-7 rocket for a number of reasons – in particular, the trajectory of test flight would pass through the rather populated areas and the rocket could have fallen there in case of the failed flight.

Calculations and analysis for a significant number of possible locations of the test range for R-7 were performed at NII-4 (I.M. Yatsunsky, I.K. Bazhinov). One of considered positions – launch in the area of Dzhusaly town (Kazakhstan) and the range of warheads fall on Kamchatka — was approved by the State Commission, and the works were started on preparation and building the test range for R-7 flight development tests*.

Once in early 1953 me and G.Yu. Maksimov were discussing the issue that many specialized institutions had been already involved into the specific works on creating R-7 rocket and the pilot work of our group in this area was becoming not very necessary. An idea appeared immediately that it is time to focus our main efforts at the problem study of creating the artificial Earth satellites. Almost nobody was dealing with these topics in USSR during that time. The draft plan of future research on the problems of satellite creation was quickly made up. Solving these problems was the next crucial

* The topic of creating the test range for R-7, or as it was later called — Baikonur cosmodrome — is a separate large issue and we will not cover it here. It is shortly described in the memories of Mozzhorin Yu.A. That's how it was… (M.: 'International education program', 2000. P. 74) and Bazhinov I.K. Yu.A. Mozzhorin and the first test range and ground support facilities in the native rocket-space technology. (Korolev: TSNIImash, Cosmonautics and rocket industry, 2000, No. 21).

condition providing the satellite launch possibility. Of course, today this plan appears to be quite simple, but in those days the ideas put in it have inspired us. We have immediately told Mikhail Klavdievich about it, he has warmly supported us and asked to make the plan more detailed, and to develop on its basis the proposal to open the scientific-research topic on justification of possibilities and ways of creating the artificial Earth satellite at NII-4. A proposal like this was prepared with the participation of the whole group, and Tikhonravov has presented it to the management of the Institute and the Department of rocket weapon at GAU (Man Autollery Administration). The proposal to open the special research and development work on satellite at NII-4 supported by S.P. Korolev was approved, and in 1954 the topic No. 72 in the institute turned into reality. M.K. Tikhonravov was appointed the scientific head, I.M. Yatsunsky having become principal investigator. All of us were responsible for the various sections of the topic. The approval of research work on satellite problems has become the direct evidence of acknowledgement of the ideas and efforts of M.K. Tikhonravov and his group. Meanwhile the strict ban on the works on satellite issues introduced earlier at NII-4 was automatically lifted.

In the network of topic No. 72 it was planned to study the basic problems of creating the satellites and to mark the ways of solving them*. Works were held in the following directions.

First, the trajectories of delivering the satellites to different orbits were studied. The practical methods of calculation of staged rockets trajectories developed earlier by I.M. Yatsunsky and by me were adopted to placing the satellites into various orbits. Using these methods we were carrying out the mass estimates of satellites to be launched by R-7 rockets.

Secondly, it was necessary to check whether the accuracy of R-7 control system is enough for putting the satellite to orbit close to the required one, and whether the launch errors will not result in the quick satellite fall to Earth. With this view G.Yu. Maksimov has evaluated the impact of such errors on the orbit deviation from the requirement under the continuous operation of rocket engines. A similar work was done by me relating to the 'discontinuous' phase of launch which can take place, as noted above, during the launch of satellites to the orbits above 300 km. It was finally shown that the control system accuracy of the developed R-7 is enough for delivering satellites to the required orbits.

Third, it was necessary to analyze how the major perturbations are affecting the operation during the long-term satellite flight and for how long they will allow for spacecraft to fly on the orbit. These issues were studied by G.Yu. Maksimov and I.M. Yatsunsky. The former was analyzing the effects on satellite orbits of noncentrality of the gravitational field of Earth due to its ellipticity, gravity tug from the Sun and the Moon, as well as the remnants of the Earth atmosphere on the low orbits, the latter — the effect on the satellite orbit from the higher harmonics of the Earth gravitational field. As a result the values of orbit deviation due to these perturbations were estimated and the conditions of their acceptability were identified.

Already during that initial period we were worried by the problem of satellites encounter on orbit. Though we knew laws of orbital motion well, still the possibility

* *Bazhinov I.K.* The activity of M.K. Tikhonravov in 1950–1956 in the field of research of the basic problems of creating the satellites. // In the works *From the history of aviation and cosmonautics*. M., USSR Acad. of Sci., Soviet national union of historians of natural sciences and technology. 1980. V. 42. P. 39–45.

of rendezvous of two satellites moving at the velocities of about 8 km/s was not easy to accept. Even the fastest artillery projectiles were flying at the speed of 1.5...2 km/s, but their approaches on trajectories...? Tikhonravov has assigned me to evaluate this problem. I have theoretically considered and shown the possibility of satellite rendezvous on orbits and their approach with the aid of docking. In the form of statement the problem of satellite control under these circumstances was also analyzed.

The vital issue of satellite flight support is the regular control of its orbit. Having analyzed the specifics of satellite flight and possible measuring facilities, I.M. Yatsunsky and G.Yu. Maksimov have developed yet in 1953 the relevant method of orbital parameters determination from the changes of satellite motion parameters (satellite range, direction angles and radial velocities measured by radar or optical facilities located in different points on the surface of Earth). The accuracy of orbit determination from such measurements was estimated. The similar method was later updated and realized by P.E. Elyasberg and V.D. Yastrebov on the *Strela** computers and implemented at NII-4 for the real satellite motion control.

In solving their tasks the majority of satellite types need to determine and stabilize in space the positions of their axes, as well as to turn so that axes would take the required position. The ways and means for these maneuvers were analyzed by G.Yu. Maksimov. Gleb Yuryevich has considered the possibilities of satellite orientation in space by observing the Sun, the Moon, Earth and the bright stars from the board and also analyzed the requirements on instruments to perform these observations. The gyro systems were also examined allowing to take reference axes in space and to provide the required satellite turns (the latter works assisted by the author).

Another important issue of satellite operation support was providing its systems with electricity. Tikhonravov assigned L.N. Soldatova to take over this topic. She has considered the various ways of obtaining the electric power on satellites, on the recommendation of Mikhail Klavdievich consulted the distinguished Soviet physicists. As a result the main efforts were focused on the photocell-based sources of energy, the outlook of this source and its basic characteristics were evaluated. Now these sources of energy are used on almost all satellites.

Another important and somehow unexpected issue was that of carrying away of satellite the heat energy produced by its instruments and obtained from the solar and terrestrial radiation, so that the satellite wouldn't get overheated or overfrozen. I.M. Yatsunsky and O.V. Gurko were solving this problem. They have studied the conditions of radiation absorption by the satellite surface from the Sun, Earth and of radiating the inner heat of satellite towards the space, analyzed the balance conditions of received and radiated heats, developed the system of special satellite surface layers providing the necessary conditions. A system of shutters was developed whose opening and closing allowed to control the thermal environment inside the satellite, the requirement on the system of internal forced ventilation were formulated.

Satellite staying for a long time in space is constantly exposed to the impacts of smaller and larger meteor particles moving at huge velocities. In this regard A.V. Brykov has estimated the possibility of dangerous impacts and came to the conclusion that it is small and can be neglected. Fifty years of space flight experience have confirmed this estimate.

* Russian for 'arrow'.

The group was giving a high value to the problem study of returning the unpiloted and manned satellites to Earth. O.V. Gurko and I.M. Yatsunsky were dealing with the issue of protecting the warheads of ICBM from overheating and have developed the relevant method and the protection calculation tools. They have applied these results to the satellites protection during their flight in the atmosphere at the return. They have obtained the corresponding estimates of the thermal protection system. The author of article was studying the re-entry trajectories of the satellites to Earth, having indicated the trajectories which met the requirements to the heating and overloads for the types of satellites under analysis. The possible deviations of the landing points from the calculated values were estimated. Together with G.Yu. Maksimov similar estimates were applied to the satellite performing uncontrolled ballistic descent in atmosphere.

The works on topic No. 72 allowed to estimate mass, size and power characteristics of the main units and systems of satellites. Based on this data the project configurations of satellites were developed in the group. Two versions of automated satellites were considered herewith. The first case — satellite orbiting at the height of 200...300 km and having no possibility to orientate in space. This satellite was given an index 'Object 'D', with A.V. Brykov and L.N. Soldatova developing its configuration. The second case — satellite able to navigate and turn in space on the data sent from Earth. It was labeled 'Object 'OD', and V.N. Galkovsky was dealing with its configuration.

Satellites have to be equipped with the onboard systems of communication with Earth providing the telemetry control of onboard systems, trajectory measurements, interaction with the ground-based radio commanding systems etc. Those years at NII-4 devices like this were studied at the relevant subdivisions applicable to equipping R-7 rockets with them. Possible characteristics of these onboard systems for satellites were evaluated by I.M. Yatsunsky, A.V. Brykov, V.N. Galkovsky on the basis of consultations with the specialists of the mentioned NII-4 divisions.

The completed works allowed to determine the possible outlook of the first automated satellites as a whole and their basic characteristics, to show the possibility and the ways of solving the major problems of creating the satellites, as well as the possibility of launching them by R-7 rocket.

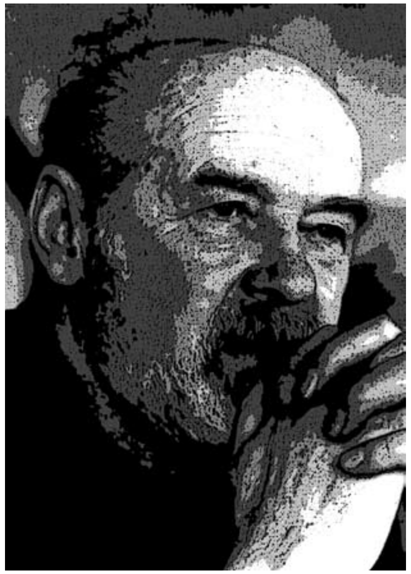
It should be noted that the theoretical analysis of a number of problems of creating satellites during that time were carried out under the auspices of M.V. Keldysh at the Department of Applied Mathematics of the Steklov's Mathematical Institute (OPM of MIAN USSR). In particular, D.E. Okhotsimsky has solved the variational problem on the optimization of the parameters of the simplest packet, together with T.M. Eneev optimized the laws of controlling the R-7 rocket at the active stage of its flight in empty space. Together with these scientists G.P. Taratynova, M.L. Lidov were studying the effects of different perturbations on the satellite operation and so on. Staff of OPM and Tikhonravov's team were constantly collaborating and exchanging the obtained results. If some important researches were to some extent duplicating each other, that was increasing the reliability of the achieved results in the new, completely unknown by the time field of knowledge.

Works on the satellites were carried out very hard, and by 1954 the ways of solving the main problems and the possible characteristics of the future satellites were already estimated. On the basis of these results Mikhail Klavdievich has given the team a command to prepare the report note for the USSR Government *About the artificial Earth satellites*. Draft of this note was prepared, and Tikhonravov reported it to S.P. Korolev and President of USSR Academy of Sciences M.V. Keldysh. The latter asked his collaborators D.E. Okhotsimsky and T.M. Eneev to take part in the preparation of the report note as well taking into account the results of studies on satellites at OPM. The final version of the note was signed by M.K. Tikhonravov and presented by S.P. Korolev to USSR Government in 1954*. As it is known, on the basis of this report note and S.P. Korolev's proposal on the launch of the first artificial Earth satellites with the aid of R-7 rockets the governmental Resolution was adopted in 1956 which was assigning OKB-1 to create and launch the artificial satellite by R-7 rocket and also determining the schedule of works and cooperation of allied institutions for solving the designated task.

In 1956 L.N. Soldatova and G.Yu. Maksimov have moved from NII-4 to OKB-1. Then in 1956 M.K. Tikhonravov has also joined S.P. Korolev who created the famous Department No. 9 at OKB-1. It was this department where the works on design of both first Earth satellites and first automated stations for the flights to the Moon, Mars and Venus were concentrated, the first spacecraft of *Vostok* and *Voskhod* series were also designed here. As soon as the projects became ready, the constructing and other divisions of OKB-1 were involved into the creation of the first spacecraft, as well as the allied institutions developing and building the necessary component parts**. All these big and hard works have finally led to the launch of the First artificial Earth satellite — *Sputnik* on October 4, 1957.

* The creative legacy of Academician S.P. Korolev. M.: Nauka, 1980. P. 343.

** S.P. Korolev's Rocket-Space Corporation 'Energia', 1996.

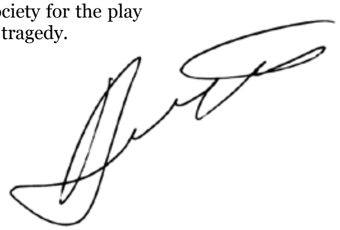


Vladimir GUBAREV
RUSSIA

A writer, journalist and playwright. Author of books, films and TV programs about scientists' lives and progress of science in the world (*Nuclear Age*, *The Bomb*, *Atomic Age*, *Chernobyl*, *Farewell to 20th Century*, *20th Century*, *Confessions*, *Dream of the Universe*, *Windows from the Future*, *Agony of Sredmash*). The first journalist to have reached the blown up nuclear reactor a few hours after the Chernobyl catastrophe. Currently working on the series of books devoted to Russian science and scientists. Leads a program *Realnaya Fantastika* (*The Real Fiction*) in *Kultura* TV-channel.

Born in 1938. Graduated from Moscow Kuibyshev Institute of Engineering and Building. Was a chief editor of scientific departments in *Pravda* and *Komsomolskaya Pravda* newspapers.

Awarded the USSR State Prize (1974), the Lenin Komsomol Prize (1975), the Sign of Honour (twice), Laurence Olivier Award from the British Theatre Society for the play *Sarcophagus* on Chernobyl tragedy.



THE VOICE OF 'PS', OR WHAT HAS THE HORN SUNG AT THE OCTOBER DAWN IN 1957?

For many of those who was at Baikonur on October 4, 1957 and saw off the first artificial Earth satellite, the count of the new space era started with the sound of horn that was heard a few minutes prior to the launch.

Suddenly — this was not in the launch preparation schedule — a horner turned up on the empty launch pad. He raised his head and took the horn to his lips.

To some, this sound reminded of the First cavalry army, of the past war, of the past years.

The others felt that the horner is declaring the future, which they were dreaming of for so long and in the name of which they did not spare themselves.

No horners turned up for any of the launches that previous years abounded with. He was there only once – on October 4, 1957, and connected the people that opened the space era, and linked the past to the future.

I know that there are stories that challenge this fact and consider it a reporter's tale. Maybe they are right, but still, isn't this a beautiful legend?!

I have to admit now: I have had a lot of opportunities to verify whether the horner was really there on the launch pad or that was just the way another space myth was born. However, I never used any of these chances, because I think this horner should have been in Baikonur on October 4, 1957!

The myths and legends in our time should become reality, otherwise we would have never been the creators, participants and witnesses of how the space era opened up before the humanity.

* * *

I believe, a few pages in the biography of the first Sputnik are of particular interest. It is not because they are more important or significant than others. They more likely bear a more 'personal touch', as these stories helped me understand why Sputnik brought together so many scientists, engineers and military. Their lives became a part of those 'beeps' that the planet heard in October, 1957. And when I see the flight of the first Sputnik in the documentaries, these sounds bring on the memories of my great compatriots who I was lucky to have met and spoken to.

Also, to be honest, I am proud of having an opportunity for the first time to tell about these milestones of our space history...

1

I guess, I should start my tale with the tulips...

For each of us, who has somehow shared in the space achievement of our people, there is his 'own' Baikonur. Everyone sees it differently, especially on anniversary celebrations.

One would think that we should have thoroughly counted the rocket launches (over a few thousand by now), number of the cosmonauts who were launched into the Earth orbit from here (quite a few dozens by now), and other memorable events, for instance, visits from various world leaders, presidents and prime-ministers (also a few dozens) etc.

However, I remember something completely different. First of all, the tulips. I saw them for the first time on my fifth or sixth visit to the launch pad. Before the spring'68 my Baikonur visits fell exclusively on the late autumn, winter or summer — this was the way the launch schedule worked out. That is why this barren steppe, where the dull landscape was only slightly animated by the rocket assembly buildings and launch pads, was very unwelcome: a scorching heat in the summer, piercing cold in the winter and constant wind blowing away any remaining romanticism from you. This was a tough reality and, to be honest, only the job necessities and sense of fellowship made you travel to this distant and inhospitable land. The cosmonautics was born from the selfless dedicated work of the people in military uniform and civilian clothes confronting the challenges. Each one of them deserved the Hero of labor medal, because their labor was really heroic.

The decision to build a cosmodrome (launch pad) was made on February 12, 1955.

Naturally, this was highly confidential, and it was kept a top secret until October 4, 1957 so thoroughly that no one knew of that, even those who worked in S.P. Korolev's Design Bureau (OKB-1).

And we, the Moscow students, had a hunch that something unusual was constructed in the steppe. I had a chance to 'raise the virgin land' in 1955, 1956 and 1957 with the first student crews.

Once we took a ride on a truck to a store in a village about 100 kilometers from where we were based. The rumor had it, there was *Raspberry wine* on sale there. A hundred kilometers in steppe is not a distance, so we drove there by a straight line – we built the first roads there. Much to our surprise, we were stopped by a military patrol. So we had to turn back.

In about ten years I found out that we were stopped on the Baikonur boundary. This construction was 'covered up' by the 'virgin land' operations. It was officially known, that the military troop trains heading for Kazakhstan were going there to cultivate the virgin steppe lands. Although, the military installers did not have to go far: they have just completed the Semipalatinsk nuclear test site, and now they were transferred to a new site – this time a rocket launch site. Not a word about the space that time...

So, what do I remember on the anniversary date?

First of all, people of Baikonur. There are a lot of them. But large meteors sometimes leave a long track even against a starry sky...

General Schubnikov met Korolev at the office of the Secretary of the Communist Party Central Committee when he was getting his new assignment. Then he spent a few days at the OKB-1 where he was introduced to an unusual project. This new assignment really was very odd even for someone who saw a lot in his life. He could not even memorize all the structures that were supposed to be constructed in the bare steppe, where there was virtually nothing – no water, no heating, no communication or roads.

'This is the place from which we make a step into space', said Sergey Pavlovich, and General Schubnikov trusted this man.

'We will do everything on time, not a single day over the schedule!' retorted Georgy Maksimovich, and Korolev never had a doubt this man would keep his word.

However, whereas Schubnikov knew nothing about Korolev, but Sergey Pavlovich was well aware of Schubnikov and his deeds.

During II World War, he first constructed defense facilities at river Don and near Stalingrad, and then, when the offensive was launched, constructed bridges and river crossing sites and built the roads. These were his river crossing structures that opened the way for Rybalko's armored tanks across Visla to Berlin, and the bridges all stood under this mighty vehicles!

The victory day for general Schubnikov was a turning point — he started reconstructing the sites that were destroyed during the battles. The bridges in Vienna, Bratislava and Berlin still serve the purpose, but few people remember that it was our general who had really built them. By the way, he reconstructed the theater in Berlin as well as marine bridges. The conclusion of the war for him was building a war memorial in Berlin's Treptow-Park.

Another great memorial for G.M. Schubnikov was the launch pad which sent Yuri Gagarin in space.

The plan was to make 25 launches from the pad, and then a new launch pad into the universe should have been built. However, this legendary pad is still in business. It turns out that if we really want, we can work like no one in the world does: name any structure which as reliable as the Gagarin launch pad! This is the Baikonur...

The tulips bloom around the launch pad in spring. The best way to bring them home is in a bucket of water — they will not wither. Not only the Chief Designers: S.P. Korolev, M.K. Chelomey (each one has their 'own' pads in Baikonur) — but regular Baikonur military officers brought these bright tulips to their wives. Of course, after a successful launch. This was an ideal present, because it told about a success, a new step on a never-ending space road.

2

Some prominent scientists got for a meeting in M.V. Keldysh's office in summer 1955. Many of them had no idea what they would talk about, very little was known about Mstislav Vsevolodovich too: the 'top secret' grading concealed everything he was doing. The invitation to the meeting was coming from the USSR Academy of Sciences which indicated how important this meeting was.

Mikhail Klavdievich Tikhonravov made the first presentation. He said 'Sputnik', but the word did not impress anyone. Everyone took this as if they were talking about a new scientific instrument. Especially when Tikhonravov started telling about the basic engineering solutions, the contents of the unit, assemblies required for the normal operation of the satellite, that the scientific payloads should be connected to the telemetry... the way the participants reacted to the word 'telemetry' Tikhonravov understood he had to explain the term, and started to patiently explain how the data is downlinked from the satellite to Earth and how it is decoded.

As was often the case with Tikhonravov, he got carried away and his presentation was becoming less like a scientific report but rather a vision – at least this is what many people thought.

Academician Yoffe, who was a bit late for the meeting, 'grounded' the event — he came all the way from Leningrad.

'The refrigeration units for such delicate items are too big', he said, 'However, the solar arrays are an interesting idea! Maybe it's worth engaging the folks from Leningrad and FIAN*'.

Keldysh dialed B.M. Vool from FIAN right away and briefed him. The future academician reacted immediately:

'We will engage physicists working in the area. The idea is really very interesting and promising...'

Keldysh told Vool's opinion on the matter to everybody and then added:

'We have to work energetically and unconventionally...'

...On the third artificial Earth satellite were already installed solar arrays, that were conceived in a telephone conversation between Keldysh and Vool...

* Lebedev Institute for Physics of USSR Academy of Sciences.

* * *

The meeting proceeded. No minutes were recorded. This was not required, because this time Keldysh did not expect any actual decisions or proposals from his partners (although there were some mentioned) — he had to outline the scope of the future space program and the main research trends.

Although I wish there were such a meeting minutes recorded. The participants at the meeting remember that the ideas for many experiments were born at the meeting. A few years later they were implemented on Earth satellites. Some scientists 'changed' the areas of their work from 'terrestrial' to 'space'.

M.V. Keldysh was the last to speak at the meeting.

'I will not summarize today', he said. 'I will not be far off if I say: we all agreed here that many research institutes can contribute in Earth satellites research, so our purpose is to make them, as well as individual scientists, interested in our programs. I rely on the cooperation of all those who are present here today...'

Keldysh kept his colleagues after the meeting.

'We need to distribute the letters to the academicians and associate members — we have to review their proposals and invite everyone who we need to build the magnetometer and the hardware for the solar ray studies'. Mstislav Vsevolodovich smiled all of a sudden. 'All in all, dear comrades, we will have to work without repose...'

'And for how long?' someone asked.

'For about a year and a half – two years... And then, maybe, the whole life, because the deed we start now is too large to anticipate all the consequences...'

Keldysh and Korolev met at the Academy the same evening to outline the future work for nearest month or two. They agreed that they would approach the Central Committee (of the USSR Communist Party) and the Government with specific proposals for Earth satellites scientific hardware. This document should include specific organizations and names of the scientists who were developing the instruments.

* * *

In 15 years time, after S.P. Korolev passed away, I asked the President of the USSR Academy of Sciences M.V. Keldysh to tell about the events in summer 1955, when the scientific space research program started to take shape.

'It was just a normal work', he answered, 'and everyone is aware of the results...'

Keldysh did not like to talk about himself. Only on rare occasions, — at the launch pad or Deep-space communications centre when he had a spare minute or two, he remembered the past days. I once was lucky to listen to a tale of the 'prologue to Sputnik', as was his own expression. I remembered one certain phrase for all my life:

'This was beautiful life, because we were young, and even the space did not frighten us at the time...'

There was sadness in his words, and it was odd to see Keldysh like that...

Many scientists in the country received the letter in summer 1955. 'How can we use the space?' Some were baffled by the question. So the answers were very different:

'I do not like science fiction…'

'I believe this will happen in a few decades and only our children and grandchildren will be able to tell us more precisely…'

'Let's first learn to fly in the stratosphere…'

But other answers were different:

'We can run unique experiments in various areas of the astronomy…'

'No doubt the study of various particles and radiation types will be of particular interest…'

'If any discipline opens up an opportunity to explore new efficient research area, this should not be missed, because the history of the science shows that opening new areas results in discovering those natural phenomena which expand the ways of the human culture', wrote academician P.L. Kapitsa.

Although the answers were very diverse, and some ideas and proposals looked extremely complicated and almost not doable, still everyone helped defining a clear space program.

The Academy send a letter to the Central Committee of the Communist Party and Minister Council of USSR which proposed a clear scientific research program in space. The 'Special panel for 'Object 'D' was established in January, 1956. M.V. Keldysh was assigned the head of the panel; S.P. Korolev and M.K. Tikhonravov were assigned his deputies, G.A. Skuridin became the academic secretary.

'Object 'D' was the first artificial Earth satellite.

As the routine required, Correspondent Member of USSR Academy of Sciences S.P. Korolev presented the progress report to the Academy presidium on the annual basis.

Here is an abstract from 1954 report: 'the prospect of building an artificial Earth satellite and a space rocket vehicle for manned missions to high altitude and the research of the interplanetary space is currently seen very close and real…'

An abstract from 1955 report: 'We have started working on the extended research of the upper atmosphere at altitudes 200-500 km this year, which was mostly requested by various institutes of USSR Academy of Sciences and other organizations. These activities were research and design. The research work was launched and general concept of artificial Earth satellite was developed late 1955…'

S.P. Korolev and M.V. Keldysh had no doubt the satellite would be launched in the nearest future…

* * *

After Yuri Gagarin space mission I started writing a book containing the interviews with the most prominent scientists of the country. I asked them a question: 'How would a man entrance into the space effect your area of science?' M.V. Keldysh recommended me some of the scientists. In particular,

among the other names there were those who participated in that legendary meeting where the scientific program of the first artificial Earth satellites had been created. Of course the scientists enjoyed remembering their first steps in researching near-earth and outer space. However, I was impressed the most by how enthusiastic they were about the future: by that time they associated themselves with space for the whole life.

The book *The Human. The Earth. The Universe* was very popular once it was published: everyone was into space. This was a beautiful and unique time!

3

There are a lot of mysterious pages in the history of our science. Not all of them have been read.

One of them is how the nuclear-missile shield was created.

So, who are the creators?

Kurchatov and Korolev should be named among the first.

They met each other only after Stalin's death.

Stalin did not trust the missiles and totally trusted Kurchatov.

Events of late 1946 and early 1947 prove that.

USSR Academy of Sciences develops a Peaceful Uses of Atomic Energy program. Council of Ministers of the USSR issues a decree No. 2697-1113 'ts' (i.e. 'top secret') on December 16, 1946. It details all trends of nuclear science and technology: from the research work on direct conversion of the radioactive energy, research of ionizing radiation effect on the metabolism through to construction of nuclear power units for vessels and planes.

A scientific council headed by the Sergey Ivanovich Vavilov (President of USSR Academy of Sciences) was set up in the USSR Academy of Sciences. The most prominent scientists of the country were on the council. However, you would not find the name 'Kurchatov' on the list.

Just a reminder: it was two weeks away from commissioning the first nuclear reactor F-1…

The country is in ruins, famine in Ukraine — there is no bread, no potato… The most basic items are missing!

Who cares about the 'energy conversion' in these conditions?!

To put it mildly, the Decree of 16 December 1946 looks odd, but Stalin signs it anyway, although he clearly understands that it was just not realistic to implement all the items in it.

However, someone needs to give the scientists a support, a prospect; otherwise the major purpose for Stalin and his loyal associate Beria would be doomed.

So Stalin assigns the latter to 'cool down' the enthusiasm of the scientists and point them in the right direction.

And there was a motive: Kurchatov commissions the first nuclear reactor in Europe, which automatically makes him a leader in the nuclear arms race and, consequently, a leader in physics in general.

Voting Kurchatov an academician is just a technicality. However, the academicians prove to be bull-headed and elect a more prominent Alikhanov to fill the vacancy. So the government has to open another vacancy and it was clear at the time this was specifically designed for Igor Vasilievich.

He becomes the head of the Nuclear Project.

The conversation with Beria was brief. The latter passes along Stalin's request to start working on the civilian nuclear program only after the nuclear bomb is available. The faster it happens the better it would be for the scientific community – the scientists would be granted a total freedom after that.

No one would know better than Igor Vasilievich.

In just a couple of weeks after the tests on August 29, 1949 he addresses the Government with a proposal to start using the nuclear power for the transport, power industry and aviation. And all his proposals receive a complete support!

There was only one area of technology left outside Kurchatov's view. These were the missiles and their Chief Designer Sergey Pavlovich Korolev.

Korolev prepares a special report on the rocket technology for Stalin in early 1947. He evaluates everything that we managed to get in Germany. A meeting on the rocket technology is held in Kremlin on April 14, 1947, after which Stalin sends for Korolev.

Sergey Pavlovich suggests trial launches of the German rockets on the meeting, evaluating their experience and then starting designing our own rockets. Stalin gives a 'go'.

Intensive work on designing the strategic bombers carrying nuclear weapons starts following this meeting. No one mentions the missiles yet…

Korolev trained the rockets to fly. They got more powerful with every launch. Once he persuaded Keldysh visit Kurchatov at his 'Wood cabin' on Institute for Nuclear Energy territory…

Kurchatov was a hospitable man. He liked to wine and dine his visitors. Although Igor Vasilievich was already ill, he had a couple of vodka shots anyway.

It is considered that 'the bomb was married to the rocket' at this particular meeting. Korolev assured Kurchatov he was able to build a rocket capable of carrying a heavy thermonuclear charge. He meant the '*semyorka*'*, the missile model still in service.

The secretary, i.e. Kurchatov's bodyguard made a few photographs. One of them came down in the history as three '**K**': there are **K**urchatov, **K**eldysh and **K**orolev in the photo.

The photo has been published in the format for many years. However, there was also the fourth person there — Vasily Pavlovich Mishin, Korolev's associate and deputy. He was 'edited' — the academician was classified for many years on.

Once I managed to publish the picture in the 'original' format…

* 'Semyorka' — Russian for 'seven'. Stays for R-7 intercontinental ballistic missile and rocket launcher.

THE BASIC SPUTNIK

Kurchatov visited Korolev's Design Bureau after the meeting. He took a look at the rockets, saw the first Sputnik. He asked to switch on the receiver. Heard the '*beep-beep-beep*'. He was happy as a young boy.

They arranged that the nuclear scientists would be given an access to Korolev's design bureau and their requests would be the top priority.

No one of the rocket scientists, even Korolev himself, could visit the Nuclear Center, the access was restricted. Stalin and Beria were no longer, but the order they introduced was still there…

Soon the first test of the nuclear charge missile was carried out.

And the first artificial Erath satellite was launched on October 4, 1957…

Soon afterwards Igor Vasilievich Kurchatov met one of his postgraduates – the future corresponding member of USSR Academy of Sciences Nikolai Chernoplyokov. He asked what he was working on. He started talking of the new ideas, in particular, using the rocket technology.

Suddenly Kurchatov brisked, as if he remembered something very important.

'Let's sit down', — he said, — 'Do you have a piece of paper? Write this down…'

And he started dictating the names…

The list included the Deputies Chairman of the Council of Ministers, academicians, industry managers, ministers. About a hundred names in total.

'Call them', — Kurchatov said, — 'and invite them to a meeting the next Saturday. We will 'marry' the rocket and nuclear technology. We'll start at 10 a.m.…'

The postgraduate was taken aback: who would listen to him?

'Well, you say this is Kurchatov's personal request…' — Igor Vasilievich gave a wisp smile.

Nikolai Chernoplyokov took the telephone.

A miracle happened every time he mentioned Kurchatov's name. The man in charge would immediately pick up the phone and tell he would certainly be there.

The Institute for Nuclear Energy territory was packed with the black limousines on Saturday. Never before or after this day there were so many VIP's here.

The meeting took place in the conference room of the Institute.

Sergey Pavlovich Korolev showed up 10 minutes before the meeting started. He walked between the aisles and greeted people he knew…

Igor Vasilievich Kurchatov was already seated in his regular sit in the third row near the aisle. He saw Korolev, stood up and walked towards him.

All of a sudden he stopped and made a profound, Russian style, bow.

'This is a bow to you, Sergey Pavlovich, from the Russian people for the First Sputnik!' — Kurchatov said. He then hugged and kissed Korolev.

Everyone who was lucky to participate at this 'marriage' between the nuclear bomb and the rocket carrier still remembers this Kurchatov's bow… This was the day when all the most critical decisions about building the nuclear-missile shield of our country were made.

* * *

2007 abounds in anniversaries. It started with centenary anniversary of S.P. Korolev's birth, and the year will be closing out with similar anniversary of another great space researcher V.P. Glushko. In between there are other great celebrations — anniversaries of the associates of both academicians and Chief Designers, including V.P. Mishin, B.E. Chertok, O.G. Ivanovsky and some first cosmonauts. These are 'good round' figures, and sometimes very 'personal'. But this year one wants to celebrate every anniversary, say warm words about the person, the team or the event that made our country proud.

However, the first among these great anniversaries is the 50th anniversary of the First Artificial Earth Satellite launch. This happened on October 4, 1957 — the day which brought together the lives of all people who opened the space era for humanity.

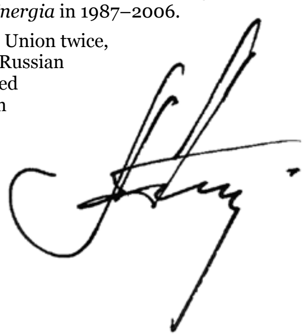
Alexander ALEXANDROV
RUSSIA

Advisor to the president of S.P. Korolev Rocket and Space Corporation (RSC) *Energia*, Candidate of Science (Engineering). Space pilot of the USSR, made 2 flights to the *Salyut-7* (1983) and *Mir* (1987) orbital space stations.

Born in 1943. Graduated from the Moscow Institute of Physics and Technology in 1969. Employed in the Design Bureau-1 since 1964, fellow researcher of operation equipment in the *Voskhod* and *Soyuz* spacecraft and of instruction manuals for *Salyut* and *Mir* orbital stations.

Took part in preparation and implementation of test flights of manned spacecraft and orbital stations in 1968–1978. In 1978, joined the space flight-test crew at the S.P. Korolev RSC *Energia*. Head of Flight-test Service at the RSC *Energia* in 1987–2006.

Awarded the Hero of the Soviet Union twice, Ukrainian State Award (1983), Russian National Award (2002). Received the expression of gratitude from President Putin in 2003.



S.P. KOROLEV — SPACE ROCKET AND THE FIRST SATELLITE OF THE EARTH

...I happened to be fortunate as a man to pursue this great wonderful cause '— a rare fortune for a man!
S.P. Korolev

...An abstract from the flight log of the second main expedition crew (V. Lyakhov, A. Alexandrov) of the *Salyut-7* long-term orbital station, dated October 7, 1983:

'...to the left along the route I saw a bright star moving above the horizon (a container discharged from the air lock looks like this after an orbit of flight), I took the binoculars — it turned out to be a satellite with solar arrays, prolate-shaped, rotating, and shining in the sun rays. I believe, the distance to it was no less than one kilometer and no more than two. It was difficult to estimate, since its dimensions were not clear. This is how the station looks like at a distance of three kilometers but it was for sure smaller than the station in its size. Then the satellite went further to the left and below our orbit and merged with the light horizon of the atmosphere. The whole period of observation lasted about a couple of minutes.'

Currently, about ten thousand artificial objects delivered to the outer space by the Earth dwellers are recorded on the near-earth orbits.

* * *

Our country opened the space era for the whole mankind by launching the first simple artificial satellite ('prosteishy sputnik' or PS-1) by a two-stage booster R-7 on October 4, 1957.

The purpose of the launch was to deliver the simplest satellite to the orbit, as well as to obtain additional experimental data on the missile launch dynamics, operation of its propulsion systems, control and regulation system, separation system, on the ground complex operation and on measuring instrumentation.

At the moment of shut down of the propulsion system of the 2^{nd} stage with the satellite, it had the speed of 7780 m/s and went into the orbit with the following parameters: perigee altitude of 228 km; apogee altitude of 947 km; time of one orbit of 96.2 min.

The PS-1, separated after the 2^{nd} stage propulsion system shut-down, was ball-shaped with a diameter of 580 mm and a mass of 83.6 kg. The first artificial satellite operated from October 4, 1957, till January 4, 1958, and covered 1440 orbits around the Earth.

By the year 1953, the development of the ICBM R-7 ('*semyorka*') conceptual design was undertaken at the Design Bureau OKB-1. The state government set a task of delivery of a thermonuclear charge to a distance of not less than 8 thousand kilometers with the payload mass of at least 8 tons. The head part should be able to enter the atmosphere at a speed of 7900 m/s with a mass of 5500 kg.

The expert commission headed by Academician M.V. Keldysh reviewed the developed design and concluded: the presented materials justify the correct choice of the schematics and basic parameters of the missile, its propulsion systems and control system, and the R-7 missile conceptual design for the systems complete with the ground equipment can lay the basis for further development. The missile conceptual design was approved by the USSR Council of Ministers on November 20, 1954.

In 1954 Sergey Pavlovich Korolev sent a formal letter addressed to the Government with a proposal to undertake practical implementation of designing artificial Earth satellites (AES) on the basis of an intercontinental ballistic missile (ICBM), being developed at that time. The memorandum presented by S.P. Korolev was based on theoretical research into the problem of feasibility of designing AES at the current level of engineering, being conducted by the M.K. Tikhonravov's team at the Scientific Research Institute NII-4 of the Ministry of Defense since 1948.

In his letter as of September 3, 1955, addressed to the Chief Designers of the missile industry and to the decision-making authorities, containing a work plan for designing the AES, S.P. Korolev also noted the following:

1. It is envisaged to launch the simplest satellite (PS) with the help of the R-7 missile.
2. The following should be installed on board the PS:
   - a radio telemetry system with a storage device;
   - a receiver of the command radio link.
3. The final mass of the missile 2^{nd} stage, launched into the orbit, is 8000 kg, including the mass of the PS itself amounting to 1100 kg.
4. The orbit minimal altitude (perigee) is 170 km. The orbit maximum altitude (apogee) is 500 km.

5. The duration of the PS operation is about 1 month.
6. The set of ground systems of observation should include the direction-finding system of the PS and determination of parameters of its orbit.

It was anticipated that the set of instrumentation and equipment to be installed on the PS and their parameters, as well as those of the ground systems, would be further specified more precisely and changed in the process of the conceptual design development.

In designing and developing the ICBM R-7, S.P. Korolev 'fitted' this structure to solving applied space programs — the launch of Earth satellites and heavy manned satellite vehicles to the orbit.

Therefore, without waiting for positive results, S.P. Korolev began 'ideological preparation' of the authorities in the USSR Academy of Sciences, in the higher echelon of management and the Central Committee of the CPSU (Communist Party of Soviet Union) so that they could accept as a reality the idea of space exploration with the use of artificial Earth satellites, being still fantastic at that time.

Mikhail Klavdievich Tikhonravov, his old-time colleague in the GIRD*, who worked at the Scientific Research Institute NII-4 of the Ministry of Defense at that time (as was pointed above), was his confederate and generator of ideas. At first, S.P. Korolev recruited him to work on the satellite and other promising space projects within the framework of a labor contract. Then, in 1955, together with a few of his staff members, Tikhonravov was transferred to the Design Bureau OKB-1: at the beginning, to a position of consultant, then, as the head of the design department.

In January, 1954 Sergey Pavlovich discussed the satellite topic with Academician M.V. Keldysh; Korolev worked with him on the problems of controlling the flight of the R-7 missile. M.K. Tikhonravov presented his project at the Department of Applied Mathematics to be reviewed by M.V. Keldysh and his people, who represented different fields of science.

Mstislav Vsevolodovich took a great interest in the satellite. He initiated a meeting to be convened at the Presidium of the Academy of Sciences, invited A.F. Ioffe, P.L. Kapitsa and other leading figures of the Soviet science.

B.M. Vool, V.S. Vavilov, B.P. Konstantinov, V.A. Kotelnikov, L.A. Artsimovich, V.L. Ginzburg, S.N. Vernov, L.V. Kurnosova, V.I. Krasovsky, B.V. Kukarkin were invited to participate in this project. As the project was developed, Academician-Secretary M.A. Lavrentyev allocated computer time for the trajectory specialists of the Design Bureau OKB-1 to calculate the orbit parameters on the computer at the Department of Physical and Mathematical Sciences.

M.V. Keldysh had a few meetings with President of the Academy of Sciences, A.N. Nesmeyanov, who attentively reviewed the project and on May 25, 1954, in the presence of S.P. Korolev, M.V. Keldysh and M.K. Tikhonravov, Nesmeyanov approved of the presentation made by Mikhail Klavdievich and handed it over to M.V. Keldysh with a positive resolution, endorsing the participation of the institutes of the Academy of Sciences in this work.

But it was more difficult to persuade administrators, ministry and party functionaries and bureaucrats. For the first time, S.P. Korolev discussed the satellite topic

* Abbreviation for Jet Propulsion Research Group.

with the Minister of Defense Industry D.F. Ustinov in February, 1954. Dmitry Fedorovich reacted in a reserved way. M.K. Tikhonravov sends his presentation to Marshal A.M. Vasilevsky, who expressed his readiness to assist in advancing the idea of launching of the first satellite.

Having obtained the support of the Academy of Sciences, S.P. Korolev sends out letters with proposals on organization of work on the satellite to the Council of Ministers, to the State Planning Committee, the Ministry of Defensive Industry.

S.P. Korolev added M.K. Tikhonravov's memorandum to the letters, as well as the translation of the US mass media reports about the AES due to be launched in the USA before the beginning of the International Geophysical Year in 1957.

S.P. Korolev's initiative plans on satellite creation were once again supported by the Academy of Sciences: on August 30, 1956 a meeting took place in the office of the Chief Scientific Secretary of the USSR Academy of Sciences A.V. Topchiev with the participation of S.P. Korolev, who reported on the status of the missile R-7 and the satellite project. One day before the meeting to be held at the Presidium of the Academy of Sciences (August 29, 1956), S.P. Korolev sent out a detailed program of space exploration with the aid of AES: from the simplest satellite to heavy manned satellite vehicles.

As a result of that meeting, a working body (Commission) of the Academy of Sciences was established, which was engaged in the scientific research programs with the aid of a whole series of AES's, including biological ones, with animals on board. The Commission was responsible for the production of scientific hardware. Leading scientists of the Academy participated in that activity. It was decided that M.V. Keldysh would chair the Commission.

The Government Decree, dated January 30, 1956, envisaged the design and inserting in an orbit of an undirected Earth satellite with the means of the developed missile R-7 in 1957–1958 ('Object 'D') with the following parameters: the mass of 1000...1400 kg; the mass of hardware for scientific research of 200...300 kg; the due date for the 'Object 'D' pilot launch set in 1957.

S.P. Korolev enlisted the following scientists from the Academy of Sciences and leading technical institutes of the USSR to take part in the design and flight development of the R-7: Professor V.I. Feodosyev from the Bauman Technical University on the problem of oscillatory processes in the missile flight, mathematicians-ballisticians D.E. Okhotsimsky, T.M. Eneev, V.A. Egorov, M.L. Lidov, as well as those from the laboratory headed by T.I. Petrov at the NII-1, for which M.V. Keldysh was a scientific lead, on the calculation of motion in the atmosphere and the Earth field of gravity, on the principles of flight control, on solving the problems of an aerodynamic task of the missile head part delivery to the Earth.

In July, 1956, Sergey Pavlovich approved of the conceptual design for the satellite with the mass of 1400 kg.

However, the schedule of scientific hardware development was violated by the institutes of the Academy of Sciences and the mockups of the devices failed to be produced by November, 1956.

A dramatic situation took place — for lack of real scientific contents for the 'D' satellite, it was impossible to upgrade the rocket: to change the program of operation for the propulsion systems with the removal of the radio equipment of the control

system, to make the cone and thermal blanket protecting the satellite, to develop a spring-loaded pushing mechanism for the fairing cone rejection, a pusher separating the satellite from the second stage of the rocket.

It was extremely important to ensure the leadership of the Soviet Union in launching the first artificial Earth satellite, and the span of time till that epoch-making event amounted to less than a year.

Sergey Pavlovich was convinced that the rocket would fly — but the question was if the satellite would be ready by that time?!

At that tense period of work, M.K. Tikhonravov proposed to Sergey Pavlovich the idea of a 'simpler satellite'...

Beginning from November, 1956, S.P. Korolev's collaborators began the design and construction of the simplest satellite PS-1.

On January 5, 1957, S.P. Korolev once again sent T*he Proposals on the first launches of artificial Earth satellites before the beginning of the International Geophysical Year* to the Council of Ministers of the USSR, which would radically solve the problem of ensuring the leadership of the Soviet Union in space by performing the first experiment on delivery of an artificial body to the Earth orbit.

Sergey Pavlovich wrote: 'We request to give us a 'go' to prepare and perform the first launches of two rockets fitted to the option of artificial Earth satellites during the period of April–June, 1957 before the formal beginning of the International Geophysical Year, to be conducted from July, 1957 till December, 1958.

...By undertaking some changes, it is possible to tailor the R-7 missile to be launched as an artificial Earth satellite, having a small payload in the form of instruments weighing of about 25 kg. Thus, the central unit of a rocket can be launched with the weight of 7700 kg, as well as a separating ball-shaped container of the satellite itself with a diameter of about 450 mm and weight of 40...50 kg, to an artificial satellite orbit around the Earth at an altitude of 225...500 km from the Earth surface. A special short-wave transmitting station can be installed as a part of instrumentation on the satellite, rated to operate for 7...10 days.

Two R-7 missiles, fitted to this option, can be ready in April–June, 1957 and launched immediately after the first successful launches of the R-7 intercontinental missile.

...According to the resolution, dated January 30, 1956, a carrier rocket for the artificial Earth satellite is being developed on the basis of the intercontinental missile, with the weight of a satellite container of about 1200 kg, including a large amount of different equipment for scientific research, laboratory animals, etc. The first launch of this satellite is due in 1957 and, taking into account the high complexity of designing and developing the equipment for scientific research, can be performed at the end of 1957...'

The Council of Ministers took a resolution to give a 'go'.

'Object 'D' article, which is now known as the third Soviet AES (*Sputnik-3*), was launched on May 15, 1958, three and a half months after the launch of the first US satellite *Explorer-1*.

But let us go back to the First Sputnik. The first launch of the R-7 missile took place on May 15, 1957. The flight continued 98 seconds and ended in disintegration of the missile.

Two more missile launches were aborted but K.D. Bushuev, Chief Designer Deputy, signed off the layout drawings of the PSS-1 on June 24, 1957, while the satellite component parts had already been manufactured in the shops of the Design Bureau OKB-1.

The fourth launch of R-7 took place on August 21, 1957, and was successful — the last operated stage of the missile rocket reached the goal. The launch on September 7, 1957, was implemented with the head part — a design similar to that for PS-1. At that time the satellite was being subjected to tests in a thermal chamber and on the vibration test bench at the Design Bureau OKB-1.

So, by the middle of 1957, three of the most important conditions for the main space event of the age were fulfilled: the readiness of the launch complex of launch pad No. 1 at Baikonur, confirmation of the R-7 missile readiness for the space launch by two previous successful launches and the flight readiness of the PS-1, as a part of the missile rocket, confirmed by complex integrated tests.

A resolution about the PS-1 flight tests was signed by S.P. Korolev on October 2 — two days before the launch and sent to Moscow as a notification about the readiness. Without getting any directions from Moscow, S.P. Korolev made a decision about transportation of the missile carrier with the satellite to the launch pad on October 3.

According to more precise data, the missile launch took place on October 4, 1957, at 10:28:34 p.m. Moscow time. It was the sixth launch of the R-7 missile.

Even after the PS-1 launch, the development of the missile systems still continued.

In January, 1960, the Ministry of Defense added the intercontinental ballistic missile R-7 to its arsenal.

The launch of the first AES opened up opportunities to build space crafts and deliver them into the outer space, which display unique capabilities for performing research and solving applied problems.

The use of satellites made it possible:

- to transfer from remote methods of exploration of the outer space and planets to research with taking samples of atmosphere, soil in case of a direct contact with a planet;
- to organize a systematic updating of information down linked from satellites about the Earth, planets, galaxies, space environment;
- to obtain an opportunity to conduct physical and technological experiments under the conditions of a deep vacuum and low level of microgravity;
- to create global communication and navigation systems.

The up-to-date level of knowledge and technology allows the unique capabilities of the artificial Earth satellites, unmanned research stations, observatories and robotic systems to be permanently built-up.

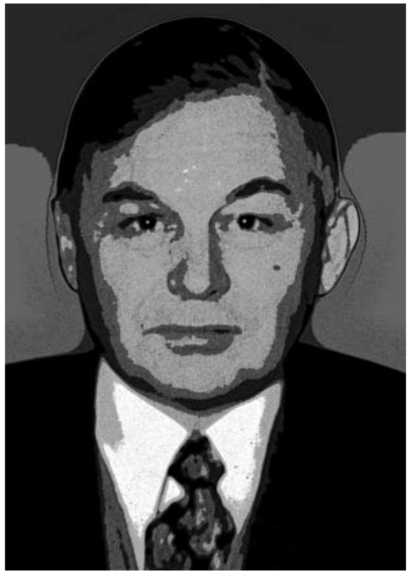
But all these systems are, in their essence, merely a more complicated version of that very first simplest satellite of the Earth, launched into space on October 4, 1957.

Heavy satellite vehicles, the construction and launch of which were carried out by S.P. Korolev after the pilot launches of the automated space vehicles, formed the basis for the development of design for multipurpose space systems in the contemporary manned programs.

...I remember very well one frosty October evening in 1957 in the Moscow region, where the sky was not illuminated either by the street lights or by the buildings around us, when, following the timeline printed in the *Pravda* newspaper, we saw a starlet moving energetically along the black sky among stationary stars. It was the second stage of the rocket missile, and our PS-1 was moving somewhere in the vicinity of it.

There could be no mistake — it was IT, our sole artificial Earth satellite at that moment!

This event of the 20th century will be assessed for a long time, if not forever, by the people of our and future generations as an event that affected the development of science and engineering, as a historical fact, that made its corrections in the political atmosphere of relations between countries and nations on the Earth.



Timur ENEEV
RUSSIA

Academician of Russian Academy of Sciences.

Born in 1924 in Grozny, Russia. Graduated from the Mechanics and Mathematics Department, the Lomonosov Moscow State University in 1948.

Expert in missile dynamics and control. Participated in development of the research program of outer space, the Moon and planets of the Solar system. One of the first scientist in the world, who has found the solution for optimization of insertion of rockets in trajectories. Developed the theory of artificial Earth satellites' orbits. Currently is involved in the *Phobos-Soample Return* project.

Awarded the Order of Lenin (1961), the Order of October Revolution (1984), the Red Banner (twice in 1956 and 1975), the Order of Honour (2005), the Lenin Prize (1975), Tsander Golden Medal (1992), VDNKh Golden Medal (1986) and the Demidov Prize (2006).

Asteroid 5711 is named Eneev 1978S04 after him.

M.V. KELDYSH — CHIEF THEORETICIAN OF THE NATIONAL COSMONAUTICS

Fifty years ago, on October 4, 1957, for the first time in history the mankind has delivered a device into space which was flying on orbit around the Earth for a long period of time sending the signals about the performance of its onboard equipment. With the aid of R-7 rocket the first artificial Earth satellite was launched.

Launch of this satellite had a long and complicated prehistory. People were dreaming of the flights to space since a long time ago. This dream first acquired a real basis after the pioneering work of Tsiolkovsky who has shown these flights to be possible with the aid of rocket technology. He has devised a famous formula which allows to calculate the fuel capacity required to achieve the necessary rocket velocity, and developed the basics of the multi-stage rockets theory.

However it was only after the war when the real works on the realization of the idea of space flight has started thanks to the urgent need of developing the rocket industry in the military goals. In order to countervail the emerged threat of nuclear attack on the Soviet Union, it was necessary to create the intercontinental multi-staged ballistic missile. It was the Design Bureau of the brilliant engineer and designer Sergey Pavlovich Korolev where such a rocket — the famous R-7 — has been created. Surely Korolev's DB was working in cooperation with other institutions developing engines, control system, launch facility and so on. One should here note the Chief Designers V.P. Glushko, N.N. Pilyugin, M.S. Ryazansky, V.I. Kuznetsov, V.P. Barmin. One can't but remember the excellent assistants to Sergey Pavlovich Korolev, his deputies V.P. Mishin, V.A. Voskresensky, K.D. Bushuev, B.E. Chertok. Sergey Pavlovich also had a first-class heads of laboratories and departments, naming here S.S. Lavrov who was leading the department of ballistic design calculations.

THE BASIC SPUTNIK

But already during the hard work on creating the rockets some of its participants were thinking about the space flight. The most serious research was carried out by two collectives – M.K. Tikhonravov's group in one of the military technical institutes and group of M.V. Keldysh at V.A. Steklov Mathematical Institute (MIAN). This research was warmly supported by Korolev who provisioned the space application of the big rockets since the very start of their development. In 1950 he amazed the scientists of Steklov's institute discussing the aspects of R-7 design with him by a phrase dropped in passing: '*But we will fly around the globe!*'

Of course, Korolev was the prime figure in the realization of the first Soviet space flights. However, along with him one should also note one more person who has made a comparable contribution into the development of our rocket and space technology – Mstislav Vsevolodovich Keldysh.

* * *

The name of Mstislav Vsevolodovich Keldysh, Academician, three times Hero of Socialist Labor, is well known both in our country and abroad. He is renowned as outstanding native scientist, mathematician and mechanic who has given the original solutions of the most complicated problems and determined a number of directions in the modern mathematics and mechanics with his works. He is renowned as the 'Chief Theoretician of Cosmonautics', one of the creators and leaders of the native space program. He is renowned as the President of Academy of Sciences having been in charge of the headquarters of the native science for many years and having done a lot for the development and consolidation of the scientific research in our country, for the growth of role and prestige of science.

Mstislav Vsevolodovich Keldysh was born on February 10, 1911 in Riga in the family of adjunct professor of Riga Polytechnic Institute Vsevolod Mikhailovich Keldysh, distinguished construction engineer, later the Academician and vice-president of Academy of Construction and Architecture.

Upon graduating from Moscow State University in 1931 M.V. Keldysh at the invitation of S.A. Chaplygin and M.A. Lavrentyev has begun working at Central Aero-Hydrodynamic Institute (TsAGI) studying various mathematical issues of aero-hydrodynamics. The young scientists has faced here the big and difficult problems which appeared during those times in aircraft engineering.

In 1935 Academician S.A. Chaplygin sent M.V. Keldysh to vibration group of TsAGI and assigned him the work on the aircraft flutter problem. This severe destructive phenomenon caused by resonance vibrations of the aircraft structure became an obstacle on the way of high-velocity aviation development. Flutter was under the wide range experimental study both in air tunnel and *in-situ*. However it was only the mathematical model of this phenomenon suggested by M.V. Keldysh, mathematical methods of its analysis developed by him and resulting theory that allowed to uncover the source of danger and to find the technical ways of fighting it. For these works M.V. Keldysh was awarded Stalin Prize in 1942.

It was 1946 when he was awarded the Stalin Prize for the second time for the successful works on the stability of the front wheel of the three-wheel aircraft chassis. Thus another dangerous phenomenon in aviation was removed called 'shimmy'. It was manifested during the motion of aircraft at a large speed on the flight strip when the nose wheel became suddenly wobbling from side to side, gear leg went broken and plane crashed. Having studied the shimmying phenomenon, Mstislav Vsevolodovich has built an elegant mathematical theory and proposed the engineering solutions of this problem.

While still working at TsAGI, Mstislav Vsevolodovich joined V.A. Steklov's Mathematical Institute and starts teaching at Moscow University.

It was during these years when M.V. Keldysh has shaped into the outstanding scientist whose talent was based on the deepest intuition of mechanic, the highest mathematical culture and professional knowledge of engineering issues. Like nobody else he was able to start from the specific engineering and technical problem, formulate the adequate mathematical model, offer the effective mathematical methods of its study and give the constructive solutions. As a result not only the practical recommendations on the solution of the original application problem were given, but the fundamental results in different fields of maths were obtained which have become classical now. This is why when the wide range of works on rocket industry was developed in the country, M.V. Keldysh by right became one of the leaders of the Soviet space program.

In 1946 at the age of 35, just elected Fellow of USSR Academy of Sciences, M.V. Keldysh was ordered the head of Jet Propulsion Scientific Research Institute (RNII) — nowadays M.V. Keldysh Research Center. Since 1948 he started works on rocket dynamics and applied celestial mechanics in the department of mechanics leaded by him at the V.A. Steklov's Mathematical Institute of USSR Academy of Sciences.

It should be noted that initially the main efforts of Mstislav Vsevolodovich were concentrated towards the military aspects of rocketry applications. However there are many reasons to believe that like S.P. Korolev from the very early stages of research he was thinking about its 'space' future, too. At least in the very beginning of 50's while answering the question of one of collaborators at the MIAN department of mechanics about the possibility to develop the theory of space flight he has not just warmly supported the idea, but proposed to start work without waiting for the future.

The work of M.V. Keldysh in the field of rocketry and cosmonautics was developing in four directions at once. First, he was heading RNII. Secondly, he was directing the scientific research on rocket dynamics and applied celestial mechanics first at MIAN and then since 1953 at the Institute of Applied Mathematics of Academy of Sciences (from the security reasons it was referred to as Department of Applied Mathematics — OPM MIAN). Third, M.V. Keldysh was assigned the coordination of works in the USSR Academy of Sciences on the development of the scientific payload for the extraterrestrial research. Finally, he was performing the state scientific expertise of the works carried out within the framework of developing the rocketry and space research.

The efforts of M.V. Keldysh at RNII were initially concentrated on the problem of creating the stratospheric winged rocket. Under his scientific conduct the major tasks of making this rocket were solved here, including the principally new for the time being issues of ballistics, astronavigation and long-term thermal protection for the supersonic intercontinental *Burya* ('tempest') winged craft with propulsive jet engine. Scientific and technical solutions achieved during the creation of this craft have later found wide usage in the aviation and rocket space technology. In particular, at RNII they have laid the ground for the start of works on the thermal protection of ICBM heads and later of landers, spacecraft and automated interplanetary stations, as well as on the astroorientation and navigation systems of spacecraft.

Since 1948, first at MIAN and later at the Institute of Applied Mathematics of USSR Academy of Sciences, at the department headed by Academician D.E. Okhotsimsky, M.S. Keldysh has initiated the wide range of activities on the rocket dynamics and mechanics of space flight. Even on the first phase, yet before the launch of the first artificial Earth satellite, the collective headed by M.V. Keldysh obtained a number of principally important results which have made a serious impact on the development of rocket and space technology. We will note several of them, the most important ones.

A series of works was performed in 1949–1951 devoted to the analysis and determination of the optimal schemes and properties of staged rockets. These works have helped S.P. Korolev to make the final choice of the staged R-7 rocket scheme. Over this period of time works on determining the optimal program control were performed with their results having seriously assisted the improvement of flight characteristics of R-7 rocket and those of intercontinental winged missiles, and having later served the theoretical basis for many future research. In the same period the difficult problems of rocket's motion around the center of gravity were solved taking into account the movability of fluid having the free surface in the rocket fuel tanks. In 1953 the ballistic descent of the spacecraft from the orbit to Earth was proposed for the first time at OPM and the possibility was shown to utilize this landing method in the manned flights. Later as a result of implementing this method the space flight of Yu.A. Gagarin was completed with a successful landing. The first real prototype of the passive stabilization system of the artificial satellite was proposed in 1954 and the theory of this stabilization created.

All the works had the original nature and were performed for the first time not just in our country, but in the world.

The creative contact and friendship of Mstislav Vsevolodovich Keldysh with Sergey Pavlovich Korolev were of historical value. It was thanks to these contacts and friendship that our rocketry was developing very quickly, with especially high pace in the techniques of space flight. Generally, within the pleiad of the brilliant people mentioned above Mstislav Vsevolodovich was playing a special role. It was thanks to his ideas and initiative that we managed to overcome very difficult moments in building up our rocket and space technology, to arrange the systematic realization of space research in our country.

After the launch of the first artificial satellite the range of works headed by M.V. Keldysh at OPM MIAN has significantly extended and for the next years there was literally no issues of the space flight mechanics which were not influenced to some extent by M.V. Keldysh and his 'team'. For instance, right after the first satellite launch works on tracking the satellites and other spacecraft were initiated at OPM. The collaborators of M.V. Keldysh have developed the methods and performed the first orbit determination with the aid of computers. The Ballistic Center was later created at OPM which has joined the common system of coordinating computational centers of USSR. Their task was to collect and process the trajectory information with the aim of determining the proper orbits of flown objects as well as issuing the necessary commands. Center has become the essential part of the closed circuit of spacecraft flight operation and assisted the successful realization of space programs.

The works on the complex ballistic projecting of the interplanetary flights of spacecraft to the Moon, Mars and Venus were started. The main efforts here were initially pointed towards solving the task of reaching the Moon and researching the circumlunar space. A brilliant example of this 'lunar' cycle of works was the study on selecting the trajectory for the flyby and imaging the backside of the Moon for the third lunar spacecraft. This was the first time in the world when the perturbation manoeuver was proposed and realized — the intended change of S/C trajectory as a result of perturbing its motion by the celestial body (the Moon).

At the height of works on preparing lunar expeditions Mstislav Vsevolodovich Keldysh and Sergey Pavlovich Korolev have made a joint decision to start the ballistic simulation of the unmanned flights to Mars and Venus. The principal technical decisions were generated which played an important role in the later development of the space technology: method of spacecraft acceleration with the transitional delivery into the open orbit of the artificial Earth satellite which has become the universal scheme of spacecraft boosting; general scheme of S/C flight operation which became the basis of all works on both ballistic simulation and practical operation of the flights of interplanetary S/C. This scheme was providing both the maximum control accuracy during the flight and minimal mass expenses related to the design of the control system itself. Headed by M.V. Keldysh, the OPM staff participated in all works on the ballistic design and the ballistic and navigational support of the spacecraft flights for researching the interplanetary space, the Moon, planets and small bodies of the Solar system. In this context computations methods were developed at OPM and hardware-software complexes were created to determine the optimal launch dates, overall control accuracy and optimal values of the input parameters for performing the flight trajectory correction.

Under the auspices of M.V. Keldysh the works were started at OPM in the new direction which has high fundamental and applied significance for the navigation and flight operation of the spacecraft. This is improvement of the astronomical constants and development of highly accurate theories of motion of the celestial bodies. For the first time in the world practice the parameters of the lunar gravity field noncentrality were determined from the trajectory measurement data. The first precise theory of motion of Venus in our country was derived. The gravitation constants of the Earth and the Moon and dynamic flattening of Venus were improved.

Finally, under the supervision of M.V. Keldysh ballistic design works were carried out on the development of a number of unique artificial Earth satellites (for example, *Elektron*), new and perspective systems of operation and stabilization of satellites (passive stabilization systems), as well as works on determination of the actual motion of freely flying satellites of Earth (for instance, of *Elektron* and *Proton* series) around the center of mass.

Mstislav Vsevolodovich was perfectly combining the qualities of the daring dreamer who was tending towards the limits of the possible, and those of the sober realist well aware where these limits are. When under the impression of the first space flight successes lots of people were seriously considering the project of manned flight to Mars in 1964 (in the fly-by mode), Mstislav Vsevolodovich immediately pointed at the nonreality of such projects due to a whole number of reasons and was noting that the automated spacecraft would be the primary tool of researching the far planets for many years to come. That didn't however prevent him from discussing the manned flights to other planets and considering in detail their different projects in the nearest future.

Scientific and managing activity of M.V. Keldysh in the area of cosmonautics itself started in 1954 when together with S.P. Korolev and M.K. Tikhonravov he expressed the proposal of creating the artificial Earth satellite and personally participated in

preparation of the reporting notice on this topic for the government. In 1956 Mstislav Vsevolodovich was appointed the head of the special commission of the Presidium of USSR Academy of Sciences on the artificial Earth satellite (commission on the 'Object 'D'). In 1958 by the decision of the Central Committee of CPSU and Council of Ministers of USSR M.V. Keldysh was assigned the president of the Interdepartmental Council on Space Research at the Academy of Sciences (MNTS on KI). Since this moment both as the leader of integrated scientific and technical research and development and the president of MNTS on KI, M.V. Keldysh was carrying the special responsibility for the progress of the USSR space program, even during the most intense period of his multiple activities while being the President of USSR Academy of Sciences in 1961–1975.

Having become the president of Academy of Sciences, Mstislav Vsevolodovich got the possibility to manage the development and realization of the Soviet space program at the new, higher level. The range of scientific problems under solution during these years was unusually broad and diverse. With his direct participation the general problems of cosmonautics, trends and prospects of its growth were researched. His field of view always covered the mechanics of space flight, the theory of operation, navigation, orientation. The start of research of the near space and the interplanetary medium, the Moon and Solar system planets is related to his name. For instance, together with Georgy Nikolaevich Babakin he was directing the development and realization of the Venus research program. He was paying the most serious attention to the manned flights, their programs and scientific experiments, supplying the spacecraft with the equipment and devices, including onboard computers. The topic of his permanent attention was extending the range of scientific research and improving their management. He was originator of creating the Space Research Institute and the Institute of Biomedical Problems.

Mstislav Vsevolodovich was possessing the incredible depth of thought, open-mindedness, huge erudition. Many people were dazzled by his ability to get to the very essence of problem under discussion, find the principal link, having rejected everything not important, of the secondary value.

M.V. Keldysh was an exceptionally principled man who had placed the interests of the business and the country above any others. He was a person of state in the highest meaning of this word. One can give one bright example here. The heavy launcher N1 was under construction at S.P. Korolev's Design Bureau. On the same time the Chief Designer V.N. Chelomey stepped out with the drawing project of new UR-500 (*Proton*) launcher. Expertise of his project was assigned to the state commission with M.V. Keldysh in charge. Having thoroughly analyzed the project, M.V. Keldysh appreciated its high technical level. Despite the negative reviews from a number of provisional commissions (which were, unfortunately, of subjective nature), expert committee of M.V. Keldysh has approved V.N. Chelomey's project opening the 'green light' for its realization. *Proton* launcher has provided our country with the successes in the research of the Moon, Venus and Mars, the flights of orbital stations. Without the high fidelity to principles and perseverance of M.V. Keldysh *Proton* would have hardly been created in those conditions.

M.V. Keldysh was paying the exceptionally high attention to the planning issues in the space research which to a large extent assisted our country in providing a number of priority achievements laying the foundation of practical cosmonautics. Complex programs of research of the near space, the Moon and planets, experiments to the benefit of the national economics were developing under his direct management.

Realization of such ambitious projects as first Earth satellite launch, first human flight in space, first flights of the automated spacecraft to the Moon and its first artificial satellite, lunar soil retrieval and delivery to Earth, first flights to Venus and Mars, the first artificial satellites of Venus, first studies of Venusian atmosphere, soft landing on its surface, first panoramic images of this 'mysterious' planet transmitted to Earth by automated spacecraft and many others are directly related to his activity. Great are his merits in the choice of the principal direction by our country towards the scientific research of space, the Moon and planets with the aim of the automated spacecraft.

M.V. Keldysh has actively supported the proposal by Institute of Radioelectronics on the mapping the surface of Venus which is covered from the observer's eyes by the thick optically opaque atmosphere. It was supposed to perform the mapping with the radar equipment of the spacecraft delivered into the orbit of planet's artificial satellite. M.V. Keldysh was discussing the possibilities of such an elegant space experiment with the scientists, pointing out the important role the issues of processing the large volumes of information should play in its realization. Unfortunately M.V. Keldysh was not able to see the results of this unique space experiment carried out successfully in 1983–1984 by *Venera-15* and *Venera-16* spacecraft.

Since the beginning of intensive development of *Space Shuttle* returnable system project in USA, the issue critically arose on the practicability of creating the similar system in our country. M.V. Keldysh was many times discussing the range of problems which could have been solved with the aid of the recoverable space system, difficulties of its realization and the ways of overcoming them. The result was creating the concept of universal transportation facility able to solve the scientific, economical and defense tasks. The accepted technical solution was considered as an intermediate step towards making the completely reusable aero-spacecraft for the flights on any heights in the atmosphere and beyond its boundary. On the same time, creation of *Energia-Buran* system allowed to solve the problems of developing the heavy rocket launcher with a carrying capacity about 100 t and oxygen-hydrogen engines, design of aero-spacecraft with a rather complex and perfect operation system.

Having made the decision on the necessity to create *Energia-Buran* rocket space system after internal hesitations and doubts, M.V. Keldysh devoted a lot of forces, talent and managing skills to the realization of this project.

Academician M.V. Keldysh played an important role in establishing the cooperation in space research and exploration with the socialist countries in the network of *Intercosmos* project, as well as the cooperation on the bilateral basis with USA, France, etc. He was one of the initiators of the famous *Soyuz-Apollo* flight program.

The name of M.V. Keldysh is related to the formation of new science – computational mathematics without which many fundamental modern achievements would be impossible. The giant atomic problem requiring huge efforts was solved in very short terms. The country's 'rocket-nuclear shield' was created, the military political balance in the world was restored. The huge role in this project was played by its scientific directorship, cooperation of three '**K**' (**K**eldysh, **K**urchatov, **K**orolev). This became possible due to the broad application of the methods of mathematical modeling which provided the choice of the optimal items of hardware, thus allowing to significantly increase the speed of creating the nuclear and thermonuclear weapon. M.V. Keldysh was participating in this titanic work both as the director of a large collective of scientists and the author of many ideas and computational methods. M.V. Keldysh became the founder of this scientific discipline and initiator of its development at

V.A. Steklov's Mathematical Institute and later at Institute of Applied Mathematics of USSR Academy of Sciences (IPM) which he has created in 1953 and was directing for 25 years. It was here, at IPM, where the solution started of many complicated problems related to atomic energy takeover and space exploration. The Institute took part in development of the largest state scientific projects aimed towards the solution of the most actual problems. All of that called for the creation of the new science, new area in mathematics. Under the auspices of M.V. Keldysh the unique collective of specialists was formed capable of solving the large applied problems. Ideas and methods developed by M.V. Keldysh, his disciples and colleagues have received a wide appreciation and dissemination finding the application in many areas of science and economy. The first calculations at IPM were performed manually with the captured electro-mechanical machines of *Mercedes* type. But soon the first computers appeared that allowed to increase the computation speed by orders of magnitude. M.V. Keldysh was one of the first to realize the role of new technological devices in the scientific research, in the science-technical progress. IPM was receiving the first samples of practically all native computers. The special divisions were created in the Institute where developments were underway on programming languages and compilators, PC-architecture, networks, visualization systems and many other topics which have turned into what is now referred to as information technologies.

For many years M.V. Keldysh was actively participating in managing the USSR Academy of Sciences which he was heading as a President of Academy for fourteen years.

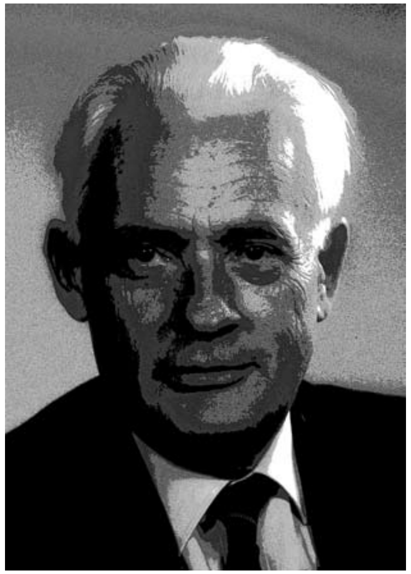
He was paying a large attention to the choice of main directions of the scientific research, perspectives of development of science and technical progress. It was in the close connection of science and technology, in the cooperation of science with industry where M.V. Keldysh was seeing the most important stimulus for the progress of science.

Since 1961 Academician M.V. Keldysh was heading the Committee on the Lenin and State Prizes. This Committee was intended to carry out exceptionally responsible functions of the objective, unbiased discussion and correct evaluation of not just the scientific works but also the outstanding achievements in the field of industry and economy submitted to seek the prizes. It is clear that the role of the Committee president is extremely high and he must be possessing an exceptional authority and wisdom. M.V. Keldysh was an excellent example of the manager endowed with all these qualities.

The activity of M.V. Keldysh, an outstanding scientist, distinguished manager who has made so much for raising the power and prestige of the Soviet science was worthily marked with the triple awarding him a high dignity of the Hero of Socialist Labor, many other medals, prizes and honored titles.

Academy of Sciences is regularly awarding M.V. Keldysh gold medal for the outstanding scientific results, the Institute of Applied Mathematics is named after him. There is a memorial room — museum of M.V. Keldysh and the monument raised by sculptor V.M. Klykov.

And the more time is going by since the moment of his passing in 1978, the more clearly and sharply we recognize his role for the country as a great scientist, patriot and citizen, his value as the manager of science as a whole and of the space research in particular.



Yuri RYZHOV
RUSSIA

Employee of the Ordzhonikidze Moscow Aviation Institute. Academician of the Russian Academy of Sciences.

Born in 1930, Moscow. Graduated from the Moscow Institute of Physics and Technology in 1954. Worked in the Zhukovsky Central Aerohydrodynamic Institute (TsAGI), Research Institute-1 (now the M.V. Keldysh Research Center), the Ordzhonikidze Moscow Aviation Institute (current workplace; from 1986 to 1992 held the position of rector).

Deputy to the Supreme Soviet in 1989–1992. Member of Presidium of the Supreme Soviet, Chairman of the Supreme Soviet Committee on Science, Culture and Education.

Ambassador Extraordinary and Plenipotentiary of Russia in France (1992–1999).

Knight of Legion of Honour (France). Awarded be the USSR State Prize, Presidential Prize of Russia, Orders of Russia and the USSR.

MY REFLECTIONS ON THE SPUTNIK-1 LAUNCH

To tell today, 50 years later, how we, engineers of my generation, took and estimated the first in the world artificial Earth satellite launched by our country, one need to imagine who we were and where we were at those times preceding that triumph.

By saying ‘we’ I mean both myself and many of my ‘fiztekh’ (the Moscow Institute of Physics and Technology or MPIT) ‘classmates’. The majority of us, who graduated from the ‘Fiztekh’ back in 1953–1956, specializing in this or that way in aviation and missile science and industry (the so-called ‘aerodynamics’ and ‘thermodynamics’), in compliance with the approach adopted at the Fiztekh, studied the profile subjects at the basic faculties of scientific-research institutes rather than at Dolgoprudny much before graduation from the Fiztekh institute. For the ‘aerodynamics’, it was the Central Aerohydrodynamical Institute (TsAGI) in the town of Zhukovsky, while for the ‘thermodynamic students’, it was the Central Institute of Aviation Engine Building (TsIAM) and the NII-1 Scientific-Research Institute in Moscow, being its affiliation at that time (currently, the M.V. Keldysh Center).

We all knew one another from Dolgoprudny, where we were taught basics of mathematics, physics, mechanics, languages, as well as a number of other, often far from developing disciplines. I am telling about this disposition in such detail in order to explain the reaction of the above-described ‘community’ or, rather, my own reaction to the epoch-making event of October 4, 1957.

In February 1954, having defended my diploma thesis on aerodynamics of feathered bodies of revolution, I began working at the same place where it had been done — at the Department of Aerodynamics of air-to-air and surface-to-air missiles of the TsAGI 2nd Laboratory. There were inspiring times: synchrophasotron, atomic and hydrogen bombs, jet plane fighters and bombers, geophysical rockets taking off vertically still higher and higher…

Under the atmosphere of extreme secrecy in the defense industry, being isolated from foreign mass media, it was highly incredible for citizens who did not deal directly with aviation and rocket science and industry to imagine that the launch of the first artificial Earth satellite (AES) was so real and imminent.

The situation was different in the society of scientists and engineers. It was not only that we communicated with one another and with our ‘senior friends’ but, for example, my ‘Fiztekh’ friends and I were eager to absorb scientific and popular science information published in foreign periodicals (e.g., *Popular Mechanics* Journal). The access to these periodicals, including those that were classified and stamped with a so-called restricting access ‘hexahedron’, was ensured by the TsAGI Bureau of Scientific and Technical Information (BNTI). Similar departments were also available at the TsIAM and NII-1 Institutes. All of them were very generously supplied with scientific and technical literature published abroad. This information, alongside with the actual work performed at these institutions, allowed us to get an idea of actual near-future potentialities of world science and engineering in the field of aviation and missiles.

Besides, at the BNTI Bureau it was possible to get acquainted with trophy German materials. From these materials we knew about quite attainable goals that had already been achieved by Germans in this field even before 1945.

We knew that the Germans had left behind both us and our anti-Hitler coalition allies by years and years. They has surpassed us in the tactic missile armament (V-1 and V-2), air-defense armament (the *Wasserfall*, *Reintochter* air-defense missiles), in air-jet engines with centrifugal and axial compressors, in creation of jet plane fighters with near-sonic velocities of flight and back- and forward-swept wings, allowing a shock wave phenomenon on a wing to be shifted to the M numbers ~0,8.

The department, where I worked, was not directly engaged in the ballistic missile rocket projects. Then, velocities of air-to-air and surface-to-air missiles did not exceed M = 3. Nevertheless, we were also ‘hit’ by the ‘fire’ of long-range nuclear-charged ballistic missiles. We were briefed about their potentialities, effective areas, depending on the number of megaton equivalent, projects of interception-destroying of warheads at the descending trajectory section (it was only at the end of the 1970’s that they began seriously discuss interception at the insertion stage).

Despite the softening of political customs in the country (after the XX Congress of the Communist Party of the Soviet Union (CPSU), the ‘cold war’ was in full swing. The US U-2 reconnaissance aircrafts were on the loose flying over our territory at altitudes not accessible to our air defense means.

Only in 1960, the yet another U-2 was finally hit by an anti-aircraft missile, the aerodynamics of which was developed in our department. After it had been shot down, its pilot Powers was taken captive. My immediate bosses, A.F. Mitykin and V.M. Shurygin, were among those who received the Lenin Prize for this evident achievement.

Twenty years later, at one of the research centers in California I witnessed a U-2 launch. The ‘old man’ continued to work, pursuing the research goals rather than intelligence ones, same as its Soviet equivalents developed at the V.M. Myasischev Design Bureau.

From our friends, working at the NII-1 Institute, we knew that the Design Bureau headed by S.P. Korolev worked in close contact with their institute. Some time before that, even before he was arrested, S.P. Korolev had worked on the same territory in Likhobory, at the RNII. We knew that, having reproduced the V-2 missile (R-1), Sergey Pavlovich created the R-5 missile and, subsequently, the famous R-7 one, which after having been subjected to numerous upgrades, is still reliable in serving the space exploration goals. Therefore, for us, young specialists, it was clear that the AES would come next. The only question was: Who would be the first to launch it? We or the USA? In the USA and in the West, they have been discussing research in this field extensively and rather openly. Within this country, this topic was 'TSSI' (Top Secret. Sensitive Information.).

Maybe, it is my personal opinion of the event of October 4, 1957, but it seems to me that it had been underestimated by the 'public opinion' of our country and had failed to impress the public as profoundly as Yu.A. Gagarin's flight into space on April 12, 1961. What a nation-wide triumph it was on April 12! I was among those crowds in Manezhnaya and Red Square and was cheering together with my compatriots, although for us, young specialists, it was not an unexpected event either: just the same question: Who would be the first? But then, in October, 1957, it was rather our friends-rivals in the West, who gasped, having lost the races. Although, for sure, they had a much better understanding of capabilities this country had in the field of AES launching. And, once again, they drew conclusions for themselves, in particular, about training of specialists in new, developing fields of science and engineering in the USSR.

And once again a few words about me. At the beginning of 1958, having been invited by Academician G.I. Petrov, I moved from the TsAGI to his 4^{th} Gas-Dynamic Laboratory of the NII-1 Institute. It was required to finish the construction (including earth excavation) and commissioning of a wind tunnel with a closed working section (which is typical of the TsAGI but did not comply with the traditions of the NII-1 Institute) with a flexible controlled exhaust section for the M numbers up to 6, with a ballast heating. I was also entrusted with other 'odd jobs', related to a cruise missile of the S.A. Lavochkin Design Bureau, having a ramjet engine and velocity, corresponding to M ~ 3, and its star-tracking spine. I got in touch with aerodynamic tests of this missile mockup in the T-109 wind tunnel back at the time when I was still working at the TsAGI Institute. Separation with side accelerating engines was simulated (the engine was developed by the Bondaryuk Design Bureau, which was located on the same territory of the NII-1 Institute, while the 4^{th} Lab was actively working on the inlet assembly and the whole gas-dynamic duct of this unique ramjet engine).

But what I remember very well is a small task on analogue simulation of a vehicle disorbit with an aerodynamic quality, allowing overloads and thermal fluxes to be considerably decreased, as compared with the ballistic re-entry, performed by Yu.A. Gagarin's capsule.

I performed this simulation under the supervision of G.F. Telenin, a remarkable person and scientists, at the end of April, 1960. Belka and Strelka dogs were already orbiting the space, leaving us no doubt about our new space triumph being close at hand. There was one year left before Y.A. Gagarin's flight.

* * *

I was lucky both in my profession and in my life. To work at such remarkable institutions as TsAGI and NII-1 during the times when such giants (irrelative of their relationships) as M.V. Keldysh, G.I. Petrov, S.A. Khristianovich, V.S. Avduevskiy, V.V. Struminskiy, A.A. Dorodnitsyn worked there, not only seeing them but also listening to them during meetings and workshops – wasn't it good luck?!

That was the time when a poet was writing: '*somehow physicists are honoured; somehow poets are neglected...*'

The poet was not utterly sincere. Lyric poets — Ye. Yevtushenko, A. Voznesensky, R. Rozhdestvensky and others were standing together with physicists in the same inspired ranks at that remarkable and unique time.

Roger-Maurice BONNET
FRANCE

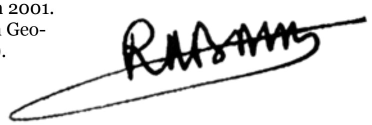
President of the Committee on Space Research (COSPAR). Executive Director of the International Space Science Institute (ISSI).

Born in 1937, France. Graduated from Paris University in Physics and Astronomy (1961).

In 1963, at Service d'Aéronomie, he launched the first French space astronomy experiment on board a *Veronique* rocket in Sahara. Director of the Laboratoire de Physique Stellaire et Planétaire (1969–1983). In 1983–2001 was involved with the European Space Agency. As Director of the Science Programme of the ESA, he established as early as 1984 the first long term programme of ESA called *Horizon 2000*.

Joint Director General for Science at CNES (Centre National d'Etudes spatiales, National Center for Space Studies, 2002–2003). President of COSPAR since October 2002.

Awarded by Gagarin Medal in 1985, Tsiolkovsky Medal in 1993, COSPAR Award in 2000, NASA Public Service Medal in 2001. Fellow of the European Geophysical Society (2001). Officier de la Légion d'Honneur.



WHAT DID SPUTNIK-1 DO US AND TO ME

France and Russia have developed a strong tradition of mutual esteem. This is based on the respect of culture, art and other common values, including literature and poetry, painting, architecture, music, dance, and science. My former Soviet friends, now Russians, had a genuine admiration for the values of the French revolution. Reciprocally, there was, in particular after the Second World War, strong admiration from a large part of the French population for the courage and the sacrifices of the Soviet people. So when *Sputnik-1* was successfully placed into orbit, that part of the admiring France, and more, was, the least to say, enthused over the exploit. I was among them, a 19-years-old student at Paris University. Honestly, I could not believe it. How was it possible to accelerate an object like that not-so-little metallic ball to the phenomenal speed of 29 000 km/h? How was it possible to get it talking to us? How was it possible that the country which invaded Hungary and sent its tanks to Budapest the year before managed to occupy again the front scene, this time with an even more stunning event? An event that we would not have been so much surprised had it been the fact of the United States, the most technologically developed country of the whole world. But from Soviet Union! Incredible!

In 1957, the international context was dominated by the 'cold war', the dominance of Soviet Union over several East European countries and also by colonial wars. France had just left Vietnam to immediately start fighting against Algeria. The United States were already thinking succeeding the French in Vietnam. These were doom days for the world a decade or so after the end of the World War. Then, suddenly, the landscape changed just because of this tiny sphere of aluminium orbiting above our heads

and arrogantly sending its historical 'beeps'. We were witnessing a planetary toggling of which we knew nothing and of unforeseeable consequences. In just a few minutes the world entered into a new era: the space age had started which would modify our ways of living and would strengthen the already strong bipolarization of the world.

Sputnik-1 was preceded by an event which was not understood immediately as related. At the end of August, I remember listening to the radio when it Announced that Soviet Union had successfully launched what was identified as a first Intercontinental ballistic missile, whose performance were astounding and above anything imaginable. The public announcement came five days after the successful test, probably because the Russians wanted to be sure they had eventually succeeded. This stunning achievement created nervousness in the media. This first test was followed by a second successful one on September 7. The general public knew very little at that time of the Russian space program which was kept under strong secrecy. When suddenly *Sputnik-1* occupied the front pages of newspapers and of all media, the unbelievable truth appeared clearly: Soviet Union was the leader of the most advanced technological prowess of the century.

Indeed, we knew nothing and certainly not the name of the man who created the event, Sergey Korolev, who had been given the responsibility in February, 1953 by the Soviet government of building an intercontinental rocket. We did not know then that the program was supposed to send a 3-ton payload at 8000 km distance, the distance separating Moscow from Washington, a requirement which was later on upgraded when the thermonuclear warhead was estimated to weigh 6 tons (a mistaken estimate of Andrey Sakharov). We did not know this powerful rocket's name: R-7 or '*semyorka*'. We did not know that it took less than 4 years to develop the launcher and that between 15th May and 21st August it was victim of 3 failures. We did not know that a special launching range had been developed at Tyura-Tam (near Baikonur) in central Kazakhstan, specially created for the R-7. We did not know that the rocket's configuration was such that it was in fact a military flop, a device too difficult to use in case of crisis and emergency. We did not know that Sergey Korolev had understood that fact several years before the first test and that he took himself the decision to adapt the top stage of the R-7 to create the rocket named 8K71 in USSR which would be capable of the first satellization at the occasion of the start of the International Geophysical Year (IGY). We did not know that he had to fight against the scientists who wanted to use this first satellite for conducting experiments which would have given them a leading scientific role but would most likely have delayed the launch of *Sputnik-1*, letting the Americans take the leadership of the conquest of space. As an excellent manager, he took the decision to make *Sputnik-1* relatively small (58 cm of diameter) and simple, weighting 83.6 kg, equipped with one single 'experiment': the genial radio transmitters responsible for sending one '*beep*' per second, a '*beep*' which would remain famous for the rest of the history of humankind as the first signal ever received on Earth from outer space. A major PR scoop as we would say now.

We did not know a lot of things but with time passing we now realize that we should have known. On first August, 1955, following the announcement three days earlier by the Americans that they would launch a satellite as part of their IGY contribution, the Russians made a similar announcement. But this was totally ignored in the West. At the special Committee for IGY held in Barcelona on September 11, 1956, the Soviet delegate announced that his country would launch a satellite during the IGY. On July 9, 1957 the Soviet media announced again that a satellite was being prepared for launch. They went even as far as giving the radio frequencies it would use. Again, the

West and in particular the United States ignored the announcement, probably considering it as intoxicating propaganda. Finally, on September 18, at the occasion of the 100th anniversary of the birth of K. Tsiolkovsky, Radio Moscow announced that the launch of the satellite was imminent, but once more this was ignored.

Another big surprise was the launch of *Sputnik-2* less than a month later which was six times heavier than *Sputnik-1* and carried the charming little dog Laika as official passenger. On 15 May, 1958 *Sputnik-3* weighting nearly three times as much as *Sputnik-2* was also successfully put into orbit. We were totally flabbergasted, as the resources of the Russian rocket seemed to have extraordinarily enormous capabilities. Korolev's machine had started its incredible career. If it was not a good military engine, it proved on the contrary to be a great space launcher which is still used 50 years after its first launch.

The early days of space research were clearly marked by the successes of the Soviet missions while, simultaneously, the Americans were catching up, painfully and slowly first but then with a regular and impressive pace. The COSPAR created in the wake of *Sputnik-1* offered a forum where their respective scientific achievements were regularly reported. I remember the rooms at COSPAR Scientific Assemblies, filled with mobs of scientists from all over the world, curious and impatient to learn the latest discoveries on the Moon, Venus, Mars or just the Sun. In spite of the great political difficulties, the open policy of our Soviet colleagues allowed the initiation of the most impressive dialogue between the East block and the West, a dialogue which has marked the whole history of the 50 years of space research and continues today at an impressive level. Even though *Sputnik-1* is a child of the military competition between the two superpowers, its main legacy has been the initiation and development of international cooperation marked certainly also by a good dose of competition.

The effect of *Sputnik-1* on my own fate was absolutely determining. I was so much impressed by the technical prowess that when came the time for me to decide on my future, I decided to become a scientist, and I told my parents that if I managed to succeed I would develop my career in space. What counted above all for me was to be involved. And I have been! After my exams were passed successfully, I rejoined the laboratory of J.E. Blamont, the only one seriously involved in space research at that time in France, and less than six years after *Sputnik-1* I was able to launch my first experiment in space on board a *Veronique* rocket from the desert of Sahara. *Sputnik-1* made it all easy for me and on October 4, 2007, I celebrate not only a very historical birthday but also 50 years of my full involvement in space science.

In parallel, other actors were entering the scene. Less than 4 years after *Sputnik-1*, de Gaulle founded the Centre National d'Etudes Spatiales, CNES, the French space agency and my country was the first after Soviet Union and the United States to launch a satellite with its own means on November 26, 1965 (A-1 also called *Asterix*). France became a privileged partner and one of the leaders of the space era. The visit of de Gaulle to Baikonur in 1966 placed France in a unique position on the international space scene and opened the way to an intense scientific cooperation which later spread throughout Europe. After the war, visionary scientists like L. de Broglie and P. Auger in France and E. Amaldi in Italy were very active in using science as a means of European integration and of dialogue among the most ferocious warring countries. They created CERN in 1954 for nuclear research, and ESRO for space research followed in the wake of *Sputnik-1* in 1962. ESRO later in 1974 became ESA, the European Space Agency.

In contrast with the situation in USSR and the USA, the development of space activities in Europe was based on a totally peaceful approach which may explain its difficult start and lengthy development. As an early actor of space science I became rapidly involved in the development of the European space effort, first as a 24 years-old 'expert' in the various ESRO committees and later at ESA where I became the Science Programme Director in 1983 until 2001. The excellent spirit of cooperation between France and USSR based on mutual respect and admiration of their respective visions in the exploration of the Moon and Venus but also in astronomy and geosciences, percolated in Europe and later on the worldwide scene.

The climax was undoubtedly reached during the preparation of the observation of Halley's Comet in 1986 at the occasion of its return to perihelion. In the early 1980's, USSR and France were developing the two *Vega* missions to Venus which were supposed to launch a set of balloons to study the atmosphere of the 'Morning star'. The Russians had clearly gained leadership in the exploration of Venus. In view of the return of Halley at perihelion, Roald Sagdeev, then head of the IKI* institute in Moscow, in agreement with his international partners, in particular France, proposed to modify the spacecraft and to observe also Halley at some 8000 km distance. In parallel, ESA was developing *Giotto* and the Japanese space agency ISAS the two long-distance *Sakigake* and *Suisei* missions. *Giotto* was aiming at a close flyby of the nucleus. Thanks to a clever navigation technique based on the utilization of images obtained first by the *Vega* missions and on their very accurate tracking by the NASA *Deep Space Network*, *Giotto* was able to approach the comet to within 600 km. In the midst of the 'cold war' this unique montage of cooperation remains still today an exemplary achievement and clearly a direct legacy of the leadership acquired by Soviet space technology masterly illustrated by *Sputnik-1*. I was proud of being the ESA responsible actor in this unique and successful story.

The respective successes of USSR and of the US in manned missions and cosmonautics also established a solid basis for international cooperation as well as a profound corps spirit between soviet cosmonauts and US astronauts which was vividly illustrated during the joint *Apollo-Soyuz* flight in 1975 and continues today on board the International Space Station.

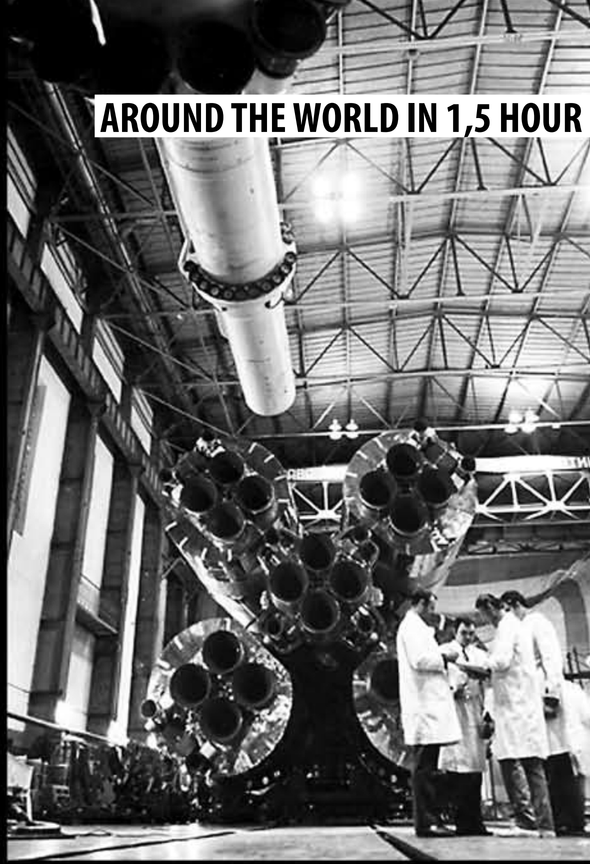
One cannot say that without *Sputnik-1*, space research and all the applications of space would not have started. It was just a matter of months for the Americans to launch their first artificial satellite. The fact that they were second behind the Soviets added some kind of spice to the evolution of the scene. Until the launch of *Apollo-11*, the Soviets dominated. One particularly exciting characteristic of that period was that we could not see any limits to their progress. The flight of Gagarin, less than 4 years after *Sputnik-1*, was another landmark in the history of mankind and, again, rightfully stunned the world. When Neil Armstrong put his feet on the Moon however the balance changed suddenly and a new era started which was marked by a remarkable record of very ambitious American astronomy and planetary missions and by the gradual disappearance of Russia (but not of Russian scientists) from the front scene of space science. A final jolt in the enormously long list of the soviet successes occurred on November 15, 1988 with the first — and last — launch of the *Buran* shuttle in a fully automatic mode. That was the last spectacular success and the end of a stunning story.

* Space Research Institute of USSR Academy of Sciences (today Russian Academy of Sciences).

In the meantime, *Soyuz*, the successor of the R-7 followed its incredible path with today over 1700 successful launches, manned and unmanned, making it the most reliable launcher in the world. The vision of the Soviet designers of R-7 and that of Sergey Korolev in particular to launch the first Sputnik, has shaped irreversibly the evolution of space exploration. Let me illustrate this with a few examples. Without the robust scientific Soviet leadership following *Sputnik-1*, France would not have been able to be the first European country to place laser reflectors on the Moon. It would not have been possible for France again to embark on the most extraordinary and unique and successful balloon expedition in the Venusian atmosphere. France and Russia would not have pioneered through their cooperation in the field of gamma-ray astronomy which then culminated with the international *Integral* mission. The incredible success of the Halley missions and in particular of *Giotto* would have much less scientifically rewarding.

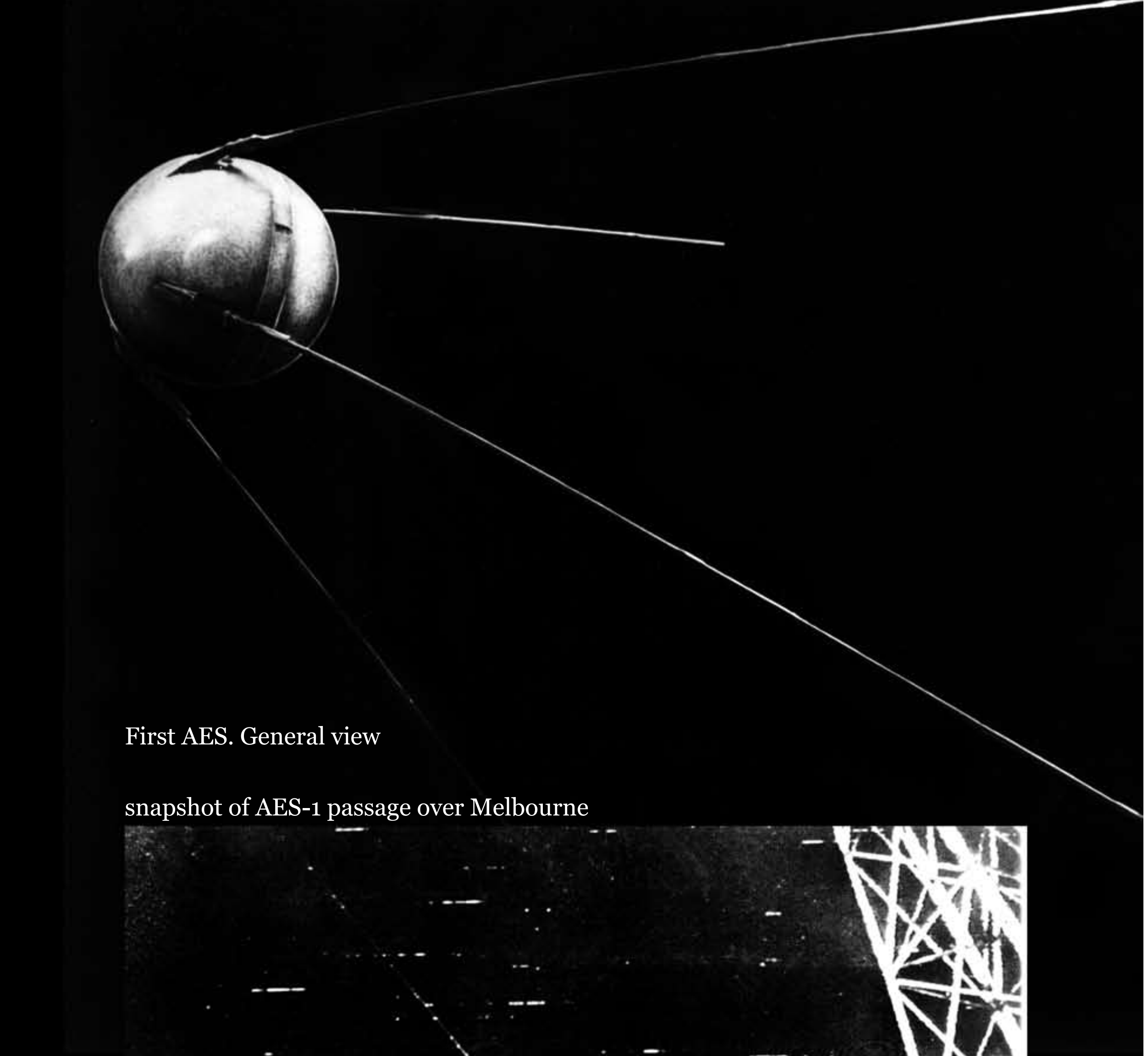
Without *Soyuz*, amazingly, the International Space Station would have been a space deserted place for more than 3 years as a consequence of the *Columbia* accident, and clearly today *Soyuz* ensures the safest and most accessible means to serve the ISS. Looking back to my favourite ESA program, I can certify that without *Soyuz*, which is not only reliable but also relatively cheap, the *Cluster* mission would have been abandoned after the failure of its first launch on board the maiden flight of *Ariane-5*. The so-successful *Mars Express* mission and its Venusian clone *Venus Express* would simply not have existed. Looking ahead, *Gaia*, *Bepi-Colombo* and *Solar Orbiter* would probably be in difficulty if they had to consider using a different launcher. The legacy of *Sputnik-1* is just immeasurable.

As far as I am personally concerned I must say that I am very lucky to have been a witness of the success of *Sputnik-1* and in the wake of this success to be able to devote my life to space and to have been — among many others — an actor of this incredible adventure which started on October 4, 1957 at 10:28:34 p.m. Moscow time, when the 20 engines of the R-7 ignited, lifting *Sputnik-1* off the launch pad, to disappear a few minutes later towards the northeast into the night sky. Let me express my admiration and my gratitude to all those who have created my dream and made it come through.



R-7 rocket in the mounting and test facility. Baikonur

Chief Designers:
A.F. Bogomolov,
M.S. Ryazansky,
N.A. Pilyugin,
S.P. Korolev,
V.P. Glushko,
V.P. Barmin,
V.I. Kuznetsov



First AES. General view

snapshot of AES-1 passage over Melbourne

Alla MASEVICH
RUSSIA

Doctor of Science. Professor. Specialist in the field of space geodesy, space geodynamics and geophysics, optical monitoring of artificial Earth satellites.

Born in Tbilisi in 1918.

Graduated from the Liebknecht Pedagogical Institute in Moscow in 1941. Senior scientist in the Sternberg Astronomical Institute, Lomonosov Moscow State University, in 1945–1957. Deputy Chairman in the Astronomy Council in Academy of Sciences of the USSR in 1952–1987. Deputy Secretary General of the UN committee on preparing the 2nd United Nations Conference on the Exploration and Peaceful Uses of Outer Space (New-York, 1981–1982).

Chief Research Fellow in the Astronomy Council (currently Institute of Astronomy Russian Academy of Sciences) in 1987–2003.

Awarded by the USSR State Award (1975), the Red Banner of Labour (1975), the Sign of Honour (1961), International Prize in astronautics (1963). Honored worker of science of the RSFSR, Full member of International Academy of Astronautics. Fellow of the Royal Astronomical Society (Great Britain).

FIRST SPUTNIK, EARLY YEARS OF OBSERVING ARTIFICIAL EARTH SATELLITES, EARLY RESULT

RECOGNITION

Academician L.I. Sedov, L.V. Kurnosova, me and the officer of the Foreign Department of the USSR Academy of Sciences were the delegation that flew to Paris on October 3, 1957. We were supposed to get our Spanish visas to fly to Barcelona to attend the Assembly of International Astronautical Federation (IAF), as the USSR had no diplomatic relations with Spain at that time. The Soviet embassy responded to our Spanish visas request that they could arrange them in two weeks time only. However, the assembly opened on October 4, and we had no other option but to go to the Spanish embassy ourselves. L.I. Sedov and I went directly to the ambassador. We gave our business cards and were immediately admitted by the Ambassador. We apologized for bothering him and explained the issue. The Ambassador was very kind, inquired about our specializations, asked what Astronautical Federation was — he was confused by the term ‘astronautics’. He was pleased with our explanations and arranged the visas to be issued immediately. We checked in a small hotel by the Northern Terminal, found out when we should arrive at the airport to board our flight to Barcelona, and peacefully fell asleep. At five in the morning the owner of the hotel woke me up and told me that BBC has just reported that the USSR launched the first artificial Earth satellite. He was concerned if this event posed any threat to humanity. I reassured him that there was no threat at all. Then I woke up my colleagues and we called our embassy to confirm the news. It turned out no one at the embassy was aware of it. All the visitors staying at the hotel kept asking us about the 'Russian Wonder' throughout the breakfast. Of course, we were informed at home about the expected launch of the first satellite those days, but no date was given. And here it had just happened. The first ever artificial Earth satellite, *Sputnik*, was successfully launched in our country. We were getting ready for our flight to Barcelona in elated spirits. Apparently, we were too excited and stayed longer, so we had to call a taxi (our embassy refused to give us a car).

It took us too long to change our Aeroflot tickets for Air France and finally we were late for our flight. When we, totally lost, returned to the hall, the newsvendors were selling extras with 'SPUTNIK' headlines across in large font. It was the first time when this Russian word turned international. An airport officer approached us and asked if we were the Russians that missed the flight. When we confirmed this, he said that the plane was turned back for us only ('You have such a great day today — the Sputnik!') and took us across the runway in his jeep to where our plane was landing. The ramp was lowered, and we found ourselves in the cabin where everyone was in slight panic. The passengers were puzzled why their plane returned to Paris after only a 20 minute flight and who these new passengers were. 'Don't you understand? — our escort said — these are Russians, they launched the Earth satellite today!' We had our first press-conference during the flight — everyone wanted to know all about the First Sputnik.

A crowd of reporters and representatives of the Spanish Astronautical Society were already expecting us in Barcelona. There were a lot of questions, but most of all everyone wondered about the weight of Sputnik, eighty something kilos seemed unbelievable. The thing is, all the publications on future satellites at that time discussed American projects only, which featured really small units that weighed about a kilo. The French named these manmade satellites 'oranges'. We were often asked if there might be a mistake in TASS message, and the real weight should be 0.8 kg.

The program of the assembly had to be totally redesigned. Almost every report discussed the options to launch Earth satellites. Many participants withdrew their reports and went together to the local radio station to listen to the signals broadcasted by the *Sputnik-1*. We were offered congratulations, people wondered how Soviet scientists managed to surprise the world without any previous messages or discussions. No one even 'noticed' that academician Bardin, the Russian representative in the steering committee for the International Geophysical Year, reported that the USSR is preparing to launch a satellite (which was recorded in the minutes), and academician A.A. Mikhaylov in his article published in Soviet Astronomical Journal even reported the orbital inclination of the satellite about 56°. Most likely, no one ever believed the USSR could manage such a great task. Everyone was impressed by the weight of our satellite which now seems insignificant compared to the weight of modern satellites reaching tones.

Some delegates of the assembly avoided us, if not to say were hostile. Whereas some US participants made no secret of their disappointment as they, as well as the whole world, had been certain that the first artificial Earth satellite would be launched in the US. The founder and the chairman of the Astronautical Federation was the world known scientist Theodore von Karman, originally Hungarian. He had long lived and worked in the US and was the chief theory analyst and government consultant on space exploration. Of course, our Sputnik was a major disappointment for him. He tried to conceal this, offered his warm congratulations on this great success in his opening speech and at side meetings. However, once he got loose all of a sudden.

At the reception of the Federation, von Karman seated L.I. Sedov and me at the head of the table on either side of himself. At some point someone jokingly congratulated the American delegate on loosing the space exploration race. Suddenly von Karman exploded and started saying in loud voice that USSR could not have made this achievement, this whole business is too doubtful, he knows this country well enough, there is no order there, and nothing is done on time. I tried to calm him down but it only made the matter worse. He started telling how he lived in Russia and could not get back to Hungary, and how he finally managed to do that pretending to be a doctor in a Hungarian delegation that arrived in Moscow for talks. He told: 'They can not do anything properly, never do anything in time'. People seating at other tables started turning their heads towards us. He was telling that addressing me and never gave me a chance to put in a word. No one even cared to help me out. Sedov did not speak English, so he did not understand what von Karman was saying and just sat and smiled. The others, men mostly, were watching the whole show with apparent interest. An English delegate sitting with me on the other side also preferred to stand back. Von Karman went on, but I was sorry to see this distinguished elderly man in such a state and did not want the whole matter end up with a major scandal. I waited till his next accusation that Russians are not able to do anything time and said in a pretty loud voice, that we still managed to launch the Sputnik just on time, right before the Assembly. Every one at the table laughed and applauded, and that finished von Karman. His face fell, he finished another glass, then he was taken home, and everybody started thanking me for finishing the matter without a scandal. 'It was too much fun watching you manage the situation', — told me the Head of the US delegation.

The next day, opening the session, von Karman apologized to me and to the whole Soviet delegation in public and gave me a ceremonial present — a 'Sputnik' hat, which he ordered urgently in London (a deep red velvet hemispheric hat with four antennas). This concluded this incident, but von Karman thanked me a few times afterwards for my patience and for hushing up his inappropriate behavior.

Our whole Barcelona trip was a total celebration. People would recognize us in the street and congratulate us. L.I. Sedov and I appeared on television, L.V. Kurnosova made a radio appearance. All Spanish papers wrote about us. One famous toreador said he would kill the next bull to honor the first satellite and our delegation. We were invited to watch this corrida, got the seats right underneath the government box, where Franco sat with his wife. Our papers had written a lot about his crimes during the Spanish civil war and I expected to see a monster. What we saw was an elderly, plump and tired man in the box, what, however, did not prevent him from reacting excitedly to what was happening on the field. The corrida was very long, six bulls ceased to come out falling victims to the art of three toreadors. 'Our' toreador, coming out on the field, waved his hat to us and heroically killed the bull. It was very hard to watch the bullfighting being new to the show. However, the audience was shouting in excitement, noisily approving or disapproving of what the toreador did on the field.

It was fun to watch how Spaniards totally disregarded the track of time. No event started in time. Only foreign scientists showed up for the Mayor's reception in time, the Spanish turned up an hour late, and the Mayor himself showed up another hour late, which was absolutely normal. We decided to keep this in mind for the final reception and came an hour late, and we still were the first. At the reception, we were presented a huge cake with a chocolate rocket that had a small ball with four antennas on its cone. The Spanish who were evacuated to USSR during the war came to visit us in our hotel. They asked about Moscow a lot, and were particularly interested if Luzhniki stadium has been completed, because they took part in preparations for the future construction. The Director of the lace factory invited us to take a look at their products. The female participants of the delegation each received a beautiful and elegant lace mantle as a gift. The Spanish department of the Astronautical Federation ceremonially presented 'Lunar Passports' to us. This was a beautiful document, which said that its owner is entitled for a priority seat on the first passenger flight to the Moon, and it also asked the Moon dwellers to pay every respect to the holder of this document.

After our two day stay in Madrid, we went home via Paris with a connection for the Aeroflot flight to Moscow. A surprise has been waiting for us in Paris. The Soviet ambassador and his escort were meeting our delegation at the airport. It turned out, that President de Gaulle's wife asked him if she could meet the delegation of the scientists that were on a visit to Spain. She read about them in the papers and wanted to get first hand news about the Sputnik and space exploration potential. That's when the embassy remembered the delegation that they initially ignored. They called Moscow, learned about our whereabouts, extended our visas and stay in Paris by four days and now were meeting us with honors. A large party was organized at the Soviet embassy and we were the 'main treat' there. The French President's wife asked a lot of questions, she was very sorry de Gaulle himself could not come because of his sickness, but promised to tell him everything in details. Other guests did not leave us either, so the party was a big success. The Ambassador was very happy and thanked us. So, our trip came to end on a high note. And all thanks to the *Sputnik-1*.

Several years later, in 1961, Von Karman founded an International Astronautical Academy within the Astronautical Federation and became its first president. He recommended in 1962 that several scientists from the space exploring countries should be included in the first staff of the Academy. L.I. Sedov and I were the first representatives of the USSR in the Academy. The Astronautical Academy is at present a recognized institution, it sponsors several interesting activities and has a lot of Academicians and Corresponding members elected based on the organization Charter.

AFTER THE LAUNCH OF SPUTNIK: ITS FIRST OBSERVATIONS AND FIRST SCIENTIFIC RESULTS

After the USSR successfully launched the First artificial Earth satellite (AES) on October 4, 1957, the primary importance was given to organizing and supporting observations of the manmade space objects. The Astronomical Council of the USSR Academy of Sciences (Astrosoviet) was responsible for organizing a system of optical observation stations to observe the first and future satellites. Astrosoviet started working on organizing the system of the ground stations early in 1957 before the satellite was even launched.

First, the visual observation stations of the *Sputnik-1* were organized at Physics and Mathematics faculties of State Universities and Teacher Training Institutes of Russia as well as Astronomy Observatories of the Academy of Sciences of the USSR and academies of Soviet republics. The students were involved as observers, and teachers and research officers were becoming Leads of these stations.

We did not know precisely how fast the orbit of the first AES would change at the first stages, with the orbit within the upper atmosphere, how bright would be the object and other issues. It was not clear which tools would be the best to use in observations, how many stations were required, what was the best method to train the observation specialists, etc.

It was clear that no regular procedures of the astronomical observations or existing telescopes were good for that, and we had to design and use different type of equipment and develop different observation procedures. Since we had no time to design special tracking cameras, we made a decision to start with visual observations. For that purpose one of the industrial enterprises in Moscow region manufactured small astronomic telescopes (AT-1 tubes) with a 50 mm lens, 6-power magnifying properties and quite considerable field of view of 11°, so that the observer was able to track the satellite against the stars for at least a few seconds.

All Station Heads took special training in summer 1957 at the training course set up at the Ashgabat astrophysical observatory. The trainers were Astrosoviet and Ashgabat observatory officers, who had an extensive experience observing stars, planets and meteors, but who never before (just like the rest of the world) had to deal with the AES. There was a lot of unknown at that time, and the students together with the trainers tried to meticulously define the conditions of observing the satellite at least partially, in order to observe it with the maximum efficiency in real time. The following 'imitation' was a big success. One of the participants would take a long pole with a lantern attached to the end. He would climb the mountain and start walking fast trying to keep the lantern steady. People down in the observatory garden tracked the bright moving light against the star sky and tried to determine its location with binoculars or small astronomic 'sputnik' tubes, specifically designed for this purpose. Later, when the observers were trained at the stations, more advance training sessions were developed. Planes with special light sources would fly over the stations, thus creating a closer imitation of an AES.

A.M. Lozinsky was one of the organizers and teachers of the course. He spend much effort to organize the Zvenigorod experimental station of the Astrosoviet, designed specifically for artificial satellites observations (now The Zvenigorod Observatory of the Institute of Astronomy, Russian Academy of Sciences). For many years A.M. Lozinsky headed the station, where he supervised experimental observations of artificial Earth satellites and modifications of the equipment.

The station received a range of new instruments and aids in 1958–1966, including printing chronographs, break-circuit chronometers, and shortwave radios, zenith tubes TZK, and BMT tubes with 110 mm lens, 20-power magnification and 5° field of view. This allowed to have more precise and accurate time tracking of the observations, as well as determine the location of weak satellites in horizon system of coordinates.

In the year 1958, a special station network was set up in a number of countries in the Northern and Southern hemispheres as part of the International Geophysical Year program. There was a massive observational support based on the method that did not require any extensive processing, and the data was sent to special computing centers in an hour after the observation was made. These centers used the data to verify the orbit.

By the time the *Sputnik-1* was launched there were about 70 observation stations available around the Soviet Union: from the northernmost station in Archangelsk to the southernmost in Yerevan, from the westernmost in Kaliningrad to the easternmost in Vladivostok. There were about 100 stations operating in the US, 59 in Japan, 24 in China, 18 in the Netherlands, 13 in Czechoslovakia, 10 in Poland and 8 in DDR.

The observations of the Soviet satellites were delivered to the Astronomical Council of the Academy of Sciences of the USSR on regular basis from 33 countries on all continents. First foreign observations of the *Sputnik-1* and its rocket were sent to the Astrosoviet in early October, 1957 from the Royal Astronomical Observatory in Edinburgh (Scotland) and school observatory in Rodevisch (DDR). The computing center in the USSR received over 900 000 observations of over 500 Soviet and American satellites and their rockets for the first 10 years of the observations. 400 000 of these observations were received from abroad. Many high quality observation results we received from Bulgarian, Finnish, Polish, Dutch and Italian observation stations.

The next step in developing optical observations of the AES was the photography of an illuminated flying object against the star sky. The photo image of the satellite track made with a telescope could be measured to better precision than it would be done with the visual observation method. However, the astronomical telescopes, as a rule, are very 'awkward' units, designed to observe celestial bodies moving at extremely low visible velocities. The photography of satellites required manufacturing of special cameras and the modification of existing telescopes.

The coordination of the activities to develop new photographic cameras, train new observers, and improve the observation methods were again given to the Zvenigorod Experimental Station of the Astrosoviet. The most efficient camera used at both the Soviet and foreign observation stations was the camera AFU-75 designed by Latvian engineers.

Apart from the station in Zvenigorod for observational purposes, the efforts were made to set up in Astrosoviet a sector of optical observations of AES to manage the routine organizational issues. In less than a year since the foundation, the sector started to publish two periodicals. This was, to begin with, *The Bulletin of Stations for Optical Observation of Artificial Earth Satellites* (which was later changed to more appropriate *Observation of Artificial Earth Satellites*), which featured the observers discussing the potential improvement of the tools and the precision of the observations, etc. Special issues of the bulletin published the results of satellite observations as a part of joint international efforts (first sponsored by the Multilateral Cooperation Committee founded by Academies of sciences of the participant countries, and from 1968 on — as a part of section No. 6 of the 'Space physics' working group in the *Interkosmos* program). Additionally, another bulletin *Observations of the Artificial Earth Satellites* featured visual observation (and later it also included photo imagery) inputs on satellite observation. This is a unique archive featured materials on orbital estimates for artifical satellites to be later used in scientific research.

As soon as the sector for optical observation of the AES was established, the Astrosoviet started to become a scientific institution, which later evolved into a modern scientific research Institute.

By 1962, five years after the *Sputnik-1* was launched, we accumulated a massive bulk of visual optical observations of low orbit satellites. This allowed setting and reaching very unique (and often absolutely pioneering) goals, the ones we would not even dream of before. The ideas to have synchronized photo observation of the cylinder-satellite *Echo-1* for space geodesy purpose was voiced by D.E. Schegolev in the Pulkovo observatory simultaneously with the idea of quasi-synchronous (basic) visual observations of low-orbit satellites to search for short-term variations in density of the upper atmosphere (Hungarian astronomers M. Ill in Baya Observatory and I. Almar in Konkoli Observatory in Budapest). M. Ill and I. Almar proposed a program *Interobs* which allowed to use geometrical methods to estimate the coordinates of the low-orbit satellite with good accuracy, and then determine the satellite period around the Earth within 1-2 days timeframe. This opened an opportunity to research the link between short-term variations in atmospheric density and Solar and geomagnetic variations. The *Interobs* program observations were also performed in the optical observations sector of the Astrosoviet in 1965–1966 for the satellite launched in 1960 and which later revolved around the Earth at 450 km altitude. The first solid link between the variations of satellite period and variations of the geomagnetic index Kp was first established on 20–29th of August, 1963. This was an absolutely new result that we and M. Ill in Hungary received simultaneously.

AROUND THE WORLD IN 1,5 HOUR

I.D. Zhongolovich (Institute of Theoretical Astronomy, USSR Academy of Sciences) proposed the Big Chord program that became the most interesting and significant program in space survey and performed as a part of the *Interkosmos* cooperation plan.

Decades later, in late 1970's and in 1980's, the accuracy of satellite orbit estimates increased dramatically, and basic observations were no longer required. At this stage early processing methods would seem simplistic and program results would not be representative. However, one should keep in mind, that these were the first successful efforts to use visual observations of the first Earth satellites to explore the area that was a blank spot before the satellites were launched in space.

One may call the observation of the booster rocket that launched satellite Kosmos-53 in 1965 as pioneering. V.M. Grigorevsky (Chisinau station, artifical satellites observation program) led the *Spin* program, which was a system of joint photometric observations at a network of observation stations. The officers of the optical observation sector in Astrosoviet processed and interpreted the inputs. The research of spin and rotation periods of the rocket revealed a good solid link to the variations of solar and geomagnetic indices. This was an absolutely new result at that time, which paved the path to using powerful photometry methods in satellites observation.

These methods, as well as later methods based on the use of laser rangers, radio units, advanced optical receivers, etc. became the basis of the modern technology in observing artifical satellites of the Earth.

Jacques BLAMONT
FRANCE

Professor Emeritus at the University of Paris VI. Adviser to the President from CNES (Centre National d'Etudes spatiales, National Center for Space Studies), the French Space Agency.

Born in Paris in 1926. Received his D.Sc. from the University of Paris.

From 1957 to 1996 he was Professor at the University of Paris VI. After having been in charge of the French sounding rockets, he became scientific and technical Director of CNES. He has participated to nearly all planetary missions (both American and Soviet) from 1972 to 2000 as a Principal Investigator for various experiments.

FROM SPUTNIK–1 TO WHERE?

In the summer of 1955, the Press Secretary of President Dwight Eisenhower announced that the United States would launch six to twelve satellites during the International Geophysical Year (IGY). That speech was followed two days later by the declaration of two Soviet academicians L. Sedov and K. Ogorodnikov in Copenhagen, that the Soviet Union would also launch a satellite. The existence of both programmes was therefore well known.

During September of the following year 1956, a general assembly of the scientists involved in the IGY met in Barcelona. My research, conducted in the small group led by Alfred Kastler which revolutionized physics by conceiving and developing optical pumping, had nothing to do with rocketry. However, since I was miserably underpaid by the National Centre for Scientific Research (CNRS), I had been working at night to prepare an UNESCO exhibit presenting the IGY. UNESCO sent me to Barcelona to eventually meet people involved in the space part of this international enterprise due to start on July 1, 1957. I heard there a repeat by Soviet delegates of the Sedov-Ogorodnikov announcement, and the imminent launch of satellites by both superpowers was greeted by the hundreds of present scientists with a complete confidence in the success of a venture unanimously considered as of minor importance. I sat near the dominant figurehead of the French astronomy, who told me: '*Their satellites, they will not even see them!*' A room had been reserved for members interested in rockets and satellites, and the attendants found themselves to be only three, including myself. Was also present a young French engineer I was to work with much later on, and Hower Newell, who had published in 1953 a book I still own: '*High Altitude Rocket Research*', and was to become later Chief Scientist of the still to be born NASA.

From *Herblock's Special for Today* (Simon and Schuster, 1958). Originally appeared in the *Washington Post*, November 21, 1957.

In the following January, having left Paris for a research fellowship at the University of Wisconsin, I devoted my first two days in America to a trip to Washington in order to finish my work on the UNESCO exhibit. Hower had been kind enough to arrange a visit to the Naval Research Laboratory, where I met John Hagen, Director of the *Vanguard* project, and I was able to admire my first satellite, a small thing devoted to the study of the Earth's magnetic field, presented to me by Jim Heppner, the scientist in charge; this spacecraft must have been a victim of the *Vanguard* failure.

During the year 1957, the scientific community was well aware of the imminent attempts by both the superpowers to place small capsules in orbit, and did not mark any particular exaltation on the potential of this idea, even any real interest. As a matter of fact, at this IGY meeting, all leaders had expressed some kind of antipathy for the coming venture, and nobody mentioned any possible applications outside telecommunications.

On October 4, 1957, I was on board the steamer *United States* between New York and Le Havre, returning to France after having been elected in absentia to a chair at the University of Paris. Maybe there was some announcement posted on the ship's news bulletin board, but I do not remember any effect on the passengers, and certainly not on me. *Sputnik-1* was certainly no surprise for scientists. The media created the event, and very soon a completely new theme appeared, the notion of a race between the Soviet Union and the United States, bolstered by the trumpeting propaganda of Moscow, glorifying the triumph of the communist system in the style of Nikita S. Kruchshchev's famous challenge '*We will bury you!*' The West held the imaginary view that the Soviet Union had cunningly kept secret the existence of an enormous programme of ballistic missiles in order to attack the capitalist world, and that its first aim was to conquer the orbital space. Nobody inside or outside the scientific community understood the nature and the magnitude of the event. At the beginning, the American man-in-the-street felt irritated by the internecine fights of the various military Agencies (Army versus Navy), which had caused delays in the programme, as is illustrated by a drawing published on November 21, 1957, in the *Washington Post* and which I remember having enjoyed at that time.

My explanation of the hysteria which engulfed the public opinion, to culminate in the invention of the 'missile gap' myth used by the Democrats to win the 1960 presidential elections, resides in what I have called the '*Wright Brothers syndrome*': any American citizen believes that aviation was invented ex-nihilo by the Wright Brothers, and therefore for him the airspace is American territory and heritage. By extension, orbital space should also be an American property, and intrusion in this sacred domain by any other nation was considered as revolting. The spectacular and most admired achievements of the Soviet program, due essentially to the high performances of the Korolev's launchers, exacerbated this frustration, which reached its acme with the Gagarin's flight. The exact coincidence in time of this major event, with the fiasco of the Bay of Pigs, led President John F. Kennedy to decide the American drive towards the Moon. Space and specially Man-in-Space had entered forever in the image of his country that the American citizen harbours deep inside his heart. By the way, this is not the case for Russia, which possesses a legitime claim on Space: the identification of the soviet space successes with the regime has led very early to a disaffection of the population for science which has showed forcefully since the disappearance of the Union.

During the immediate post-Sputnik period, some smaller countries also felt frustrated in front of the grandiose applications of the sciences and techniques they had in earlier times contributed so much to elaborate and perfect. Everybody was convinced that the access to orbit was so difficult and costly that it was reserved forever to the two superpowers. But there was one ruler in the world who perceived that it was not that hard, and listened to a group of ambitious young men convinced that they could do it if given a reasonable support. That ruler was Charles de Gaulle and in 1961, he decided the creation of a French Space Agency and the development of a national satellite launcher, which was successfully tested in 1965, making France not the contender of the major powers, but the first of the average-sized nations to launch satellites, and by consequence the leader of European space activities.

Before General de Gaulle moved in this direction, we poor European scientists, were trying to catch the train. Certainly *Sputnik-1* changed my life. The heads of French science had altered their mind and wanted action. As soon as I arrived in Paris on October 9, 1957, I was given the task to conceive and direct the scientific use of the sounding rocket *Veronique*, developed in France for the IGY and never tested before. It was launched successfully in March 1959. I had become a space expert when, in January 1960, at the first COSPAR Assembly in Nice, I approached the Soviet Vice-President, the general and Academician Anatoly A. Blagonravov, to whom I suggested a French participation to the Soviet programme (some nerve, we had nothing to offer!). To my surprise, he declared a few days later in an interview given to the influential daily *Le Monde:* '*Foreign scientists and particularly the French, can propose to the Academy, the study of a science programme. It could become a form of possible cooperation: our Academy would very likely respond positively to these offers*'. These words were not followed by any concrete step, and since a similar proposal had been made by NASA in March, 1959, we negotiated an agreement for the launch of the first French satellite by NASA.

However, the idea went through the Soviet system, a formal offer was made in 1964 and the diplomatic machine started to move: a delegation led by Sedov visited us in October, 1965 and proposed to launch a French satellite. Andrei Gromyko deposed in the hands of the French ambassador in March, 1966, the draft of a protocol to be signed the following June by de Gaulle during his planned trip to the Soviet Union. A small delegation I was a member of, as the scientific and technical director of our Space Agency, was sent to Moscow (19–24 April, 1966) in order to finalize the agreement. In the most friendly atmosphere, the discussions were led by the 'Glavny Teoretik' Mstislav V. Keldysh, President of the Soviet Academy of Sciences and of the State Committee for Space.

With emotion, I remember the lunch offered to our Soviet hosts by the French ambassador. After the coffee, Keldysh took my arm and expressed in perfect French his desire to involve us not only in the exploration of the Moon, but also in the study of the life on Mars. As I have written in one of my books, the portrait of Peter the Great, given by the tsar himself, one of the few relics of our Representation in St.-Petersburg, in front of which I listened enthralled these confidences, reminded me that in this country which I visited for the first time, tradition dictates to force Nature. It is difficult to relive today the sensation of exotic which filled us in full 'cold war' as we discovered this immense, unknown and mysterious Soviet Union crowned by its successes in space.

If I had been impressed by my conversation with Keldysh, it is because I had the ambition to introduce France into the exploration of planets, the nec-plus-ultra of the space adventure. It will happen only once. The country of the d'Alembert, Lagrange, Laplace, Fourrier, Le Verrier, Poincaré could not, should not stay motionless as the most beautiful consequences of their ideas and would majestuously unroll through the solar system. The collaboration with the Soviet Academy would introduce us into the major endeavour of the century, associated with them as the Germans were helping the Americans to the conquest of the Moon and beyond. This is why, one year later, I placed in the hands of Keldysh passing through Paris in November, 1967, a proposal for the launch of a flotilla of small aerostats in the Venus atmosphere. Born in a dream, the idea was bringing to the planetary exploration not only the needed mobility, but also a touch of strangeness which added poetry to our technical preoccupations.

Unfortunately, the friendly ambitions cherished by Keldysh and myself at that time, did not come to fruition, essentially because of the lack of interest for space science displayed by the successive French governments. The Prime minister Pompidou sneered: '*The Moon, it would make all Paris laugh!*' Our participation to the lunar missions were cancelled. After many vicissitudes, my Venus balloons were incorporated in the Vega mission and developed by the Soviet scientists and engineers without French participation for a perfect flight in June, 1985 — eighteen years after the initial proposal!

No more than us, our Soviet friends were able to take advantage of our partnership. If we had succeeded in building a serious political basis for our cooperation, we could have helped in the development of the liquid hydrogen engines so sorely wanted in their lunar programme. The N1 and the *Energia-Buran* failures were caused by a lack of system engineering across multiple complex components, an organizational flaw that propagated during the whole Soviet era and was never fixed. If we had had open access to the Lavochkin Association, kept total out of contact with the outside world by the mania of secret, our mastering of space systems, demonstrated by the success of *Ariane* and of all the CNES missions, could have contributed to save *Mars-4* to *-7* in 1974 and *Phobos* in 1988: our cooperation can be considered as a succession of lost opportunities for both partners.

The evolution of space has not followed any of our predictions. Human spaceflight which for a long time, looked as the heart of the space activities, proved to be a dead end. The landing on the Moon shines as the obelisk of the century, followed by fifty years of abandon, a prowess without future. It became clear early that the manufacturing of materials in orbit could not become an economic reality. Astronauts are left with a bike to exercise and spend their time. Like *Buran*, like the NASA shuttle, the ISS has lacked a clear mission. Conceived as a laboratory with the unique facility of no-gravity, it has so far proved valuable only as a training field for international hand-shaking and an hotel for super-wealthy tourists (imagine what Lenin would have thought of it...), draining money and talent from useful investments.

What has proved to be the engine of history is not space as we believed in 1957, but the physics of solids which provides electronic components whose performances increase exponentially with a time constant of two years since 1962 without relenting, and should follow the same expansion in the next decades. In twenty or thirty years, minicomputers with the processing capacity of the human brain will become available: this is why I maintain that the exploration of space will be performed not by fleshy humans, but by minds made of silicon or carbon.

In our years, robotic spacecraft, not manned flights, have triggered a total revolution in all the sciences of the Universe. Astronomy, planetology, geology, geodesy, meteorology, oceanography... you name them, none of them look as what they were in 1957. For these matters, we had at that time, a vague glimpse of the potential of space. On the opposite, nobody figured out the stupendous scope and importance of space applications. Telecommunications and specially diffusion of television have changed the mind of all the men on Earth since they started in earnest around 1990, spreading Hollywood-mode culture down to the poorest. The 'Revolution in Military Affairs', responsible for the *blitzkrieg* success of the American forces in the recent conflicts, relies on space assets. In the very recent years, localization by GPS and dissemination of space images by networks like *Google Earth*, have entered the daily life and habits of hundred of millions people, and this is only the beginning. Add operational meteorology and, soon, disaster control and crisis management: space applications married with Internet are fast becoming the backbone of our civilization.

During the past half-century, the space club has grown from two to a dozen nations that have their own access to orbit. Military imperatives, commercial needs, the scientific lure of the heavens, but above all prestige and pride have shaped these efforts. Europe, spurred by France, has become a top player and is clearly the most advanced space power after the United States and Russia. India, inspired by my dear friend the late Vikram Sarabhai, has concentrated on using space assets to deliver services for the intellectual and economic development of the country. India, Japan and China dispose of a strong expertise in space and follow the path of the two superpowers of the 1960's by entering the man-in-space club, a prowess already achieved by China in 2003, but also a quagmire wisely avoided by Europe. Who would have said that Israel with only five million citizen, would become a space power as soon as 1988? Others nations like Iran are on the verge of space flight. The motivation of these nations is not different from that of the Soviet Union and the United States a half-century ago. Space flight and military power are the two sides of the same coin, whether it results in virtual or real capability: space, I have said, is the sceptre of the Prince.

Let us look in the crystal ball of the future, even if, with a time constant of two years, it has become very opaque. Under the major threats hanging on our heads, generated by the projected rise in population, the dangers of the increasing urbanization, the vanishing of natural resources as water and oil, the extinction of species, mankind is faced with the problem of its very survival, which could become acute during the coming century. Observations from space provide a surveillance of the environment of unique scope, precisions and wealth. For instance the monitoring of oceanic altitudes, the cartography of polar caps, the multispectral analysis of forests, deserts and cultivated terrains furnish data essential for the diagnostic of climate changes. No doubt that environmental studies from space platforms will receive a high priority

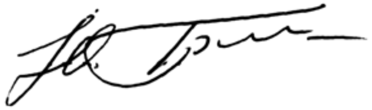
in all countries. Unfortunately, the assessment of a situation deteriorating towards disaster is not sufficient to reverse the course of events. The power to stop history does not reside in space. We will describe the dangers with more and more accuracy and will not be heard. And do not believe that leaving the Earth in spaceships is an option.

Yuri BATURIN
RUSSIA

Space pilot. Made two flights to the *Mir* orbital station in 1998 and to the International Space Station in 2001. Professor of the Moscow Institute of Physics and Technology, Department Chairman in the Moscow Engineering Physics Institute, Professor of the Lomonosov Moscow State University and the Diplomatic Academy (Ministry of Foreign Affairs of Russian Federation).

Born in 1949 in Moscow. Educated in the Moscow Institute of Physics and Technology, the Institute of Law, the Journalistic Department of MSU, high courses of the Military Academy of the General Staff and the Diplomatic Academy at the Ministry of Foreign Affairs of Russian Federation.

Worked in the S.P. Korolev RSC *Energia*. Former Assistant to President on national security and the Defence Council Secretary. Qualified cosmonaut-researcher in 1998, flight-test cosmonaut in 2001. Fellow of Gagarin Cosmonaut Training Center.



FIRST SPUTNIK: FROM RIVALRY TO HISTORIC GAIN

The launch of the First Artificial Earth Satellite had geopolitical importance. Originally geospace (habitation space on the Earth) was *piecemeal*, it was a world of distributed locations. Navigation made it more *holistic*. Aviation made it even more holistic. Communication systems added the final touch to it — geospace became closed. Stages of geospace formation can be measured very approximately, to an accuracy of centuries. As for transition of geospace to a new quality, it happened before our eyes in one moment. And we know the exact date. On October 4, *1957 geospace became unclosed.*

RULES OF THE GAME

I suggest we consider the process of unclosing geospace in terms of the mathematical theory of games. By definition, a game is a certain set of rules that describes the formal structure of a competitive situation. If the 'players' are states, then the rules that they have agreed upon are nothing else but international law. In brief, the level of competitiveness in a game is inversely related to the volume of rules (law). But what made the rivalry in the launch of the First satellite special was that the space game had started long before its rules were established. This is a unique situation for a game.

The strategies of the players were as follows:

- The USSR tried to win the game without any rules, to win the game using technologies;

- The USA also participated in the race of technologies but it decided to create its own rules that would ensure the victory.

I'll describe the situation in more detail.

More than fifty years ago, on March 28, 1955, the U.S. National Security Council recommended informing the President that it would be efficient and expedient to establish the principle of 'Freedom of Space': '...launching a small artificial satellite into an orbit about the Earth presents an early opportunity to establish an early precedent for distinguishing between 'national air' and 'international space', a distinction that could be to our advantage at some future date when we might employ larger satellites for intelligence purposes'.* The reason was simple: by accepting the policy that favored the legal regime of outer space which was similar to that established for high seas, the USA could establish a 'Freedom of Space' precedent — a precedent of US space crafts overflying the territories of different countries freely and legally. It is amazing that at the height of the 'cold war' such a powerful country as the United States was considering international legal grounds for its further political steps. It must also be said that in this respect the United States of fifty years ago was different from the United States of today, when the right of force dominates the force of law in foreign policy development and implementation.

On May 20, 1955 the US National Security Council approved a top-level policy document on US satellite program (NSC 5520). It stated in part:

'Re-examination should be made of the principles and practice of international law with regard to 'Freedom of Space' from the standpoint of recent advances in weapon technology...'**

Meanwhile the Soviet Union gave practically no consideration to any international legal aspects of space exploration: the first publication on the subject would appear in the USSR only in a couple of years. To be exact, the first ideas concerning future outer space law were voiced in the Soviet Union in the late 1920's – early 1930's, but those ideas can be regarded just as an anticipation of cosmonautics and its future legal problems voiced by the most insightful scientists. In 1926 V.A. Zarzar speaking at a meeting of the Air Law Board of the Aviakhim Union*** put forward a supposition that in future, there would be established an international regime for space flights at a specific altitude and it would replace state sovereignty over airspace. According to him, beyond the confines of the airspace of the Earth there becomes effective a special regime of spaceship flights, which is free from earthly jurisdiction.**** At a conference of lawyers specializing in air law, which was held in Leningrad in 1933, E.A. Korovin made a report '*Conquest of the Atmosphere and Air Law*' where he focused on the right of the state to take measures to defend its security irrespective of the altitude of flights over its territory. The report was published in a *French Journal on Interna-*

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* See: Exploring the Unknown. Selected Documents in the History of the U.S. Civil Space Program. V. II: External Relationships. John M. Logsdon, / Ed. Day D.A., Launius R.D. Washington D.C., NASA History Office, 1996 (hereinafter ExUn-II). P. 273.

** Quoted from: ExUn-II, P. 241.

*** Organization in support of Aviation and Chemical ('Khimia' – Chemistry) readiness.

**** See: *Зарзар В.А.* Международное публичное воздушное право // Вопросы воздуш. права: Сб. тр. секции воздуш. права Союза Авиахим. М.: Союз обществ дружбы авиац. и химич. обороны и промышленности, 1927. Т. 1. С. 90–103.

tional Law in 1934.* Basically it was the only doctrine hint at the official position the Soviet Union might take.

Thus we see that at the early stage of space race there were practically no norms of international law applicable to space exploration. However, the military and political competition reached a high point. Considering the fact that space race was gaining momentum, the situation became dangerous. One of the primary ways to reduce that danger was to start drafting international space law. It must be acknowledged that the USA was the first to understand it at governmental level.

THE SATELLITE PROBLEM

History shows that very often the political effect of cosmonautics achievements was of such significance for state leaders that it determined directions for space programs development. In fact, space policy was being formed as a follow-up to military policy, therefore it originally contained an 'ad extra – oriented' element. In other words, foreign space policy began to form since the initial steps of space exploration. Strictly speaking, it was space policy that gave an impetus to space exploration.

Space policy as an integral part of the general policy of the state began to evolve after World War II and the USA was pioneers in this respect. The administration of every US president as well as military agencies constantly drafted and revised guideline documents on exploration and use of outer space. It is worthy of note that as early as 1952 a special report was prepared for President Truman on the present status of the satellite problem. In fact, H. Truman discussed it in detail with Brigadier General Wallace Graham, who was Truman's personal scientific advisor and a physicist. Wallace Graham introduced Truman to Aristid Grosse, a chemist who had worked on the *Manhattan* Project. President Truman requested Grosse to conduct a deeper study of 'the satellite problem'. Major General Kenneth D. Nichols, former deputy for Lieutenant General Leslie R. Groves, who headed the *Manhattan* Project, arranged Grosse's meeting with space scientists, particularly Wernher von Braun. Grosse completed Truman's assignment. However it was to President Eisenhower that Grosse reported the results of the study on September 24, 1953.** As for the Soviet Union, it was only in 1954 that the satellite problem was submitted for top-level consideration and political decision-making.

As far as research is concerned, both countries were moving almost at the same pace.

In May 1945 Wernher von Braun, who had already arrived in the USA, prepared a report for the US Army discussing the possibility of creating an artificial Earth satellite (AES). In October the US Navy proposed its own satellite. On April 9, 1946 the issue was discussed at the Joint Army-Navy Aeronautical Board. However they did not come to any decision and decided to reconsider it a month later, on May 14. Major General Curtis LeMay, Director of USAF Research and Development, imme-

* See for further detail: Международное космическое право / Под ред. Г.П. Жукова и Ю.М. Колосова. М.: Международ. отношения, 1999. С. 18–19.

** The report was submitted through Donald Quarles, the new Assistant Secretary of Defense for R&D. See: Exploring the Unknown. Selected documents in the History of the U.S. Civil Space Program. V. I: Organizing for Exploration. John M. Logsdon / Ed. Lear L.J., Warren-Findley J., Williamson R.A., Day D.A. Washington D.C., NASA History Office, 1995 (Hereinafter — ExUn-I). P. 266–269.

diately decided to commission an independent study of the issue. Project RAND, set up as a division of the Douglas Aircraft Company, brainstormed the potential use of satellites for USAF for three weeks. On May 2, 1946, RAND released *The Preliminary Design of an Experimental World-Circling Spaceship** (Report No. SM-11827)** which described meteorological, reconnaissance and communication satellites. In April, 1951 RAND, the Rand Corporation at that time, released its next report *Utility of a Satellite Vehicle for Reconnaisance*.*** In September, 1954 Wernher von Braun formulated new proposals for a Minimum Unmanned Satellite Vehicle.**** Later the military selected that project as a potential candidate for the International Geophysical Year (IGY) Program but ultimately rejected it in favor of the *Vanguard* project. The *Vanguard* project started in March, 1955 and was developed by the US Navy. In August, 1955 it beat two other projects in a contest — the US Army *Orbiter* project and the USAF project.*****

Early in 1945 engineer-colonel M.K. Tikhonravov gathered a team of specialists (N.G. Chernishev, V.A. Shtokolov, P.I. Ivanov, V.N. Galkovsky, G.M. Moskalenko, A.F. Krutov and others) on the basis of the Rocket Research Institute which was established by M.N. Tukhachevskiy back in 1933. They were assigned to design a manned high altitude rocket (with a pressurized cabin for two pilots) based on a single-stage liquid-propellant rocket whose specifications would enable it to fly up to an altitude of 200 kilometers. By the middle of 1945 the team had designed a model of the high-altitude rocket (VR-190). On March 23, 1946 the project was submitted to M.V. Khrunichev, the then Minister for Aviation Industry, and on April 12 it was considered by the Ministerial Panel of Experts headed by Academician S.A. Khristianovich. The panel of experts gave a positive evaluation of the project and submitted its decision to one of Khrunichev's deputies for signing. However the deputy minister procrastinated. The delay was caused by red tape only. By that time there had already been drafted the USSR Council of Ministers' Decree *On Establishing a Special Committee on Rocketry under the Auspices of the USSR Council of Ministers* and it stated rocketry design among its priorities. Khrunichev's deputy just thought that the design of the rocket-propelled device would be considered at a higher level, by the Special Committee on Rocketry, which would do the decision-making. The Decree of the Council of Ministers of the USSR on *Questions of Rocket-propelled Weaponry* that mentioned the Special Committee was released on May 13, 1946.

Meanwhile the procrastination made M.K. Tikhonravov and N.G. Chernishev, who had been waiting for an answer too long, submit a memorandum on VR -190 project to Joseph Stalin. They stressed not only *the scientific* but also *the political* importance of the project. It must be stressed that the memorandum did not say a word about *military* applications of the rocket. (At that time Iosiph Stalin still held the office of the Minister for Defense and later the Minister for the Armed Forces along with the offices of the Chairman of the Government and the General Secretary of the Central Committee of the All-Russian Communist Party (Bolsheviks). It was only in March, 1947 that he handed the office of the Minister for the Armed Forces over to N.A. Bulganin.) Stalin entrusted M.V. Khrunichev with studying the project by

* Experimental World-Circling Spaceship.

** ExUn-I. P. 236–244.

*** Ibid. P. 245–261.

**** Ibid. P. 274–281.

***** See: *Караш Ю.* Тайны лунной гонки. СССР и США: сотрудничество в космосе. М.: ОЛМА-ПРЕСС Инвест, 2005. С. 33.

M.K. Tikhonravov and N.G. Chernishov. It did not take Khrunichev much time and effort to remember that document and find it in the maze of the ministerial red tape. The document was submitted for a second consideration: this time not only aviation industry specialists but also specialists from the Weaponry Ministry and the Ministry for Electrotechnical Industry studied it. On June 20, 1946, M.V. Khrunichev informed Stalin on the possibility of designing a manned space rocket, stressing that in the memorandum Tikhonravov and Chernishev had indicated a one-year term for developing the space vehicle, however upon the consideration of all the documents by the commission Tikhonravov and Chernishev indicated a two-year term. M.V. Khrunichev especially stressed that two years was a minimum term and it was very tough. To the letter M.V. Khrunichev attached the Draft Decree of the USSR Council of Ministers on the issue. Stalin however did not endorse M.V. Khrunichev's letter and the Decree was not adopted.

Proceeding from the 'rocket packet' idea, M.K. Tikhonravov made calculations and in 1948 he came to the conclusion that technically it was possible to launch an artificial Earth satellite into orbit on the basis of the existing technical achievements.* In July, 1949 the main documents for the 'rocket packet' were provided to S.P. Korolev. In March 1950 M.K. Tikhonravov made a public report in which he touched upon the prospects of creating an AES and a possibility of using it for a manned flight. On March 16, 1954 Korolev voiced the idea of creating an AES at a meeting organized by academician M.V. Keldysh. The latter received an approval of the proposal from A.N. Nesmeyanov, President of the Academy of Sciences of the USSR. On May 27, S.P. Korolev submitted a memorandum *On Artificial Earth Satellite* (prepared by M.K. Tikhonravov) to D.F. Ustinov, the then Minister of Defense. In August 1954 the Council of Ministers of the USSR approved the proposals on elaboration of spaceflight related scientific and theoretical problems.

The projects under elaboration represented a stage of the military rocket programs of the USSR and the USA, hence what made the launching of the artificial satellite particular was that being regarded as a military step, it could have complicated the already difficult relations between the USSR and the USA.**

President Eisenhower followed the advice of his consultants and made a decision to launch a scientific satellite as part of the US contribution to the International Geophysical Year (IGY) – an international effort of scientists from 67 countries that lasted from July 1, 1957, to December 31, 1958 and followed the resolution, that called for launching scientific Earth satellites during the IGY to support precision-mapping of the Earth. The resolution was adopted by the International Council of Scientific Unions in October, 1954.

A statement was written. It was endorsed by Congress and voiced by the spokesperson for the White House:

July 29, 1955

The White House

Statement by James C. Hagerty

On behalf of the President, I am now announcing that the President has approved plans by this country for going ahead with launching of small unmanned earth-circling satellites as

* See: 4 Центральный научно-исследовательский институт 1946–1996. Исторический очерк. М.: МО РФ, 1996. С. 18.

** See for further detail: *Батурин Ю.М.* Космическая дипломатия и международное право. Звездный городок, 2006.

part of the United States participation in the International Geophysical Year which takes place between July 1957 and December 1958. This program will for the first time in history enable scientists throughout the world to make sustained observations in the regions beyond the earth's atmosphere.

The President expressed personal gratification that the American program will provide scientists of all nations this important and unique opportunity for the advancement of science'.*

The statement did not contain a hint at other than scientific purposes of the program. But it was no coincidence that it was made just a few hours after an official statement on H-bomb stocks that had been created over the last six month as directed by Eisenhower.**

To avoid provoking an international debate over 'freedom of space', the Eisenhower administration leaders restrained government officials from any public discussions of spaceflight at that time.*** In the USSR any public discussions of the kind were forbidden for reasons of confidentiality.

In early August, 1955, M.V. Khrunichev, V.M. Ryabikov and S.P. Korolev sent a memorandum to N.S. Khrushchev, First Secretary of the Central Committee of the CPSU, and N.A. Bulganin, Chairman of the Council of Minister of the USSR, in connection with America's statement of its intentions to launch a satellite. On August 8, 1955 the Presidium of the Communist Party of the Soviet Union adopted a decision *On Designing an Artificial Earth Satellite*.

A SPACE ZERO SUM GAME

The USA more than once stated in numerous polls and surveys that it did not intend to lose and that it would not stand the USSR's leadership. Politicians voiced that predominant opinion. All the terminology of space race did not admit of any other interpretation of further development of events: the USA would be either ahead or behind, i.e. it would either be a winner or a loser. Such thinking is typical of a zero sum game, a situation in which a participant's gain or loss is exactly balanced by the losses or gains of the other participant(s).****

Academician B.V. Rauschenbach was one of the most prominent specialists in space industry. He was not a politician and called this process in a more lenient manner a process of 'sport and romance'. He wrote in his memoirs: 'The sportsmanship character of the process had two sides. Firstly, all of us who worked in the field of designing space vehicles experienced the emotions that are typical of all athletes — to be the first. The USA was doing something similar and none of us wanted to let our American counterparts be first. It was an absolutely genuine feeling of competition. Secondly, the results of the competition had political importance: in case of success, the leaders of the country could use the international prestige that it had gained and that's why their assistance was generous. Everything was new, it was being done for the first time, and that's what made it romantic. There had been no previous experi-

* ExUn-I. P. 200–201.

** See: *Karash Yu.* Op. cit. P. 15–16.

*** ExUn-I. P. 224.

**** According to the theory of Von Neumann and Morgenstern, any zero sum game has a solution. In other words the following theorem can be proved: 'There is a strategy that ensures the gain of Side A or there is a strategy that ensures the gain of Side B'. (*Saati T.S.* Matematicheskiye modeli konfliktnikh situatsiy. M.: Sovetskoe radio, 1977. P. 131.)

ence of the kind, and we considered ourselves explorers like Columbus, who set out to discover new lands'.*

Up until 1957 the USA had always been ahead: first in creation of the atomic A-bomb, later – in long-range bombers, then came the H-bomb.

And now it was all about a satellite. The USA did not doubt that it would be the first as usual; nevertheless the specialists closely monitored what the USSR was doing in that field.

On July 5, 1957, Allen W. Dulles, Director of Central Intelligence wrote a letter to Donald Quarels, Deputy Secretary of Defense, in which Allen W. Dulles gave his assessment of the reconnaissance data:

'...Information concerning the timing of the launching of the Soviet's first earth-orbiting satellite is sketchy, and our people here do not believe that the evidence is sufficient as yet for a probability statement on when the Soviets may launch their first satellite.

However, data has been recently received that Alexander Nesmeyanov, President of the Soviet Academy of Sciences, stated that, 'soon, literally in the next few months, the Earth will get its second satellite'. Other information, not so precise, indicates that the USSR is probably capable of launching a satellite in 1957, and may be making preparations to do so on IGY World Days... The U.S. community estimates that for prestige and psychological factors, the USSR would endeavor to be first in launching an Earth satellite... The Russians like to be dramatic and could well choose the birthday of Tsiolkovsky to accomplish such an operation, especially since this is the hundredth anniversary of his birthday...'**

The US was right in indicating one of the political and psychological factors — desire to be the first. On September 25, 1955, when the Moscow Bauman High of Technology (MVTU) celebrated its 125th anniversary, Sergey Korolev, an MVTU graduate, chief designer and Corresponding Member of the USSR Academy of Sciences said in his report at the anniversary session:

'Our goal is to ensure that Soviet rockets fly higher and earlier than anyone else's.

Our goal is to be the first in a manned spaceflight with a Soviet man onboard the rocket

Our goal is to ensure that the First Artificial Earth Satellite is made in the Soviet Union by the Soviet people.'***

There was nothing bad about it. Similar approaches also existed in the USA: Eisenhower's special adviser, N. Rockefeller, convinced him that it was inadmissible for the USA to lose in space race, the domineering form of relations between the two countries in space in those days. The policy of rivalry determined very much.

And on September 17, 1957, on the day of Tsiolkovskiy's 100th anniversary, the day that the U.S. reconnaissance indicated as a possible launch date for the first satellite, S.P. Korolev made a report in the House of Columns devoted to the famous scientist. He said one important thing: 'In the very near future the USSR and the USA will do the first test launches of artificial Earth satellites for scientific purposes.'**** He had known by that time that the Soviet satellite would be launched on October 6. But it so happened, that S.P. Korolev, without any concordance with Moscow top-level officials, shifted the launch to October 4 by his own authority right at Baikonur.* On that day the world learned that the Soviet Union had launched the First Artificial Earth Satellite, which ushered the Space Age.

* *Раушенбах Б.* Пристрастие. М.: АГРАФ, 1997. С. 376.

** ExUn-I. P. 329.

*** Cited from: *Королёва Н.* Отец: в 2 кн. Кн. 2. М.: Наука, 2002. С. 274–275.

**** Ibid. P. 282.

The Americans had almost made it to being the first in launching a satellite however for them the level of competition did not supersede the legal constraints that were to be first introduced. For example, the successful launch of the US two-stage rocket booster *Jupiter-C* on September 20, 1956 happened only after a Pentagon representative had done a thorough inspection for a possible third stage under the head fairing that could launch some payload into the orbit.** From the military and political perspective, such strict requirements and careful attention were justified, taking into account the tense international situation.

GEOSPACE UNCLOSING

The attitude in the White House was generally dismissive of the Sputnik launch for about 24 hours, before the public and scientific reaction of the country became known, stated General Andrew Goodpaster, Eisenhower's staff secretary.*** Then they remembered that Eisenhower had been warned plenty of times of the propaganda effects of such a satellite launch but had always dismissed them. 'The Memorandum of the Meeting with the President of October 8, 1957' prepared by Goodpaster said that, when the President asked about the possibility of a satellite launch he received a positive answer that 'it had been possible to do it a year before and even earlier. However the Consulting Committee on Science thought that creation of an AES must go separately from developments in the military sphere. One of the reasons was to emphasize the peaceful character of this program and the other was the strife to avoid the use of military rockets technologies to which foreign scientists could get access'.****

Eisenhower attempted to downplay the significance of *Sputnik*, but in vain. He also admonished his officials not to comment on the issue of whether the United States could have 'beaten' the Soviets into space. He wanted to avoid the interpretations of space exploration as a space race.*****

Henry Kissinger tried to play down the importance of the first satellite in *Diplomacy*. He writes: 'When the Soviets launched an artificial satellite — a *Sputnik* — into earth orbit on October 1957, Khrushchev interpreted it as a one-time achievement, as evidence that the Soviet Union was ahead of democratic countries in scientific and military respect. ...President Eisenhower was practically the only one who refused to share the panic. As a military man he understood the difference between a prototype and a military operations issue type.'******

Eisenhower understood the situation very well, but at that particular time he was most of all concerned about international legal aspects of the flight of the first artificial space craft. Sputnik was making one orbit after another over the territories of

* See: *Голованов Я.* Королёв. Факты и мифы. М.: Наука, 1994. С. 537–538.

** See: *Karash Yu.* Op. cit. P. 34.

*** ExUn-II. P. 245.

**** Cited from: *Karash Yu.* Op. cit. P. 94.

***** ExUn-II. P. 246.

****** *Kissinger H.* Diplomatiya. M., 1997. P. 514.

many countries. The USA closely followed the reaction of those countries. There was practically no reaction in the world in terms of diplomatic demarches or rallies of protest. Four days after the launch of the satellite Eisenhower decided to discuss that significant event with his team of advisers and top officials. 'The Russians have in fact done us a good turn, unintentionally, in establishing the concept of freedom of international space,' Deputy Secretary for Defense Quarles said. 'The President asked the group to look ahead five years, and asked about a reconnaissance vehicle. Secretary Quarles said the Air Force has a research program in this area and gave a general description of the project.'*

The political effect of Sputnik was much more important than it's scientific results. The launch evoked a worldwide response. The USSR's international prestige had immensely risen just overnight.

Establishing space game rules seems to be of even more importance and the credit for initiating these rules belongs to the USA. Therefore, launching the First Sputnik was a *common gain*.

The USA wanted to win the race, but what it won was that later the game was played according to its rules.

The USSR won the race in terms of technology but had to agree with the rules of the game.

The USSR and the USA began to play a non-zero-sum game and it was their common gain.

Humankind also gained a lot in having the rules of the game and a technological foothold established for followers.

This is how October 4, 1957 witnessed the transition from geopolicy in the space of the globe to the policy in the unclosed space of cosmos, which we can call *caelumpolitics***. Indeed, in the first decade the UNO and member-states of this reputable international organization were concerned about establishing the rules of the game for exploration of the Moon and other planets (the *Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies* came into effect in 1967). Then there was a long pause because space exploration turned out to be a longer and more challenging task than it was assumed in the times of the *Sputnik-1*.

Almost half a century has passed since that day. In 2004 US President George W. Bush announced new vision for space exploration which envisages returning Americans to the Moon, building an outpost on the Moon and sending an expedition to Mars. The USA, the only remaining superpower on the planet Earth, finds the limits of international relations too narrow.

In 2006 the USA adopted a new national space policy which already has all the features of caelumpolitics. The purpose of the document is to enable unhindered U.S. operations in and through space to protect U.S. interests. ('The USA preserves its

* Exploring the Unknown. Selected Documents in the History of the U.S. Civil Space Program. V. IV: Accessing Space. John M. Logsdon / Ed. Williamson R.A., Launius R.D., Acker R.J., Garber S.J., Friedman J.L. Washington D.C., NASA History Division Office of Policy and Plans, 1999. P. 52.

** From the Latin word *caelum* which means 'sky, heaven, all the space between the Earth and Celestial bodies'.

rights, capabilities and freedom of action in space. Freedom of action in space is as important to the United States as air power and sea power'). The US new space policy is characterized by the USA distancing itself from international law. The USA will not commit itself to any arms reduction treaties that will impede the development of systems designed to protect US national security interests. The Directive underlines the refusal of Washington to conduct any formal negotiations on arms control that may limit US access to or use of space.

Russia, China, Japan and India have also announced their plans to establish outposts on the Moon. The USA and Russia have manned missions to Mars on the agenda. A new space race has begun. The USA appears to begin it by establishing its own rules of the game once again. It augurs an absolutely new era for international relations. There has just been a regular succession of epochs: 'He who governs the World Island governs the world'; 'He who owns seas is the Master of the World'; 'He who has superiority in air space rules the world'. And finally, 'he who has control over space is the future Lord of the World'. In this respect we can already today say that the transition from geopolitical paradigm to *caelumpolitical* paradigm has happened, the transition that began on October 4, 1957, when the *Sputnik-1* was launched.

Vladlen VERESCHETIN
RUSSIA

Judge of the International Court of Justice of the UN in Hague, 1995–2006.

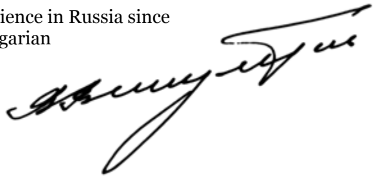
Born in 1932 in Bryansk.

Graduated from the Moscow State Institute of Foreign Affairs in 1954 (a diploma in international law, post-graduate diploma from the same institute in 1958).

First Deputy Chairman of *Interkosmos* Council of the Academy of Sciences of the USSR (1967–1990).

Vice-President of the International Institute of Space Law in 1977–1995, Director Emeritus since 1995.

Honoured worker of science in Russia since 1995. Fellow of the Bulgarian Academy of sciences. Member of the International Academy of Astronautics.



FOR THE BENEFIT AND IN THE INTERESTS OF ALL MANKIND

The launch of the first artificial Earth satellite was not only a revolutionary breakthrough in science and technology which brought our civilization on to a new level, but was an event that had a major impact on the understanding of close link between a human and humanity. I believe, the latter became already apparent in the first years of the space era and in particular in the way people around the world greeted the flight of Yuri Gagarin.

On the day of this flight I happened to be in Italy participating as a member of USSR Academy of Sciences delegation in a conference organized by the International Committee on Space Research (COSPAR). It's easy to imagine the feelings of the Soviet participants of the conference after we received the news of the first manned space flight. Of course, we were proud of the fact that this first man in space was our compatriot. But we also witnessed how genuinely excited this news made not only other participants of the 'space' conference, but also all the people we met.

I have it imprinted in my memory, as people of Florence, the city which hosted the conference, were virtually staking out the entrance to the hotel in which the Soviet delegation was staying, in order to talk to Yuri Gagarin's fellow countrymen to express their sympathy. Newspaper extras were published with huge photos of Yuri Gagarin on the front page. The local authorities arranged a meeting with the Soviet scientists in the magnificent Palazzo Vecchio — XIV century palace on the central square in Florence. The hall was packed and the people greeted each speech with standing ovations. As it is known this event was met the same way all around the world. No matter which country Yuri Gagarin later visited, people would greet him not as a dignified foreigner, but as a close and dear friend.

I believe, this common excitement evidenced that the space flights made all people closer, created the feeling of common link between them regardless of the state boundaries or any differences whatsoever. After the First Sputnik and opening of the manned space flights era, we started to perceive the planet Earth with it's environmental and other global problems as our common home the fortune of which is closely related to every human living on the planet. Certainly, the global thinking was also promoted by various types of space technology applications: space communications, meteorology, navigation, Earth remote investigation sensing — which had a significant impact on our lives.

Considering the impact of the First Sputnik on various aspects of social life, human activity and scientific disciplines, I, being a jurist, would like to mention, that a new field of law — international and national space law — has it's origins in the launch of the First Sputnik. Almost the next day after the launch of the Sputnik there was a discussion in the media if a state could make similar launches without prior consent of other states, keeping in mind that the airspace over the land and water territories of states are placed under their sovereignty regardless of the altitude. Fortunately, the fact that these kinds of issues were not settled did not become an obstacle for launching space crafts into the Earth orbit. One of the reasons for this was the immediate recognition of the common importance of space exploration for all mankind.

There is a great logic behind the fact that the basic document of the international space law — *Treaty on Principles Governing Activities of States in Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies*, 40 years of which we mark in 2007, starts with the solemn declaration, saying that the States Parties (they are over 100 of them now) to this Treaty concluded it, 'inspired by the great prospects opening up before mankind as a result of man's entry into outer space, recognizing the common interest of all mankind in the progress of the exploration and use of outer space for peaceful purposes, believing that the exploration and use of outer space should be carried on for the benefit of all peoples irrespective of the degree of their economic or scientific development…'

An array of International Agreements, first of all the aforementioned Space Treaty of 1967, secured a number of important provisions resulting from universal importance of space exploration: outer space was declared free for exploration and the use by all states; outer space, including the Moon and other celestial bodies, was not to be subject to national appropriation; a number of prohibitions and restrictions were introduced for certain military uses of outer space.

The global nature of space activities requires maximum international cooperation. The principle of cooperation and mutual assistance in space research and use featured among the fundamental principles of 1967 Space Treaty. However, the development of international space cooperation was not all roses, especially at the early stage. I had a chance to contribute to organizing and legally supporting the international space cooperation of our country at this challenging stage.

This was the time of open standoff and ideological struggle between two social and political systems, when in relations between the two leading space powers prevailed competition and rivalry rather than cooperation. The potential of dual use (both military and civilian) of the majority of the space vehicles and systems ensured, on the one hand, lavish state financing of these activities, but on the other hand, the military and political leadership of each state primarily addressed every major step in space activity from strategic and geopolitical point of view.

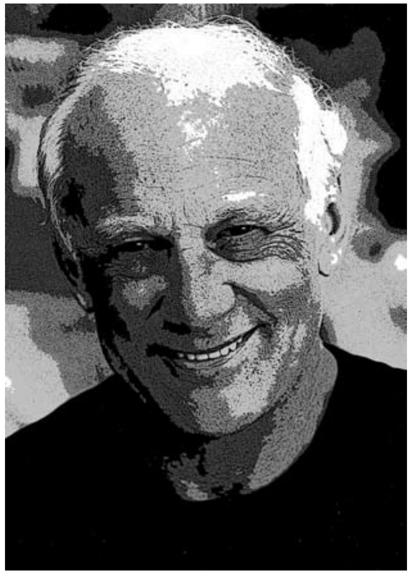
Besides, the cooperation carried a lot of ideological content, and it's scope depended on the state of political relations between the countries concerned. The military component of space activities also manifested itself in the fact that it added more barriers to international cooperation, connected with security considerations.

At the early stage, the space cooperation was mostly limited to sharing scientific results and coordinated optical observations of the satellites. Gradually, it extended to installing foreign and then jointly produced payloads on Soviet space crafts, and later to large scale joint scientific projects including a series of *Interkosmos* satellites, complex projects involving interplanetary probes and, finally docking and joint flight of Soviet and American space vehicles *Soyuz* and *Apollo* as well as a number of other international manned missions.

A lot of credit in promoting the cooperation goes to a number of Soviet and foreign scientific and industrial organizations and individuals. Among them honorable mentioning should be referred to the prominent Soviet scientists M.V. Keldysh, B.N. Petrov, V.A. Kotelnikov, R.Z. Sagdeyev, O.G. Gazenko, K.D. Bushuyev, G.N. Babakin, V.M. Kovtunenko. It is sad that neither S.P. Korolev, nor V.P. Glushko, nor a whole cohort of other distinguished space engineers and managers of space industry could personally cooperate with their foreign counterparts due to security reasons. They have contributed a lot to the development of space cooperation and certainly would like to have personally participated in it. Once I happened to be present during a discussion on this subject between M.V. Keldysh and S.P. Korolev.

At the present time, the scope of international cooperation in space increased tremendously. This is evidenced by numerous international agreements, efficient functioning of international space organizations and systems, building of international launching sites and the International Space Station. However, one should remember that the space component of the armed forces of some states also considerably increased. The modern armed forces largely depend on the presence and efficiency of their space assets. The major challenge is to prevent the new or recently resumed space military programs from resulting in violations of the well and universally established principles of space activities which may lead and leading to a space arms race. May the 'star wars' be confined to virtual world only.

AROUND THE WORLD IN 1,5 HOUR



Buzz Aldrin

USA

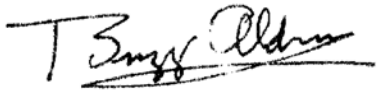
One of the early astronauts. Together with Neil Armstrong, on July 20, 1969, he made the historic *Apollo-11* moon walk. He has logged 4500 hours of flying time, 290 of which were in space, including 8 hours of extravehicular activities.

He was born in 1930 and graduated with honors from West Point in 1951. Later he earned a Doctorate in Astronautics from the MIT in Manned Space Rendezvous.

In 1993 Dr. Aldrin received a US patent for a permanent space station. More recently he founded his rocket design company, Starcraft Boosters, Inc., and the ShareSpace Foundation, a nonprofit devoted to space tourism.

The author of two space novels *The Return* (2000) and *Encounter with Tiber* (1996), his autobiography, *Return to Earth* (1973), children's book *Reaching for the Moon* (2005), and the bestseller historical documentary, *Men from Earth* (1989), describing his trip to the moon.

Awarded the Presidential Medal of Freedom.



THOUGHTS ON THE ANNIVERSARY OF SPUTNIK

While the launch of Sputnik may have stunned the world, it also galvanized it. An artificial satellite was orbiting planet Earth for the first time in human history: the Space Age had begun.

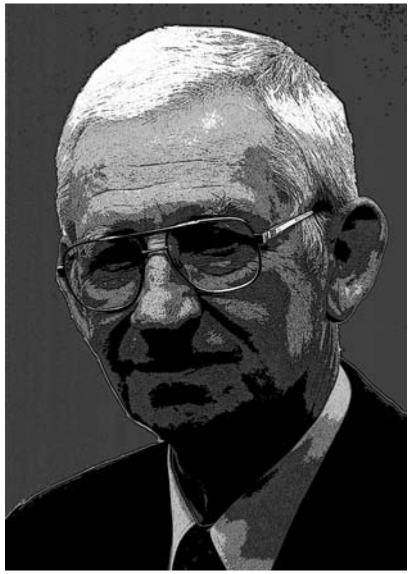
I was a pilot in the United States Air Force in 1957 and had already seen the rapid development of jets that could fly faster, farther and higher during my career. The Americans had also been working to develop their own space program, but the Soviets achieved the first successful launch of a satellite. Sputnik spurred the US to switch into an even higher gear. Now, space travel was a fact rather than a dream, and I wanted to be a part of it.

In 1959 I left my nuclear delivery fighter squadron in Germany to enroll in a USAF astronautics program at the Massachusetts Institute of Technology (MIT). I departed three years later with my doctoral degree in Orbital Mechanics to command the Test Pilot School at Edwards Air Force Base. My thesis was written on how to pilot and rendezvous two spacecraft in orbit. I was looking to the future! Of course, at the time I could not have foreseen the role I would play in the world's space program, but twelve years after the launch of Sputnik, I stepped off the Lunar Module ladder onto the surface of the Moon.

A half century has passed since Earth's Space Age began, and most of the world's population has never lived in a world without artificial satellites orbiting the planet. Over 80% of the people living today were born after 1957. They have grown up in a world where weather patterns are tracked by satellites, news programs send live broadcasts around the world, and people talk on the phone or by e-mail with friends on another continent as easily as with their next door neighbors. Technologically, the Space Age has made the world a smaller place.

Psychologically, it has made it a grander one. Over the last 50 years, hundreds of men and women have orbited Earth, and twelve Americans have even walked on the Moon. We have sent robotic missions to every planet in the Solar system and to a few asteroids and comets as well. Right this moment there are rovers exploring the surface of Mars. And we have looked at our own planet from space and have seen the Earth as one world, not a globe divided by manmade boundaries and borders.

I believe that future historians will look back at the Space Age as a turning point, a time when we finally began to think of our home as larger than a house or a town or even a country. Humanity's home is Earth itself. And one day we will 'grow up' and will be ready to leave home — as all children do — and travel to other worlds, such as Mars.



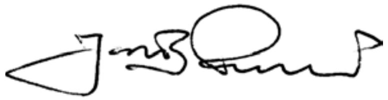
Janusz Bronisław Zieliński
POLAND

Professor of Geodesy at the Institute of Navigation of the Polish Navy Academy. Coordinator of the 6-FP Project *GalileoApp* and *Galileo Info Point* for Poland. Vice-President of the Committee for Space Research of the Polish Academy of Sciences (PAS). Member of the Bureau of COSPAR. Corresponding Member of the International Academy of Astronautics. Member of the International Committee of the Global Navigation Satellite Systems (UN body). A senior scientist at the Space Research Centre PAS and until 2006, Head of the Department of the Planetary Geodesy of the Space Research Centre.

Born in 1935 in Lodź, Poland.

He was the assistant professor at the Warsaw University of Technology until 1968, then moved to the Institute of Geophysics, PAS. In 1976 he became a Deputy Director for Science of the Space Research Centre and held the position until 1986.

He was a Scientific Manager of the *Baltic Sea Level* Project and a Principal Investigator of the DIDEX Project.



MY PERSONAL CONSEQUENCES OF THE SPUTNIK-1

The autumn 1957 was quite significant for me. In September I finished my studies at the Warsaw University of Technology and I returned for few days to my family home in Łódź. I was interested in astronomy and I was aware that Americans are working on the project to launch an artificial satellite. However, in Łódź everything was very far from the space projects. It was a city with very traditional textile industry, the city where the revolution 1905 started. Old factories looked like 50 years before. There, we suddenly got the news by radio: the Soviet Union launched an artificial satellite. For me it was spectacular. I had the feeling that something great had happened. But my family was not impressed. My father, who was a strong anti-communist, told me: '*Don't believe it, it is the communist propaganda...*' However neither he, nor myself, had the idea how much this event would influence the history and my personal life.

One year later I started a job at the Warsaw University of Technology. I have got the position of an assistant in the Chair of the Geodetic Astronomy. The salary was ridiculously low, but I was happy to work in research. There, I got the chance — my elder colleague Ludoslav Cichowicz asked me to work with him on the calculation of the orbit of the *Sputnik-3*. This satellite was launched on May 15, 1958. Its radio-signals were recorded in various places in the world and were available. The Polish leading expert on radio-wave propagation prof. Stefan Manczarski wanted to use these recordings to develop the model of the ionosphere and he needed positions of satellite in function of time. Cichowicz with my small contribution calculated the orbit and it was the first practical task in satellite geodesy solved in Poland.

Starting from this work, the satellite geodesy, the new-born science, became the leitmotiv of my professional life. Our Polish group collaborated with the teams from other countries in the frame of the Working Group chaired by prof. Alla Genrikhovna Massevich, dealing with the satellite observations and data analysis. This Working Group evolved later into the INTERCOSMOS Programme, that covered very broad spectrum of space activity.

In 1963 I had the first encounter with COSPAR. Poland invited this organization to hold its yearly scientific meeting in Warsaw. The President of the Polish Academy of Sciences Janusz Groszkowski, the President of the Polish Space Research Committee Włodzimierz Zonn and its Scientific Secretary Ludoslaw Cichowicz welcomed the Assembly. I was working in the secretariat. Renowned scientists came to our capital, among them Jean Kovalevski, William Kaula, Mike Gaposchkin and others. The friendly contacts established at that time endured the years and were the source of my intellectual joy and development. COSPAR proved to be the bridge between the eastern and western worlds for me and for a number of other young scientists from the 'socialist camp' fascinated by space.

But not all the things were pleasant. Space activity was and still is strongly connected to military problems. In 1967, after finishing my Ph.D. thesis, I applied for the fellowship of the Ford Foundation. The fellowship was awarded and the Smithsonian Astrophysical Observatory accepted me as scholar. However, the State Department refused to give me a visa with the explanation that proposed topic of my study (the Earth gravity field investigation) is not suitable for the international exchange program.

The military and political connotations of the space program were the curse and blessing for the space research. The bad thing was that the flow of information, individual contacts or joint projects were very restricted. On the other hand the rivalry between USSR and USA opened almost unlimited resources on both sides. In US the *Apollo* Lunar Program or NASA would have never been created without political competition with the Soviet Union who answered with equally remarkable achievements in form of manned missions of the long duration, space stations (*Salyut*, *Mir*) or interplanetary missions.

From the historical perspective we can say, that partial replacement of the arms race by the space race was an excellent process and until now both great space powers can benefit from the potential and the infrastructure developed during the 'cold war'.

Another interesting development, characteristic for the space activity, is the inclination to the mass media. Space achievements are spectacular by their nature. Big rockets ascending slowly from their launching pad in clouds of fire, satellites with bizarre shapes hanging in the space, astronauts in white space suits floating in heaven, all these phenomena are ready movie pictures. Risks of failure or even disaster dramatize the situation. These circumstances enable to sell well the stories of space conquest.

However, in my opinion there is something more behind this successful public relations of space. There is something what we can call the fascination of mankind by space. It is a dream, eternal dream of Icarus striving towards the Sun, the dream of Columbus looking for a new path, the dream of Tsiolkovsky to go beyond the Earth. Going forward, higher and further – it has forever been the internal compulsion of man.

Let us come back to historical reminiscences. After the COSPAR meeting in Warsaw, the international space research developed even more. In 1966 the Soviet Union proposed to the so-called 'socialist countries' the program for cooperation under

the name INTERCOSMOS. This political decision opened the way to space for several small countries, including Mongolia and Cuba. Of course Poland became also the partner of INTERCOSMOS. Thanks to this program several INTERCOSMOS satellites were launched enabling the scientists from smaller countries to put experiments on the boards of space probes and satellites. In Poland we were proud in particular of the mission *Kopernik-500* (*Intercosmos-9*), the solar radio-waves experiment devoted to the 500th anniversary of the birth of Nicolaus Copernicus. The project was led by Jan Hanasz from the Astronomical Institute of the Polish Academy of Sciences in Torun and dr. V. Aksionov from the Institute of Radioelectronics in Moscow.

The INTERCOSMOS program was an excellent example of the beneficial influence of the space research on the political and cultural relations between countries and people. The close and intense cooperation on projects developed mutual understanding and friendships. It permitted to see the human faces of individuals behind the iron mask of the official propaganda. In particular I would like to recall with great admiration the President of the INTERCOSMOS program Academician Boris Nikolaevich Petrov. His deep scientific knowledge, intellectual superiority and superb personal culture gave him the unique qualification to run the international cooperation program. His demise in 1980 was a great loss for INTERCOSMOS. On the Polish side responsible for the INTERCOSMOS activity was astronomer professor Stefan Piotrowski, who developed friendly relations with Pietrov.

The next stage of the INTERCOSMOS program was a series of the manned flights on board of the spaceship *Soyuz*. This undertaking was highly political, but we, within the Academy, tried to make it useful for the research, too. It was a remarkable experience to take part in the arrangements for these flights: I witnessed almost all phases of preparations of the Polish cosmonaut Miroslaw Hermaszewski, from his selection to the completion of his space mission. Hermaszewski did very good job performing perfectly the reach research program prepared for him by the scientific committee. He was supported by his flightmate Piotr Klimuk who later on visited Poland many times.

The announcement of the possibility of manned flights for cosmonauts from socialist countries has been met with very strong interest of the governments of these countries. In particular, the Government of Poland, controlled by the communist party with Edward Gierek as the First Secretary, strongly insisted that a cosmonaut from Poland should have the first flight in the sequence. It was motivated by the Polish Government political doctrine that Poland, being the second largest country in the 'socialist camp' should be considered as an ally number one by the Soviet Union. However, for some unknown reasons, the Soviet Government reserved the first place in the sequence of flights for Czechoslovakia. I observed this controversy continuing for a few months with bewilderment. I would never have believed before that the Government of the socialist Poland could be involved in the such hard quarrel with the dominant Soviet Government. But the result was easy to predict: the Czechoslovakian cosmonaut flew the first.

My most traumatic experience related to the space activity was the organization of the COSPAR Scientific Assembly in 2000. Poland decided to invite COSPAR for the second time and it happened at the turn of the century year 2000. I was appointed the Chairman of the Local Organizing Committee, prof. Piotr Wolański from the Warsaw University of Technology and prof. Zbigniew Klos from the Space Research Centre supported me immensely as co-chairmen. We had five years of hard work of preparations, but finally the meeting went well and some two thousands participants were satisfied. Besides of regular scientific sessions we organized open sessions and lectures for the public. It was my great satisfaction to observe the enormous interest of the society in problems of space, demonstrated by hundreds of people coming to lecture rooms to hear presentations by eminent scientist.

It is impossible to discuss in a relatively short article the immense progress in the science and technology, resulting from the applications of the space methods and means. Let me comment on what happened in space geodesy, the field most interesting for me. Of course the last 50 years brought the progress not in the space techniques only, but in many other fields, like computer technology, telecommunication, aviation and so on. But the impact of space is the most significant. First, both the geodetic science and applied geodesy called surveying, became global. Almost all over the world the geodetic measurements are done with help of GPS, the global satellite positioning system, and by virtue of this method, they are in the same coordinate reference frame, the same scale and the same time system. We can use satellites for the navigation on the sea, on the land, in the air and also in space. The GPS will be soon supported by the Russian GLONASS and hopefully in few years by European *Galileo*. The maps which are now available are to large extend the products of the Earth observation satellites. The Earth's globe dimensions, Earth's rotation and the Earth's gravity field model are known with the precision incomparable to that of fifty years ago. Thanks to special dedicated missions like CHAMP, GRACE and GOCE we can observe the temporal changes of the gravity field of the Earth, what is equivalent to the shape of it. Thanks to the altimetric satellites like *Topex/Poseidon*, *Jason* or *Envisat* we can observe the changes of the shape of the ocean surface, caused by the temperature, pressure or chemical composition of the water. Using satellites for Laser Ranging System, in particular LAGEOS, we are measuring the motions of the continental tectonic plates, which a few years ago was a pure hypothesis only. The changes in the geodetic science and technology are as profound as those which followed invention of the theodolite and the triangulation method in XVIII century. Certainly the last 50 years have changed the geodesy more than the former 200 years.

I think I can consider myself a happy man who had a privilege to live and work in the time of such dynamic development and to contribute to it to some extend. Also, I can feel happy that on my way of life I met so many people so much involved and so enthusiastic about space. It was the case in the years of the INTERCOSMOS program, it was the case in my service for COSPAR, my cooperation with ESA and my work in the Space Research Centre in Warsaw. All this important stages of my professional life were the follow up to this particular day of the October 4, 1957.

AROUND THE WORLD IN 1,5 HOUR

Gurbax S. LAKHINA
INDIA

Professor Emeritus and former Director of the Indian Institute of Geomagnetism (IIG), Mumbai.

He received Ph.D. from Indian Institute of Technology, Delhi (1972). Fellow of the Indian National Science Academy, New Delhi. Visiting Professor, Research Institute of Sustainable Humanosphere, Kyoto University, Japan (2005). Senior Resident Research Associate of NRC at NASA Jet Propulsion Laboratory, Pasadena, California (1996–1998). Alexander Von Humboldt (Germany) Research Fellow at Ruhr University Bochum (Germany) in 1981–1982 and 1985. Research Scientist, Courant Institute of Mathematical Sciences, New York University (USA) (1988–1989).

Member of the Executive Council of International Association of Geomagnetism and Aeronomy.

Recipient of K.R. Ramanathan Award (2005) of the Indian National Science Academy, Delhi and the Decennial Award-Gold Medal 2000 of Indian Geophysical Union, Hyderabad.

HOW SPUTNIK CHANGED MY VIEW OF LIFE

I came to know about *Sputnik* nearly two years after the historic launch of *Sputnik-1* on October 4, 1957. When *Sputnik-1* was launched, I was 15 year old boy studying in 5th grade in Sanatan Dharm High School, Panipat, a small town about 90 km away from Delhi. At that time, Panipat was a sleepy handloom town. I came to know about *Sputnik* and Yuri Gagarin, not from my school, but from the magazine, *Soviet Bhumi*, which was the Hindi translation of *Soviet Land*, which my father had subscribed at the insistence of a newspaper agent in 1959. As an incentive for subscribing for one year, he gave my father back volumes of the previous two years. I was very much surprised when I saw this Hindi magazine at my father's shop and he gave them to me for reading. I was in the 7th grade and was studying Science subject in addition to Mathematics, English, Hindi, Punjabi, Sanskrit, History and Geography. I was very fond of reading magazine and novels. In one of old issues there was an article about *Sputnik-1*, the first man-made object or satellite orbiting the Earth. I was surprised to know that it could get unique data pertaining to the density of the upper layers of the atmosphere and radio waves propagation. I found all this very strange and interesting at the same time. I started taking special interest in the science subject then onwards. Seeing my interest, my father renewed the subscription for the *Soviet Bhumi* for the next several years. In 1961, when I was in 9th grade, one issue of the *Soviet Bhumi* carried the interview of Yuri Gagarin, the first man in space. He went into space in a sputnik named *Vostok* on April 12, 1961, orbited the Earth once and came back. This was an historic moment not only for the Soviet Union but for the entire world. I was fascinated to see the pictures of the Earth taken from space and to read the interview with Yuri Gagarin, the first astronaut. This fired my imagination about the mysteries of space.

I was born on April 7, 1943 in Mianwali (now in Pakistan) in undivided India. It was a very small town, and most of the people were either doing farming or handloom business. My father's family was among the few well-to-do families. Unfortunately, we lost everything during the mania following the partition of the country on August 15, 1947, when we were forced to leave Mianwali and come to the Indian Territory. After staying in many refugee camps in Amritsar and Delhi, finally my father's family was settled in Panipat. We had a tough time initially. My father started two handlooms in a part of our house itself, the income were low and we barely survived. He then started the retail business of colour and dyes. He would buy these products from Delhi and sell it to the handloom owners for dying the yarn. He worked very hard and the business started picking up by early 1960's.

It may appear strange now, but in early 1950's, when I was a young boy, very few parents would send their children to school in our community. My father had no formal education himself. He had a rudimentary knowledge of Urdu and arithmetic. He realized the importance of education, and sends me and my brothers and sisters to school. I got a scholarship from the School Board for doing well in my 8th grade examination. This provided an impetus for further studies. I did well in my school leaving (10th grade) examination which was conducted by the State Education Department. My name was in the Merit list and I won the National Merit Scholarship. One condition of the Scholarship was that it will continue till Master's degree provided the award gets more than 60% marks in each annual examination. There was a great pressure on my father not to send me to college from our community. The community people had misconception that the boys develop bad ways when they go to college, and stop regarding their elders with respect. Seeing my interest in higher studies and the importance of the Scholarship, my father allowed me to get admission in Bachelor of Science in Arya College, Panipat. I got the scholarship through out my college education and passed my B.Sc. in 1967 with a first rank in my college.

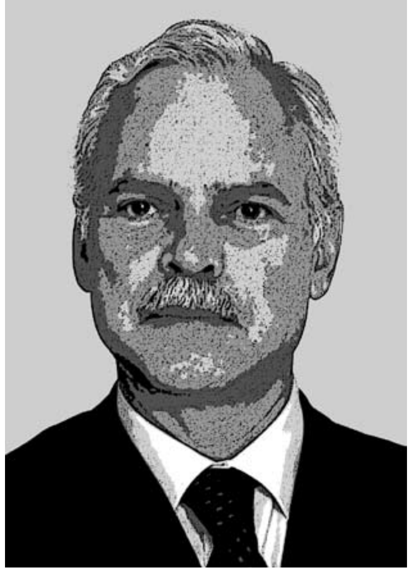
I wanted to do Master in Science and told my father. Everyone in the family was against it as I had to go out of Panipat. Eventually my father agreed but insisted that I should study in Delhi. I applied to Indian Institute of Technology (IIT), Delhi for admission to M.Sc. course. When I got a letter from IIT, Delhi for the test and interview, my father accompanied me to Delhi. This was my first visit to the Capital of India. He left me at IIT and promised to come back in the evening to pick me up after finishing his work. The admission test of IIT was very much different than any examination I had earlier. I did not know about the multiple choice questions and about the negative markings. With great trepidation, I started solving the paper. I could finish about 70% of the questions. I was feeling very low. All other boys were cheerful and laughing as most of them have done the whole paper. And some even told me to go home, as my name would not be in the list for interview. I felt like going home, but I had to wait for my father. When the list of candidates selected for interview was put up on the notice board, my name was there and I heaved a sigh of relief. I was called for interview and became very nervous on seeing five members of the interview committee. This was my very first interview of any kind. As I came to know later, Prof. M.S. Sodha, Head of the Physics Department, was the chairman. After some preliminary questions to test my knowledge about Physics, he asked me why I want to do M.Sc. in Physics and what I want to become. I blurted out I want to study space and become astronaut like Yuri Gagarin. We were not taught anything about space in our B.Sc., I told him frankly about reading about the *Sputnik* in *Soviet Bhumi*. I told him that I want to do Master in Physics as it will provide me skills to explore space,

which is not empty. I felt some Members were laughing at my reply, but I was not sure. Prof. Sodha asked me seriously '*What is it* (*i.e., space*) *then?*' I told him that is what I would like to find out. I do not know how I could say all this at that time. I was told to go home and that the result of the interview will be intimated to me by post. When I came out of the interview, my father was waiting for me and we came back to Panipat.

More than 3 weeks had gone after my test and interview at IIT Delhi. I had nearly lost hope, and was thinking of ways to convince my father to let me go for studies in Panjabi Univeristy, Patiala where I had already been accepted. One day a letter from IIT Delhi arrived informing about my selection for the admission to M.Sc. Physics course. This was a moment of great joy for me. I immediately took admission in IIT, Delhi after paying the admission and hostel fees. I have never lived in a hostel before, and the thought of living in IIT hostel excited me. The courses started and so did my Nation Merit Scholarship. Studying in IIT was a whole lot of new experience. There were regular assignments, some weekly and some bi-weekly, all geared towards application of the theory taught in the classroom. The IIT Library had lots many books on physics, mathematics and all engineering subjects. It also had a good collection of literary books and novels under its humanity subject. Initially, I used to go home during the weekends but the study pressure increased and I could go home hardly once a month or even less. During the second year, we were taught a course on plasma physics, during the 3rd and 4th semester, by Dr. Bimla Buti. She had done her Ph.D. from Chicago University under the supervision of Prof. S. Chandrasekhar, a well-known astrophysicist, who later on was awarded the Nobel Prize! I got interested in plasma physics and thought of doing Ph.D. in this subject after completing my Master degree. This subject had tremendous potential for thermonuclear fusion as well as for astrophysical applications.

When I told my father about this, he was not very happy to hear this as there was family pressure to get me married. Luckily, by this time, my father's business was going well and there was no financial pressure for various family obligations. I was hoping to get a fellowship for my Ph.D. from either the Council of Scientific and Industrial Research (CSIR) or from the IIT itself. I discussed with Dr. Buti about my desire to do Ph.D. in plasma physics under her supervision and she agreed. I applied to CSIR for the junior research fellowship and was successful. I registered for the Ph.D. at IIT, Delhi with Dr. B. Buti as my supervisor. I started my Ph.D. career from July, 1969 and the topic of my thesis was *Study of some electromagnetic instabilities in magnetized plasmas*. I started work on ordinary mode electromagnetic instabilities in counter streaming plasmas. I was working very hard during this period, and many a time I would get frustrated. After about a year and a half my work picked up pace and I started making good progress on my research problem. At this time, Dr. Buti decided to leave IIT, Delhi and join Physical Research Laboratory (PRL), Ahmedabad as a Professor. Luckily, CSIR fellowship allowed the junior research scholar to travel and work at another laboratory for 3 months at a stretch with the approval of the supervisor. But before that I had to find a co-guide from the IIT faculty otherwise my Ph.D. registration at IIT would be cancelled. Prof. A.K. Ghatak of the Physics Department, who has taught us mathematical methods and quantum physics, came to my rescue by agreeing to be my co-guide. For the next year and a half, I was shuttling between PRL, Ahmedabad, and IIT, Delhi, regularly spending about 3 months at Ahmedabad and a month or so at Delhi (this time was required to get approval from CSIR to visit PRL for my work). After two years as junior research fellow, I got the senior research fellowship from CSIR. Finally, I submitted my Ph.D. thesis in April, 1972 and was offered a Visiting Scientist position at PRL (this is similar to post-doc position). I successfully defended my thesis during an open viva and was awarded the Ph.D. degree in October, 1972. My stay of about 18 months or so at PRL as Visiting Scientist proved very productive in terms of publications as well as broadening my perspective. I published 5 papers during this period and in one of the paper applied my theory to solar wind discontinuities. In a way this was my first paper on microstructure of the interplanetary space! I think this paper was in a way responsible for my selection as Fellow at the Indian Institute of Geomagnetism (IIG), Colaba, Mumbai. This institute was carved out of the well-known Colaba and Alibag Magnetic Observatories with a mandate to study geomagnetism from all aspects. Well, I started my first regular job as a scientist in the post of Fellow in IIG on November 13, 1973. Initially, I started working on the topic of plasma instabilities in the magnetosphere and solar wind, and slowly expanded the activities to coherent radiation mechanism, solar wind interaction with comet, magnetospheric substorm, storms, and space weather. I had a good fortune to work with many well-known space physicists and visited several space research institutes including the NASA Jet Propulsion Laboratory. In my own small way, I have contributed towards understanding the Earth's near space environment where many satellites are orbiting. I could not become an astronaut but could at least fulfill my dream to solve some mysteries of space to some extent. This is how *Sputnik* changed my view of life!

AROUND THE WORLD IN 1,5 HOUR



Marcio BARBOSA
BRAZIL

Deputy Director-General of the United Nations Educational, Scientific and Cultural Organization (UNESCO).

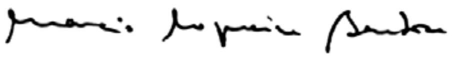
Born in 1951, Mr Barbosa holds a M.Sc. degree in Systems Analysis and Applications (1975) from the National Institute of Space Research (INPE), Brazil.

In 1973 Mr Barbosa joined the Brazilian National Institute of Space Research where he finally worked as Director-General in 1989–2001. He established at INPE the Center for Numerical Weather Forecast and Climate Studies (CPTEC) and the Inter-American Institute for Global Change Research (IAI).

Since February, 2001, Mr Barbosa is Deputy Director-General of UNESCO.

From 1996 to 2000, he was Vice-President of the International Society for Photogrammetry and Remote Sensing (ISPRS) and from 2000 to 2004, President of the International Astronautical Federation.

He is a member of the International Academy of Astronautics and the Brazilian Academy of Engineering.



THE LAUNCHING OF SPUTNIK-1 AND ITS IMPACT IN DEVELOPING COUNTRIES

On October 4, 1957 the launching of *Sputnik-1* changed humanity's history opening new perspectives for scientific and technological development in industrialized countries (called Super-Powers at the time). It also contributed, very determinately, to the progress and development of many other developing countries (as they are currently known).

What seemed only a scientific challenge, from the proposal made by the International Council of Scientific Unions, in October, 1954, to launch artificial satellites to commemorate the International Geophysical Year (1957–1958), became in fact, the beginning of the so called 'Space Race' between the USA and the former Soviet Union. The perception and concern of the public, at the time, were that in the military field, the former Soviet Union demonstrated its capacity to launch nuclear weapons, through ballistic missiles, leaving from Europe in the direction of the USA. And, as a reaction to the established political uproar, the USA had approved, among other acts, voluminous resources for its *Explorer* space program and the creation of NASA. The race involving basically two actors also won, from then on, the interest of many other countries that until then were rarely convinced of the importance of investing in space.

Brazil, for example, in 1961 was already taking its first steps to organize its space activities with the creation of the precursor to the current INPE (National Institute of Space Research). After the pioneering experience of some of its countries at the end of the 1950's, notably France with the CNES, Europe was reorganized in an ambitious and integrated manner with the creation of ESA (European Space Agency) in 1975. Similar enthusiasm was seen in India, China, Canada and Japan, to cite the largest investors.

The initial concept of small scientific satellites orbiting the Earth that initiated with *Sputnik-1*, associated with the increasing capability of development and launching of large masses, not necessarily in circular orbit of low altitude, allowed an extraordinary evolution in the exploration and use of the space for peaceful purposes, benefiting all of humanity. What was only scientific began to have a more immediate application interesting to everyone, and thus, at the end of the 60's, the so called 'Space Applications' (use of the space for communications, monitoring the environment, meteorology, positioning and navigation) are born. These applications became operational and gained commercial potential in a lot of fields, like in communications for example, already in the beginning of the 1970's.

This does not mean that the scientific activities were left behind. From the simple possibility to detect radio signals at the ionosphere with the *Sputnik-1*, or the discovery of the Van Allen Belts with the *Explorer-1* in 1958, continuous investments have been made by a great number of countries, individually or in cooperation, in order to explore the Universe, not only in the regions close to Earth but also the Moon, Mars, Venus, other planets in the Solar system and the outer space.

The advancement of space technology and the discovery of new materials, processes and procedures, particularly in the field of flight safety, have made scientific experiments possible through spacecraft, carrying men or not, for periods of short or long duration (some months). Special attention should be given to the manned missions and the scientific experiments on board stations *Mir* and ISS (International Space Station), the Hubble telescope and the many probes successfully launched into space, plus, naturally the engaging successes of the precursory flights of Gagarin, Glenn, the *Apollo* program and the conquest of the Moon in 1969. Since 1961, 400 men and women had the chance to go to space in missions aimed at the improvement of the quality of life on Earth and exploring the Universe and its wealth.

International cooperation is a crucial issue given the point of view agreed by all countries about the necessity to keep the space as a region of interest to humanity and using it for peaceful purposes with universal benefits. These concepts are being formalized since the launching of *Sputnik-1*, through the various international treaties under the responsibility of the United Nations and of its COPUOS (United Nations Committee on the Peaceful Uses of Outer Space). The most important of them is the Outer Space Treaty, adopted in 1967 and ratified by over 90 countries. In its first article it states that 'the exploration and use of outer space, including the Moon and other celestial bodies, shall be carried out for the benefit and in the interests of all countries, irrespective of their degree of economic or scientific development, and shall be the province of all mankind.'

However, in reality, space cooperation only takes its first step between the two great powers of the time — USA and the former Soviet Union — with the historic *Apollo-Soyuz* mission of July, 1975. It is also true that bilateral cooperation was being practiced by other countries since the 1960's, but was concentrated in the fields of space research or data exchange, with practically no interaction in the technological field. Nevertheless, these exchanges were fundamental for training professionals and maintaining the developing countries interested in the benefits drawn from investing in space.

Today, 50 years after the launch of *Sputnik-1*, what is noticeable is a great exchange between the countries that have space activities, not only in sciences, but also in the technological development. Also, not just between industrialized countries, as reflected in the scope of the ISS program since the beginning of its assembly in 1998, but also between developing countries. An example is the cooperation between Brazil and China in satellite development, which materialized in 1997 with the launching of its first satellite, the CBERS-1 (*China-Brazil Earth Resources Satellite*). One must also mention that the ISS, involving more than 20 countries, is the most ambitious program in terms of scientific and technological cooperation ever developed by humanity up to this day.

The 'scientific and professional societies' in the space field have been playing a relevant role in the space cooperation and exchange of information among the professionals of the area, particularly the IAF (International Astronomical Federation) created in 1951. Even in the critical moments of the so called 'cold war', the IAF served as a useful arena for dialogues and exchanges between the conflicting parts.

From the technological point of view, the small *Sputnik-1* (approximately 83 kg of mass) served as an inspiration for numerous space programs that came about from that moment on, especially in developing countries. For reasons associated with the low cost and the relatively low complexity in the technology involved, many countries, that until then were isolated from the space run, saw in the *Sputnik-1*, a model to engage in the space field. Until then, these countries considered themselves only able to share data of scientific experiments obtained by others. They now began to dream about also having their own satellites for their own applications and specific needs. They could stop being spectators and start being actors. Moreover, the cost of launching in orbit a small satellite would be much less than launching a large one. The developing countries did not realize, however, that this leap or advancement would necessarily demand, for a number of years, a lot of effort in capacity building as to human resources and a reasonable investment in laboratories and specialized facilities. That is how, only in the mid 1980's, did viable space programs based on small satellites start to surge in developing countries. In the case of Brazil for example, for financial reasons as well as those regarding the access to technology for launching into orbit, its first satellite developed entirely with indigenous technology was only successfully launched into orbit in 1993. It is the country's first environment-data-collecting satellite with an approximate mass of 115 kg, and it is still in operation today.

Another interesting aspect is that with the advancement of microelectronics and the so called 'new materials', from the 1970's the usage of small satellites began to be considered not only for scientific experiments, as in the beginning, but also for missions consisting of space applications, particularly regarding the collection of environmental data (as in the case of Brazil), Earth observation, and navigation. Finally, what was only possible to do with satellites of large mass (above 500 kg), high technological complexity, and in geostationary orbits, began to be possible through small satellites in low orbits, isolated or in constellation (group of satellites operating in a network). This allowed for an even larger interest in the concept of small satellites by the scientific community, information users, and the aerospace industry. Similarly to Brazil, other developing countries in Asia and Africa advanced along the same concept, and in the last decade entered the selective group of countries that today explore the space through their own means, as it is the case for Algeria, Argentina, Nigeria, Turkey and Thailand.

Satellite SCD-1

SCD-1 orbit

SCD-1 is a Data Collection Satellite with following specifications:

- Format: octogonal prism
- Dimensions: 1 m diameter, 1.45 m height
- Total Mass: 115 kg
- Power: 110 W
- Structure: Honey Comb Aluminum Panels
- Attitude: Stabilization by rotation
- Passive Thermal Control
- Data Collection Transponder in UHF/S
- S band TT&C
- Solar Cells Experiment
- Circular Orbit at 750 km altitude, 25 degrees inclination
- Mission: Environmental Data Collection through remote ground platforms SCD-1 orbit

It is true that in consequence to the space run initiated by the *Sputnik-1*, the advancements of satellites in the field of technological development with military and defense purposes are obvious, however, humanity was also capable of conceiving fundamental space applications in strictly civil fields that have unprecedented benefits to all peoples, such as: telecommunications, monitoring, navigation, sustainable development of the environment, prevention and mitigation of natural disasters, meteorology and oceanography, and collecting all sorts of data that would be otherwise impossible.

Humanity has gained a lot from all this and will certainly continue benefiting itself from the consequent scientific and technological development as long as its search for answers about the dynamics of the systems that support life on Earth and the origins of the Universe may last. The question raised today is that, despite these great scientific and technological achievements, our planet continues to have its 'sustainability' threatened, especially due to the great climatic changes recently observed, which are caused by many factors. The technology and the space means are available, the international accords are signed, therefore, it is time to make an individual and collective effort to maintain, on Earth, the life conditions acceptable to all, and consequently the obvious benefit which that entails for future generations.

Jose Francisco VALDES GALICIA
MEXICO

Full Professor at the Institute of Geophysics of National Autonomous University of Mexico (UNAM). Researcher and Head of the Space Sciences Department of Instituto de Geofнsica-UNAM.

Born in 1952.

Doctor of Philosophy by the Imperial College of Science and Technology (the London University). Appointed as Director of the Geophysics Institute-UNAM for the 2005–2009. Vice President of the Cosmic Ray Commission of the International Union of Pure and Applied Physics (Member of the Commission from 1999 to 2009) and founder of the Latin American Space Geophysics Association (President of the Steering Board 1993–1998).

Member of the Mexican National Researchers System with the high-est level. Member of the Auger International Collaboration.

He is in charge of the infrastructure and operation of the Neutron Monitor (Mexico City); the Moun telescope (México City) and the Solar Neutron Telescope (Volcán Sierra Negra Volcano, Puebla 4580 m asl).

OCTOBER 4, FIFTY YEARS AFTER

A very personal start into space issues

My infant days elapsed amongst everyday news concerning events related to space exploration as the newest, dearest and direst adventure of mankind history. My teachers at elementary school, my older brothers and sisters, parents and relatives alike, everybody was talking excitedly about the outer space and imagining all kind of possibilities for science and development. There was a 'space mania', a pervasive mood invading all earthly souls, filled with hopes of a new era.

I remember myself glancing through the pages of an issue of the *Life* magazine with a special report to commemorate the first woman in space: Valentina Tereshkova. The then short history of space travel included there allowed for several detailed descriptions; the one that captured my attention was that of the first living creature sent to space: the dog Laika and her unavoidable death, as the capsule was not designed for recovery. On those years space was paramount: the names of Yuri Gagarin, John Glenn, Gordon Cooper, Alan Shepard, Alexei Leonov, were fading out those of Elvis Presley or other of the blooming rock stars.

I am a child of the space age; the life I remember is contained in the years after the *Sputnik* launch, much of the gossips or games organized at school breaks were related to the world beyond our blue sky, the race to the Moon occupied a substantial part of my teenager thoughts. The remembrance of the first photograph of the Earth taken from the outer space brings back my own surprise and the stupefaction of the faces of all those surrounding me. So vivid is in my mind the amazement of my complete family gazing at the non-colored TV image of Neil Armstrong and Buzz Aldrin walking through the Moon, a breathtaking memento. Nonetheless, looking at the 1964 Olympics in Tokyo or the soccer world championship in England in 1966 in real time, were normal events for me and many others of my generation, a measure of the contradictions of the epoch.

In a way, the space excitement was a proper balance to the anguish coming out from the cold war events. I also remember sleepless nights, fearing the truth in the end of the world stories told by many at the time of the Bahía de Cochinos (Bay of Pigs) invasion, or the occupation of Prague. The world was moving through a pathway of development on one hand and of confrontation on the other. No wonder the development path was much more attractive as it promised an enlightened future; the other had no future at all.

A BRIEF ACCOUNT OF SPACE RESEARCH IN MÉXICO

Following the enlightened path I decided to enroll for a B.Sc. in Physics to afterwards pursue postgraduate studies in Space Physics. Cosmic rays were the main subject of my endeavors; this topic was the most developed in México thanks to the heritage of Professor Manuel Sandoval-Vallarta, a world class scientist that had the vision to make our country look into the space issues as early as the 1930's. The crucial experiment to discover the east-west effect of cosmic rays arriving to Earth was performed in México City in 1935 by Louis Alvarez, guided by the proposal of Sandoval-Vallarta. Just before the break of the space age, Manuel Sandoval-Vallarta brought to México one of the most important scientific meetings dealing with space phenomena: the 5^{th} International Cosmic Ray Conference was held in Guanajuato in 1955.

New actors came into the scene: Ruth Gall was a proper heir of the seeds planted by Sandoval-Vallarta in the National University (UNAM); thanks to her leadership and of an engineer from the National Polythecnic, Eugenio Mendez Docurro, the Space Sciences became a respected subject in the nation at large. They were instrumental for the creation of the Comisiyn Nacional del Espacio Exterior, CONEE, (National Comissión for the Space) in 1962, with the clear mission to launch México into the space technology era; programs for rocket and balloon development were created, stations to receive information from meteorological satellites were installed, a collaboration agreement with NASA for remote sensing was signed and many other actions were planned; unfortunately lack of support by shortsighted governments cancelled the CONEE in the following decade. Nonetheless, Ruth's efforts never faded away, her endeavors led to the creation of an interdisciplinary working group on Space Activities in México in the 1980's, which was later transformed in the University Program for Space Research and Development (1990). On an international level Ruth and a handful of scientists from the less developed countries created the COSPAR Panel on Space Research in the Third World (1982), with continued activities up to our days.

From 1962 a group of Basic Space Sciences was created in the Institute of Geophysics of the National University of México (UNAM). The group has grown into a mature research department, known and respected in many parts of the world nowadays.

The contemporary research interests of the group are most varied: from the Sun to the solar wind, planetary magnetospheres and ionospheres, the planets themselves and, of course, cosmic rays. The group operates several observatories of world quality: a cosmic ray station with a neutron monitor and a muon telescope in México City, a Solar Neutron Telescope at the top of the Sierra Negra Volcano (4600 m a.s.l.) 200 km east of México City, an Interplanetary Scintillation radio array in Coeneo, to the west of the country, a ionosonde some 60 km away from the UNAM main campus and a solar radiointerferometer at the campus. Many of the researchers of the group are part of international teams dealing with the design, implementation and operation of experiments in spacecraft from NASA and ESA.

Space technology has not been able to flourish completely in México. Since the cancellation of the CONEE, few efforts have been done for further developments: a multiinstitutional project surged in the decade of the 1980's to create a Mexican satellite (SATMEX); the enterprise faded away due to lack of financial support by the sponsoring agencies. In the 1990's a new initiative from UNAM took shape; this time for a micro satellite (UNAMSAT-1) that was designed, developed and built locally; unfortunately UNAMSAT-1 was lost due to a failed rocket from Baikonur in 1995. After that failure money did not flow again to a space enterprise until very recently. As these lines are written, UNAM is developing a new project for a further attempt to have its own satellite program. On the political side a law for the creation of a Mexican Space Agency has already been approved by the lower chamber of the Congress and is under consideration by the Senate. Let us hope that the shortsightedness of the Mexican decision makers on the space issues is coming to an end.

THE WORLD BEYOND BECOMES OUR OWN

But if my country has been restricted to develop only the basic space sciences from earthly based observatories or through collaborations with foreign agencies, and the space infrastructure development was hindered; many other countries did explore directly the outer space from the 1960's and many others started to do so as the 20^{th} century waned. This exploration of the world beyond our atmosphere has changed forever the way we see our planet and ourselves, it has had also a drastic effect in the way we communicate, travel, eat, work, spend our free time, search for information, fix our holidays, every aspect of human life has been touched if not completely modified in the last fifty years.

We have gone from locating primitive communication satellites into Earth's orbit to the launch of sophisticated equipment for the study of the Earth vegetation, mineral, petrol or aquifer resources, meteorological, navigation, perform speedy communications within the Earth surface, measure the crust plate displacements, know our exact location in the Earth and many other activities. Men have gone into the space, walked and driven wheel cars through the Moon's surface. Man made rovers searched through Mars. Long distance probes took pictures of every planet from Mercury to Uranus, our spaceships landed in the surfaces of Venus, Mars and the satellite Titan. Comet tails were sampled several times. We discovered *in-situ* that the solar wind has a sharp transition at a distance near a hundred astronomical units from the Sun. The 'star trek' is just one step from going into science reports and leave science fiction stories.

No wonder the attitudes of men in the early 21st century are in many respects completely different from those of the 1950's, much of this change is undoubtedly due to space exploration achievements. Fifty years ago the thought of exploring the outer worlds of the Solar system was a mere chimera; today mankind has gone beyond that stage. Very long distance communications within the Earth surface were difficult to establish in the 1950's, today it is an easy everyday practice. Many of the gadgets we use in our quotidian life from iPODs to minicars are products of the space age, unimaginable before October 4, 1957. Conditions of life are drastically diverse; this overwhelming technical progress was helped if not started by the achievements of the space age, where sizes and weight should be small, performance must be extremely optimized, precision is crucial for the mere existence of the planned experiments, they can not be repeated since the lab is thousands of kilometers away. Therefore the demands of space technology promoted an unprecedented development that has then been applied to gadgets of common use today, modifying our everyday environment little by little. Now, after fifty years we can barely imagine how people sorted out their lives then.

The world has shrunk literally, for as now we can see what is happening in any distant place over the surface of the Earth at the same time we are having our meals or as we do our shopping, or just for a break during working hours. There is almost no mysterious land we can not visit and search through their most guarded secrets in real time; and this can be done from our home, office or any everyday site. This has changed drastically the way we see the world, the way we communicate with others, the way we organize our thoughts and concepts. Now for us, the Americans, the Asians or Africans are no longer distant people alien to us, they are part of us, we share a common planet and a common fate. We are aware that our actions might affect them as theirs could affect us, a feeling I could hardly believe the humans had before the space age.

Unfortunately, as pervasive as they are, the developments associated to the space age have not changed the lives of many that remain on the survival line; progress is still beyond their grasp. For there are millions of people in Asia, Africa, Latin America or even in the USA or Europe for whom the microelectronics, optical fibers, sophisticated medical treatments or instant telecommunications over the whole planet means nothing. They are still pathetically struggling to get a meal, a home, a school, care for their health, clothing; they lack the basic things that should have reached them not fifty but hundreds of years ago. But here we start to go beyond the scope of the present essay, science and technology can serve to the humans on the condition that their societies have the organization and the institutions which assure that everybody can be provided for. So we are invading the field of mere politics, but a part of this field has been profoundly touched by the space age.

POLITICS AND SPACE SCIENCE AND TECHNOLOGY

The way international politics is done has also changed in the last fifty years. A significant part of this change is due to the space era. The first element easy to identify here has to do with the resources every country has assigned to develop space science and technology. The richest and technologically more evolved nations were the first to come into the scene, establishing the pace and

the lines under which space exploration was to come into existence. Others had no alternative but to follow their footsteps. Much of the frontier basic space science was done exclusively in the countries of the so-called first or second worlds, giving way for the germination of space technology there.

Thus, space communications, remote sensing, microelectronics, low gravity production of new materials, exobiology and many other discoveries were done by nationals of a handful of countries. The rest remained behind. These new conditions gave even more advantages to the developed world for they could establish telecommunications, possessed unique information on natural, mineral and oil resources, land development, forest and crop evolution, etc. Therefore the gap between the knowledge of the rich and the rest of the world became wider. The first group could impose conditions on the others in all the fields space technology gave them advantages: they could sell communication channels, assess the resources of every nation without touching their land, do spying activities unnoticed, charge unfair amounts for technology transfer on new materials, seeds, medicines and the like.

As it has happened with other scientific and technological outbreaks, i.e., atomic and nuclear physics, the will of the decision makers and the money lenders, and the lack of societal instruments to stop them, were the conditions that allowed space science and technology to be during many years for the service of the few and not of most of us.

Nevertheless, as the technologically less evolved societies became aware of the importance of the use of space, the gap begun to close. Many underdeveloped countries have nowadays their own space agencies and programs. Let us keep the hope that the benefits they will get from such decisions are widely spread within their own spheres of influence.

SPACE RESEARCH, GAINS AND LOSSES?

Knowledge is always good for it provides us with better understanding of the Universe we live in. When we understand something we may use this knowledge in our own benefit, building new tools to ease our lives, providing means to protect us from potential dangers, producing new and versatile materials, getting the cure for uncontrolled diseases, inventing sophisticated methods for diagnosis or just the mere satisfaction and change of attitude that the comprehension of a certain natural phenomenon brings. Within this view space research is already one of the assets of mankind.

As many human activities, the space age has also produced some inconveniences; the first and most obvious has been mentioned above and was the expansion of the gap between the rich and the poor nations. But there are also other drawbacks that come not explicitly from space science and technology itself, but from the misusage of them, i.e., sophisticated weaponry that could destroy our planet in less time than it takes to read this page or leave our neighboring space invaded with waste from thousands of scrap satellites.

It is obvious that there are some paths to be corrected. The new research should be conducted on a more collaborative and environment careful basis among nations. Peace and well-being of men and women should be paramount aims of the new approach into space.

Anyhow, the exploration of the world beyond our atmosphere produced unquestionable benefits for the quality of life of many; it has also expanded possibilities for our evolution as a species. As new challenges are set, the mind and the instruments it produces have to evolve even further, saving us from stagnation that would inevitably lead to a backward path. The human history shows that when a society stops developing the signs of decline appear soon. Therefore we must be glad that space is there to be conquered, to help our minds spread out, imagine new worlds, make the hopefully fiction become true.

AROUND THE WORLD IN 1,5 HOUR

Marcos E. MACHADO
ARGENTINA

Astrophysicist, expert in solar active phenomena and space research.

Born in 1949, Buenos Aires (Argentina). He has devoted his professional career to the study of solar active phenomena and space research. He was the Project Director of Argentina's first indigenous scientific satellite project, launched in 1996.

Member of the COSPAR Bureau and the COSPAR Scientific Advisory Committee. He has been Vice-Chair and Chair of the Panel on Space Research in Developing Countries and currently a member of the Panel for Capacity Building.

He has served in many national and international scientific advisory committees, held, and holds, various responsible positions in the Argentina Space Agency and is also a Member of the International Academy of Astronautics. Among several awards and distinctions is Vikram Sarabhai Medal (2006) for his outstanding contribution to space research in developing countries.

FROM SPUTNIK-1 TO CONSTELLATIONS OF SATELLITES

My first thought, when I was invited to write about my recollection of the *Sputnik-1* launch, was that probably I would not have much to say, since I had just turned eight years old that year and I was mostly interested in playing and reading comic books and novels. However it turned out I could remember much more than I had anticipated and, furthermore, I have for the first time realized that October 4, 1957 and the days that followed had a rather profound impact in my life. I vividly remember being in the car with my parents asking my father, a mathematician, many questions, far too many I am sure. But there was one in particular that brought an answer that disturbed me. I asked my father when Argentina was going to build its own satellite and he answered (not his exact words, I am sure): '*Probably never, we shall just buy them in the future from those that know how to build them*' (while driving a car built in the USA).

Just a year and a half later we were 'building and launching', with a friend of the same age, our own 'rockets'. Needless to say these were not real rockets, but produced rather strong explosions thanks to alcohol and the oxygen we managed to extract from the oxygenated water that we were using (instead of the liquid oxygen that we had read it was used in the real rockets). When that 'thing' exploded (fortunately our neighbors got used to the noise rather quickly!), its top part that we had left somewhat loose flew up in the air and we happily (over)estimated the altitude it had reached. Some of our launches even included live animals (ants) that, of course, we never recovered dead or alive.

Besides these anecdotes, which reflect the early impact that *Sputnik-1* had on my life, what I believe is the most important legacy of October 4, 1957 is the uneasy feeling I had about my father's answer.

Jumping in time, by the mid 80's I was in the midst of a rewarding career in astronomy and solar physics, with space research and the use of advanced spacecraft very much installed in my life, having analyzed OSO-6 and *Skylab ATM* data, as well as participated in mission operations and analysis of data gathered by the *Solar Maximum Mission* (SMM) spacecraft. It was then decided by Argentine authorities to embark in the process of designing, build and launch the country's first indigenous satellite. This was the chance to answer my own question, the one I had asked my father some 30 years earlier! For several reasons the whole process still took about a decade, but in 1996 an Argentine spacecraft (built in house, not elsewhere) devoted to solar and astrophysical research was launched into orbit.

Irrespective of these personal remembrances, *Sputnik-1* as we all know led the way to open new frontiers in science, technology and applications. Although for quite some time space research was an exclusive 'club' of just a few members, the latest part of the half-century that has elapsed has shown more and more countries beginning to take part in an active way in the challenging venture that used to be called the space race. I expect this trend of increasing number of countries to continue in the near future. In the case of developing countries, which conform a sizeable fraction of the latest comers, some will drop out (in terms of building their own satellites) after the initial exploits, but the number of newcomers will continue to exceed the dropouts for quite some time. Then the need to use forefront technology to obtain world-class results in science or applications, may prove to be far too expensive for most developing countries working in isolation. Notable exceptions are emerging space powers, such as China and India, and it is likely that a few others will join in the near future. For this to occur it will demand a political decision by such country, based not so much in scientific issues but rather in a perception of increased international prestige, power, aura or business opportunity. In other cases the country (developed as well as developing) may decide to have a different role, act just as a supplier of specific sophisticated instrumentation. Some members of ESA have taken this attitude already. The ESA experience is also enlightening in another aspect, by showing the benefit of joining forces to obtain greater results. Its example, I believe, should be followed by the creation of other consortia at either regional or maybe hemispheric levels.

In a geopolitical sense *Sputnik-1* also started a major revolution. In close resemblance to the importance it had, a few centuries ago, to have the capability to navigate and explore the seas, access to space became a major asset in a global context. The difference with the situation we had before regarding the seas is that we were then dealing with a two dimensional (2D) exploration, that has since *Sputnik-1* expanded into a three dimensional (3D) space. It is not surprising that developed countries, with well established global influence, also have a leadership role in space science and exploration. In this context, we also see that countries like the aforementioned China and India, with strong emerging economies and leadership potential, devote major resources to space research, its applications as well as exploration.

Looking ahead, my personal view is that the pace of technological advances as well as the never to be underestimated level of human ingenuity, make it very complicated to predict what we shall see in the next 50 years. Although space travel had been in the mind of people, since Jules Verne's time, it is hard to believe that somebody

would have dreamt in 1957 about the global positioning systems that we regularly use today, our precise measurements of the cosmic background, the early structure of the universe and distant galaxies, discoveries related to Dark Matter and energy, our current studies of the Earth and planets using advanced remote sensing techniques, our possibility to map, *in-situ*, the Earth magnetosphere and its phenomena and similarly obtain a high resolution 3D view of the structure of the solar corona as well as to probe the solar interior, to mention just a few recent achievements. It is my belief that precision and a systemic approach will be the name of the game in the years to come. Be it in studies related to the fundamental laws of physics, astronomy, solar-terrestrial physics, planetary exploration and the monitoring of the Earth land, oceans, atmosphere, ice cover and global climate. The word *precision* does not just entail precise measurements by sophisticated large aperture telescopes and state of the art detectors, it also involves precise formation flying of many spacecraft, as well as very high precision pointing systems, cryogenic devices and inertial sensors. In the case of Earth sciences, global monitoring and research will be performed by constellations of satellites (systems, or even systems of systems), rather than single spacecraft like those of the outstanding *Landsat* series. To make it clear, I recognize and admire the *Landsat* data value. Furthermore, as we astronomers so much know, long standing observational series are invaluable tools that unfortunately are not that common nowadays. As a member of a space agency, I have seen far too many times, people asking for a '*Landsat* image', rather than 'an image', because of its value added characteristics. It simply happens that global monitoring will demand a variety and frequency of coordinated measurements that will have to be obtained by many satellites. The proliferation of constellations and/or systems will also enhance one of the most distinctive characteristics of space research, international cooperation, that will become not just convenient but also necessary. This again underscores the importance of the creation of international consortia.

Last, but not least, a word about human exploration. Even though resisted by many of my colleagues, scientists that rightfully point out that with the funding spent in sending humans to space many world class missions, including robotic missions to the Moon to Mars and other planets, could be afforded, I am certain that human exploration will be very much alive in the next fifty years and may also bring unanticipated benefits to science and life on our planet. During this period man will again walk on the surface of the Moon (men and women of more than one nationality) and most likely establish a permanent or semi-permanent presence there. On the other hand I am very skeptical about a Mars mission in the next five decades. The challenges of such mission, in terms of the resources and life support systems that are necessary are, needless to say, far greater than anything we have experienced before in history. It can only be accomplished in such timescale by a space consortium, the largest possible consortium. In fact, if this were to be realized, it may turn out to be the ultimate societal benefit that space exploration can bring to humankind.

Since *Sputnik-1* not only marked the beginning of the space age, but was also in many ways 'a product or child of the cold war era', in case it happens it would be its greatest legacy!

Atsuhiro NISHIDA
JAPAN

Executive Director at the Graduate University for Advanced Studies (Sokendai), and President of the Asia Oceania Geosciences Society.

Born in 1936 and graduated from the University of Tokyo in 1958. He received his Sc.D. degree from the University of British Columbia in 1962.

He spent most of his carrier at the Institute of Space and Astronautical Science (ISAS), Japan, and served as its Director General from 1996 to 2000.

He wrote a monograph *Geomagnetic Diagnosis of the Magnetosphere* (Springer) in 1978 around his early works. Since 1980's he managed the *Geotail* satellite program to investigate the dynamics of the magnetotail.

He has been awarded by the American Geophysical Union, European Geophysical Society, Russian Astronautics Association, Japan Academy, and COSPAR.

LEGACY OF THE SPUTNIK-1: A VIEW BY A JAPANESE SCIENTIST

The launch of the *Sputnik-1* was received with excitement in Japan. Signals received at each orbit over Japan were reported by radio, and a scientist who operated a ground receiver became an instant celebrity. It was the time when the effect of the post-war ban of the aeronautical research was still lingering in Japan, and development of a sounding rocket for the International Geophysical Year had just been started. The magnitude of the achievement was clear to everyone. It gave the fledgling Japanese space program a powerful impetus.

In the fall of 1957 I was a student at the University of Tokyo majoring in geophysics. I was at the fourth school year and planned to proceed to the graduate school. But I could not decide which branch of geophysics to choose. Like many students who enrolled in the Department of Geophysics I wanted to clarify the secret of nature and thereby contribute to the welfare of humankind. Seismology, meteorology and oceanography are the areas which can satisfy the desire to do both basic and applied research as they address the earthquake, weather and environment that exert significant influence on human life and society. But I could not find the geoscience at that time particularly attractive. Recall what the geoscience was like in 1957. Plate tectonics was in the minds of a few pioneers only and it was still a few years before the idea was published and revolutionized the solid earth science. Electronic computer was still a subject of the engineering research and it took a few years before it became available as a popular tool of research. In short, this ignorant and a little ambitious young student thought that the classical geophysics was boring.

Then the *Sputnik* was launched. As a geoscience major I had learned the critical importance of the observations. Observations are the fundamental element of geoscience which provides problems and invite solutions. The stagnation of the classical

geoscience in 1950's was mainly because of shortage of new means of observations. The launch of *Sputnik* changed the scene. All of a sudden the vast new space was literally opened for active research. This new space is going to reveal fascinating new phenomena that await challenge, I thought. The observations in space would make it possible to test the hypotheses that had been built on the remote-sensing observations from the ground and to move ahead toward the deeper understanding of nature. This is the direction I should take. So I joined the laboratory of geomagnetism which addressed the physics of space by using the geomagnetic observations on the ground. This choice determined the course of my life. Coming from this background, I am very pleased and feel much honored to be invited to join this Celebration of the *Sputnik* launch exactly 50 years after that day.

I was soon to witness the power of the observations by spacecraft for my own research. In early 1960's the mechanism by which the solar wind imparts its energy and momentum to the magnetosphere was the hot issue. Two possibilities were suggested: one was mechanical and the other was electromagnetic. According to the latter the reconnection between the interplanetary and geomagnetic fields couples the solar wind with the interior of the magnetosphere. I originally favored the former which I thought was simpler. So when I compared the interplanetary magnetic field data of IMP-1 released from the NASA Data Center with geomagnetic DP2 fluctuations in 1967, my objective was to show that they were not correlated. (DP2 is a new type of geomagnetic variations which reflects time variations in the magnetospheric convection I had discovered it in 1964). Contrary to my expectations, DP2 variations and IMF were beautifully correlated peak-to-peak, which suggested that the mechanism was electromagnetic. I immediately converted and became a firm believer of reconnection. Later I proposed and managed the *Geotail* satellite mission that delves into the magnetic reconnection process in the magnetosphere. This satellite was launched in 1992 as the forerunner of the International Solar-Terrestrial Physics Program (ISTP).

ISTP was a program where three space agencies of the world, namely European Space Agency, NASA, ISAS*and also Space Research Institute of Russian Academy of Sciences (IKI), collaborated to study the physics of the plasma environment of the Earth. These agencies deployed a flotilla of spacecraft that formed a network of space observatories at strategically key regions in the solar wind and the magnetosphere. It was an ambitious project that involved ten satellites plus some subsatellites. Not surprisingly the people who promoted and led this program at each agency belonged to the *Sputnik* generation, by which I mean the first generation of space scientists who like myself started their carrier right after the launch of the *Sputnik*. It was a most pleasant experience to make friends with the peers of this generation worldwide and to join the forces to build the milestone program overcoming various difficulties on the way.

The advent of the artificial satellite has had profound effects over a broad range of human activity. To us, the Japanese, the opening of the intercontinental TV transmission via telecommunication satellites was marked by an unforgettable event; assassination of President Kennedy in November, 1963 happened to be the first scene transmitted by a satellite from the other side of the Pacific. One year later the 1964 Tokyo Olympic became the first Olympic game that was telecast to the world via satellite. The meteorological satellites have become an indispensable means for forecasting weather. A meteorological observatory on the summit of Mount Fuji (3776 m) which had played a key role for 72 years was replaced by a robot station. The use of satellite

* Institute of Space and Astronautical Science of Japan Aerospace Exploration Agency.

network for the precise positioning is relatively new but the Global Positioning System has quickly become a common tool for navigation. One can go a long way listing the areas where artificial satellites are being used to make life more convenient and more comfortable.

But the most far-reaching consequence of the advent of artificial satellites may have been the détente. In the days of the ‘cold war’ the competing super-powers developed super-weapons against each other and the state of their readiness was the super-secret. To penetrate the secrecy US developed the U-2 plane but it proved to be an extremely risky mission politically and strategically. With artificial satellites it became possible to monitor the backyard of the other party routinely from a safe distance. Hide-and-seek became an extremely costly game to play and eventually they had to give up. This may be just a part of many reasons that brought about détente, but I guess it was one of the most significant.

When the space age began we had even grander expectations that satellite communications would make the world everywhere a peaceful place to live. Communications via satellites would spread any news instantly over the world and unite the humankind by the shared information. Unfortunately this expectation has proved to be naïve; In spite of détente, armed conflicts are still rampant in the world today. The global exchange of information does not seem to have made us more rational, either, as judged from the fundamentalist movements whose influence seems to be even on the rise. It is clear that humankind gained much by the space development and did not lose anything, but the gain has not been as grand and sweeping as we had expected.

From the mythological times, humankind had three basic questions. These are the structure and origin of the Universe, of the Solar system, and of life. The availability of observations in and from space has done a great deal in advancing our pursuit in the questions on the Universe and Solar system, and our hope is rising high that it can also contribute to the clarification of the origin of life. If life can be found on the planets and/or satellites other than the Earth, its genes and their comparison with those of the lives on the Earth should provide canonically important material in this quest. Evidence of water that nurtures life has already been detected on Mars, and there is also a strong indication of its presence on Europa. Fascinating new era of science is expected to open before us.

On the technological side, the Japanese asteroid mission *Hayabusa* is pushing the limit of the robotic exploration of the Solar system. Even if it is foreseeable that astronauts would be sent to nearby planets in the 21st century, such approaches cannot be expanded to most other bodies in the Solar system. It will be required to build more sophisticated, efficient, and reliable spacecraft to explore a variety of Solar system bodies. Advances in the robotic technology should be essential, and this would be particularly important for exploring traces of life and examining possible evidences of its evolution on other bodies of the Solar system.

Space technologies driven by science requirements will continue to push the frontier of engineering. Robotic technologies that are developed for use in extreme conditions of space, such as high/low temperature and high radiation dose, will stimulate the development of robotic instruments for use in other extreme conditions in nature and in industrial devices. Space opened by *Sputnik* is a fertile ground for innovation as well as imagination.

AROUND THE WORLD IN 1,5 HOUR

Risto Juhani PELLINEN
FINLAND

Director of Science in Space Research at the Finnish Meteorological Institute.

Born in 1944. M.S. in 1966; Licentiate of Philosophy (theoretical physics) in 1970; Ph.D. in 1979. Employed in the Finnish Meteorological Institute (FMI) since 1972 (Senior research scientist, Chief of Aeronomy Division, Professor, Head of Department of Geophysics, Director of Science in Space Research since 2003).

Advisor to the Swedish and Finnish Space Boards for 15 years, to ESA (European Space Agency) Director of Science for 6 years, and to ESA Director General for 4 years. Key scientist in starting and coordinating co-operation in the fields of geophysics and space physics with the Soviet Union/Russia for nearly 30 years.

Head of a small delegation that made the first official contacts with IKI and *Intercosmos* and agreed on the principles of scientific collaboration between research institutes in Finland and Soviet Union.

Awarded by Gagarin Medal (2005); EGU (European Geosciences Union) Honorary Membership and Jean Dominique Cassini Medal (2006).

SPUTNIK SHOWS THE NEW WAY

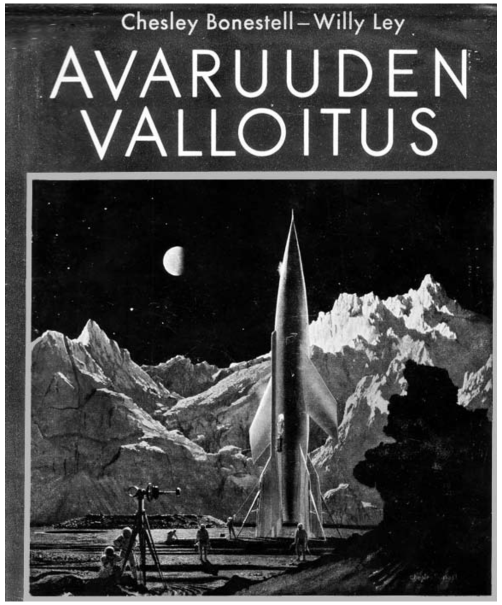
SPUTNIK IN MY PERSONAL LIFE IN THE MID 1950’s

By the time when *Sputnik* was launched I was a 13 year-old schoolboy. I was at that age of transition from childhood to the days of youth. Toys were exchanged for transistors, books of fairy tales for books of excitement, lullabies for rock’n’roll sung by a new star, Elvis Presley. The environment was also changing. Technology students in Finland started TV transmissions in 1955 and Finland joined the United Nations the same year. News was received only through radio or newspapers. Short, non-stop movies presented at ordinary movie theatres served as an important information channel for the continuous change and development of the world. By the end of the 1950’s and beginning of the 1960’s this task was gradually transferred to regular TV broadcasts that brought daily news to every home.

By the time *Sputnik* was launched, I had on my bookshelf two interesting books about space. I still have them as valuable pieces of evidence about what was thought about space at that time. One book was published in 1952 with the name *Conquest of Space*, which gave an impressive view of a round trip in our Solar system with colour pictures. They are artist’s views, but quite close to the real ones that we can catch today from any media dealing with space. Another book, which has my signature from 1956, is named *Conquerors of the Solar System* and was published already in 1947. In this book atomic-powered rockets flew from planet to planet, Titan being the last destination. Through these books I became aware of spaceflights, rockets and dreams of mankind's future, even before the space age had started.

At school my physics classes started in autumn 1956. The teacher was very inspiring and somehow he was also involved in the preparation activities for the International Geophysical Year (IGY), which started July 1, 1957. Through him I learned that something remarkable was going to happen and I can still feel the excitement created during his lessons. In principle, I was well prepared for the start of a new era for mankind. I do not remember where I was exactly when the news of the launch of *Sputnik* was announced. I assume it was an ordinary day and the event was made public through radio news. During the following days newspapers followed *Sputnik's* flight closely and the *Helsingin Sanomat*, the main news media by that time, gave precise timetables for the evening-time passages of the satellite.

Near my home at Helsinki was a Russian church, the Uspenski Cathedral, which was located on a high hill with a relatively dark background. I remember going there evening after evening to follow the bright spot that crossed the dark sky with a visibly high speed. There were plenty of people, and there was always someone who was well aware of the satellite's timetable and kept us others informed of the right observing moment and direction. Staring at the dark sky covered with spots of stars and waiting for *Sputnik* to come has remained clearly in my memory like it had happened yesterday. But up to that time I was still not aware that my future professional career would take place in this field.



The cover of *Conquest of Space*, written by Willy Ley and published in Finnish in 1952. In right is an artist's view of the Saturnian moon Titan, not too far from the real ones we have seen recently. Painted by Chesley Bonestell. (Avaruuden valloitus, WSOY, 1952)

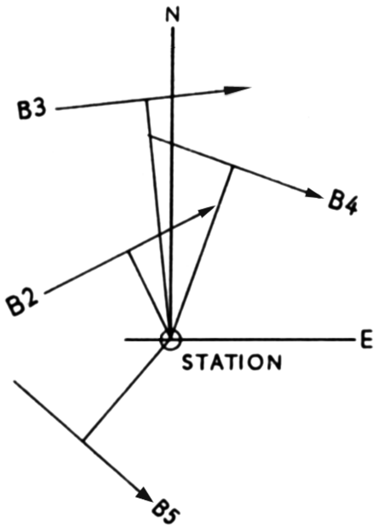
AROUND THE WORLD IN 1,5 HOUR

A group of directors from the Finnish Meteorological Institute visiting IKI (Space Research Institute of Russian Academy of Sciences) in January 2006. I am standing second from the right and a full-size copy of *Sputnik* is hanging above us

SPUTNIK TRIGGERS THE START OF FINNISH SPACE ACTIVITIES

An essential part of Finland's participation in the IGY were the satellite observations of the University of Helsinki's astronomy professor, Gustaf Järnefelt, which began on October 13, 1957, only nine days after the launch of *Sputnik-1*. Optical theodolites made for observing weather balloons were used at the meteorological observatory at Jokioinen, under the direction of M.Sc. Pentti Järvi. Visual observations enabled very accurate measurements of the satellite's orbit, from which properties of the Earth's atmosphere, the Earth's shape, and the structure of the Earth's gravity field could be calculated.

Also, Dr. Vilho Vaisala, founder of the Vaisala Ltd. company, joined the satellite tracking activities by converting his radiotheodolite, normally used for tracking balloon-borne radiosondes, to a frequency of 40 MHz, which allowed reception of the *Sputnik* radio signals. Altogether 12 passages during the nights from October 10 to October 13 were recorded at the observing site near Helsinki. The mean value of the orbit inclination was found to be 65.40 degrees with a 65.79-minute orbit period.



Four *Sputnik* passages during the night 11-12 October 1957 tracked by a 40-MHz radiotheodolite near Helsinki. (*V. Väisälä* // Geophysica, V. 5. No. 4)

During the IGY numerous satellites were orbiting the Earth. By April, 1959 some 15 satellites had been observed at Jokioinen, as well as the final stages of their launch vehicles. The Jokioinen observation station distributed its results daily to a network of foreign stations. Dissemination took place in the form of airmail, teleprinter, and telegram, originating at first from the Helsinki Observatory, but from May, 1958 data were distributed by the communications centre of the Finnish Meteorological Office.

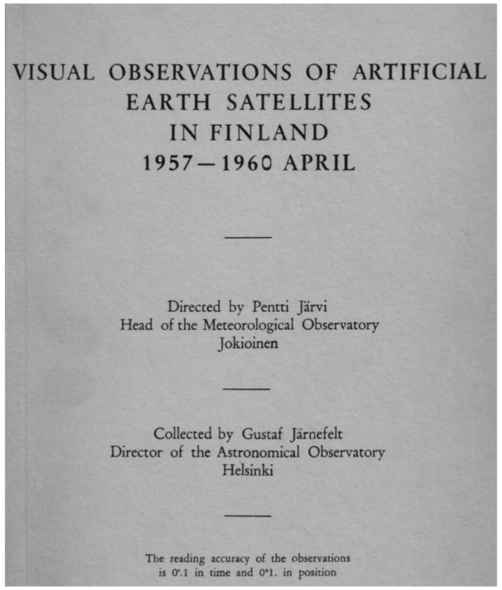
Finland's government and other official quarters showed a surprising enthusiasm for the observations. The Finnish Government, the Finnish Broadcasting Company, and the University of Helsinki donated enough funds to purchase a new, automated theodolite and to hire observers. Fortunately, as Järnefelt had foreseen, there were already sufficient trained personnel at the meteorological observatory at Jokioinen. These people had already been tracking balloons, even at night, using the same sort of process needed for tracking artificial satellites, just as Järnefelt had pointed out with pleasure.

Politically the decisions made in the late fall of 1957 concerning satellite observations were connected to assuring cooperation with the great powers. In this regard there were no problems from abroad; Finland worked in the satellite observation network in a perfectly normal way. Everything took place in the IGY framework. Satellite observations were collected for publications, which could be used later to support joining COSPAR. Of course, this was not part of the original intention, because COSPAR only materialised in the space research world a year later, in November, 1958.

Thanks to the IGY and the launch of *Sputnik* space research matured and rose to a new level worldwide. Satellites played a significant role in that development, but the IGY raised that level when it brought to life a joint effort by the international community of unprecedented breadth.

In November, 1963 the Finnish Academy of Science and Letters formed a committee chaired by Prof. Järnefelt to prepare for Finland's membership in COSPAR. Shortly thereafter the committee submitted a request to the Ministry of Education for funding to cover the 1 000 US dollars membership fee, which was immediately approved.

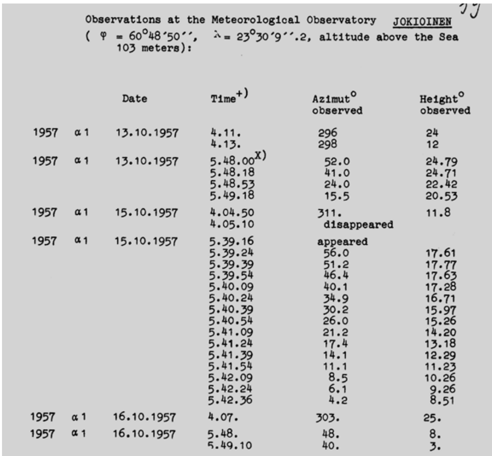
Upon receiving the grant the committee stressed its being merited with the remark, '*...moreover, the following reports and publications demonstrate the ability in our country to produce important and significant space research results*.' They were publications of Professor Järnefelt's results in tracking artificial Earth satellites: G. Järnefelt, *Visual observations of artificial satellites in Finland. Three volumes 1957–1962*; G. Järnefelt, *On the satellite observation work done in Finland*; and G. Järnefelt, *Nabljudenija za iskusstvennymi sputnikami Zemli.*


VISUAL OBSERVATIONS OF ARTIFICIAL EARTH SATELLITES IN FINLAND 1957—1960 APRIL

Directed by Pentti Järvi
Head of the Meteorological Observatory
Jokioinen

Collected by Gustaf Järnefelt
Director of the Astronomical Observatory
Helsinki

The reading accuracy of the observations is 0ˢ.1 in time and 0°.1 in position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Observations at the Meteorological Observatory JOKIOINEN
(φ = 60°48′50″, λ = 23°30′9″.2, altitude above the Sea 103 meters):

		Date	Time+)	Azimut° observed	Height° observed
1957	α 1	13.10.1957	4.11.	296	24
			4.13.	298	12
1957	α 1	13.10.1957	5.48.00x)	52.0	24.79
			5.48.18	41.0	24.71
			5.48.53	24.0	22.42
			5.49.18	15.5	20.53
1957	α 1	15.10.1957	4.04.50	311.	11.8
			4.05.10	disappeared	
1957	α 1	15.10.1957	5.39.16	appeared	
			5.39.24	56.0	17.61
			5.39.39	51.2	17.77
			5.39.54	46.4	17.63
			5.40.09	40.1	17.28
			5.40.24	34.9	16.71
			5.40.39	30.2	15.97
			5.40.54	26.0	15.26
			5.41.09	21.2	14.20
			5.41.24	17.4	13.18
			5.41.39	14.1	12.29
			5.41.54	11.1	11.23
			5.42.09	8.5	10.26
			5.42.24	6.1	9.26
			5.42.36	4.2	8.51
1957	α 1	16.10.1957	4.07.	303.	25.
1957	α 1	16.10.1957	5.48.	48.	8.
			5.49.10	40.	3.

Satellite observations from the meteorological observatory at Jokionen started nine days after the launch of *Sputnik-1* (Finnish Meteorological Institute)

In the years following IGY it was seen clearly that Finland was that sort of '*country that was active in tracking satellites and other space research*'. Such was the description offered by the committee appointed by the Finnish Academy of Science and Letters to prepare for Finland's COSPAR membership in November, 1963, reflecting COSPAR's rules.

In early January, 1964 the committee requested the Finnish Academy of Science and Letters to apply formally for COSPAR membership and named the first Finnish National COSPAR Committee, with Prof. Gustaf Järnefelt as chairman. Membership began on 2 June, 1964.

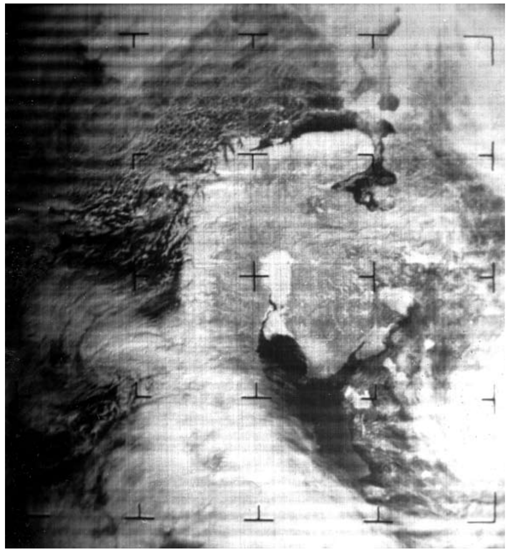
It is clear from the above that the readiness in Finland to observe satellites with both optical and radio methods existed due to the earlier development work for observing wind drift velocities of meteorological balloon sondes. The techniques were immediately utilised for satellites, which provided a firm background for Finland to take the next step, joining the international COSPAR organisation.

SPUTNIK GIVES A BOOST FOR INTERNATIONAL DEVELOPMENT

After it was demonstrated that satellites could be launched into Earth orbits it was quite natural that rapid development and competition took place on this field.

Sputnik-1 was an aluminium ball with a 58 cm diameter. It had two radio transmitters onboard, but no other dedicated scientific equipment. Scientific instruments to monitor solar radiation were launched already one month later with *Sputnik-2*, which carried as well the first live passenger, the dog Laika. In practice this meant that within

The *Space Future Forum* was arranged in Moscow around the 30th anniversary of the *Sputnik-1* launch, in October, 1987. The photograph taken in the front of the Juri Gagarin museum in the Star City highlights the history of space conquest. From the left are Valentina Tereshkova, first woman in space, Kathryn Sullivan, second US female astronaut, Jean-Loup Cretien, first French astronaut, Dick Gordon (with sun glasses), an *Apollo-12* astronaut on the Moon surface, and Aleksei Leonov, the first space walker. Just by chance I happened to be the next face on the right hand side of Leonov. I am very proud of this 'family' picture, which was taken with my own camera. (Finnish Meteorological Institute)



Weather satellite image received at the Helsinki University of Technology Radio Laboratory on 27 March, 1967. This image, showing ice conditions on the Gulf of Bothnia, was one of the very first received in Finland. (Helsinki University of Technology Radio Laboratory)

one month, at the very beginning of the space era, all the various disciplines of modern space activities were carried out and tested.

And the development work was even accelerated. On 12 April, 1961 Yuri Gagarin made the first manned flight in space onboard the *Vostok-1* spacecraft; President Kennedy announced in May 1961 that the US would land astronauts on the Moon before the end of the decade and Aleksei Leonov made the first 12-minute space walk on March 18, 1965 from the *Voshod-2* spacecraft. This was an incredible boost of international activities, all realised or started before ten years had passed after the *Sputnik-1* launch. This was the era of miracles and rapid growth in various space technologies.

Space organisations were founded all over the world. Some of them were able to progress quickly, while some needed more time to mature for their task. Europe is a good example of the latter case. Balancing between civil and military goals in space was not an easy task, especially when in some cases most of the funds for development work seemed to come from the military side. '*Peaceful purposes*' was a key word in many actions dealing with pure scientific activities. Scientific purposes created pressure on industry to work with something they never had done before. The impossible was made possible through scientific space projects.

On the technical side, computer technologies started to develop more rapidly due to the new pressure. The same happened with software technologies. New materials had to be developed for space and semiconductor technologies, too, had to meet the demands for reduced mass, size and power consumption. Telecommunication methods had to adapt to the growing demands for operation in an extreme environment and transmission of more and more data in shorter times. Radiation hazards for materials and components and even living organism had to be estimated quickly and preventive technologies developed. Most of these research and development activities had to be carried out within only 15 years after the *Sputnik-1* launch.

Gradually benefits for everyday life started to become visible. Already in the late 1960's several new application areas were introduced to the public. Weather satellites started to support forecasting services. In Finland the first satellite images of ice cover on the Baltic Sea were received in spring 1967. This was a modest start but it occurred only 10 years after the start of the space age. Today land resources, weather patterns, traffic conditions, and television and data transmissions are obtained through satellites. We have grown to be so dependent on satellite technologies that if all the functioning spacecraft were switched off only for an hour the whole world would enter into a complete, long-duration chaos.

The symbol of the *Apollo* programme for the future generations: an astronaut's footprint on the Moon sand

In the wake of the highly successful *Apollo* programme actions were taken that have expanded our knowledge and understanding of the Universe. *Pioneer-10* and *-11*, together with *Voyager-1* and *-2*, all launched around the mid 1970's, have provided images and data of all the bodies in our Solar system except Pluto, which is in today's focus. The image of the Universe has been expanded by other space probes, especially the *Hubble Space Telescope*, launched in 1990 and in operation ever since. Society has received the 'gifts' of these missions with high respect and pleasure, and when there was a risk of closing *Hubble*, it was public pressure that forced NASA to retract its decision. This is a completely new dimension of behaviour in space matters and of importance for the future. Future large missions must have a clear and visible cultural impact and have to be approved and supported by the public at large.

The very earliest steps in space history have had a strong manned flight component. Bringing man to space has been considered to be the highest grade of space qualification for a nation or an organisation. Today it seems to be relatively easy and 'cheap' to launch a human to space and more and more nations are joining astronaut training programmes. Making long-duration flights is a different issue and creates much higher challenges for individuals. The psychological and physiological aspects are focus areas of research in many organisations at the moment. The lessons learned also have an immediate impact on human life on the Earth. The two large-scale space stations put into orbit since 1986, *Mir* being the first one, have offered suitable test platforms for studying various aspects of human behaviour and life in microgravity conditions.

Working with space projects has enhanced international cooperation in remarkable ways. Pioneer organisations have seen newcomers entering the field and proceeding towards their goals in a very determined way. China and India are on express routes to the Moon and other destinations in space, while Japan is continuously developing and expanding its space programme. The traditional balance between Europe and the US has got a third leg in the Asia. This looks promising, but success in building an effective network of collaboration is still to be seen. The potential is high but many compromises and accommodations have to be found on a political level.

Today we can cross the Atlantic in less than 10 hours by paying less than 10 USD/kg for the ticket. When Charles Lindbergh first made it in 1927 the cost was uncountable, because it was the first time. Sending instruments to space costs today between 4000-10 000 USD/kg and the price goes down all the time. Sending a tourist for a week to the ISS costs about 250 000 USD/kg including the training program. A short 3-hour trip to near space has been estimated to cost ~250 USD/kg. In 1927, 80 years ago, obviously nobody could imagine just buying a cheap ticket and getting onboard a fancy plane to be on another continent after just a few hours without too much extra trouble. This same development could be true with space in a not too distant future.

SPUTNIK, THE FIRST MILESTONE FOR THE FUTURE

Since the launch of *Sputnik-1* and *-2* in 1957, on the average two satellites per week have been launched into space. Today nearly 700 operational spacecraft serve the needs of the population on Earth. Humans have visited space (among them five tourists) more than 800 times and spent altogether about 20 000 days there. Twelve men have walked on the Moon. Humans have been living at low-Earth orbit (LEO) continuously for 20 years. The International Space Station (ISS) is about to be completed and manned activities beyond the ISS era and establishing a permanent Moon base are under consideration.

Sputnik was the first milestone in space, landing man on the Moon the second one and everything that has occurred since then can just be considered as preparation for the third milestone, which, without a doubt, is sending humans to Mars.

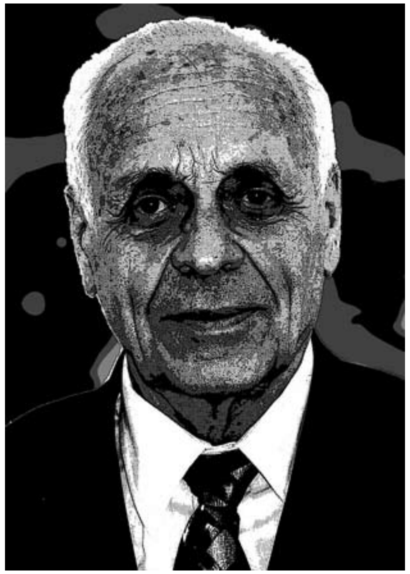
Today we are much better prepared to take the next step than mankind was in 1961, when US President John F. Kennedy announced that US would go to Moon before 1970. Up to that time only one manned flight had been carried out in space. Today we have enough knowledge and experience that we could start working towards a manned Mars flight almost immediately. However, it is advisable to stay cool and first take the scientific steps needed during the coming 20-25 years. This is a great opportunity for planetary science and we should not lose it.

Keeping in mind the *Hubble* experience cited above, the scientific community should start acting now. It is not enough that we are aware of the opportunity; we have to bring the message to the public. Only scientists can redirect people's minds by advertising the new challenging visions and by spreading information about their scientific activities. Some 20-25 years from now nearly every human being on this planet should anticipate with excitement mankind's next explorative step and feel willing to contribute to the event. The media's appetite for Mars information should be stimulated continously. Mega-publicity is needed to generate the required public interest.

Whatever the future of the world, space activities are growing in volume and importance on a global scale and integrating ever deeper in each nation's every-day life. Today, when space research has revealed striking new features of the Universe and our own Solar system, we know one fact for sure: coming generations will know incredibly much more than we, who have only witnessed the first few decades of space research.

And so it is most appropriate that today we celebrate the two launches a half a century ago that opened the space era. *Sputnik-1* and *-2* startled the world and thus set into motion the efforts in space that have led to so many advances and astonishing discoveries. They outlined and defined the nature of much of the work of the next 50 years. And, finally, they pointed to the future.

Possibly the first Finnish spacecraft, presented at the *Space 2003* exhibition in Helsinki. It is a small Mars lander, built together with some Russian institutes. It uses inflatable technologies during the descent phase. Professors Risto Pellinen and David Southwood are discussing the feasibilities of the lander



Grigory CHERNYAVSKY
RUSSIA

First Deputy Director General – Chief Designer of Federal State Unitary Enterprise 'Russian Institute of Space Device Engineering', Head of Research Centre for Earth operative monitoring. Doctor of Science. Professor. Corresponding Member of Russian Academy of Sciences.

Born in 1926 in Moscow. Graduated from Moscow Ordzhonikidze Aviation Institute in 1949. Head of System Designing Center in TsNIIMASH (Central Research Institute for Machine Building) in 1984–1992. Acting Director and then Director (1992–1998), later Director and Chief Designer in the Center for Program Research of Russian Academy of Sciences (1998–2000). Director General and Chief Designer in the Centre for Earth Space Monitoring in 2001–2006.

Awarded the Order of Lenin twice, Lenin Prize (1976), State Prize of the USSR (1969) and 8 medals.

RETROSPECTIVE LOOK AT THE LAUNCH OF THE FIRST ARTIFICIAL EARTH SATELLITE

50 years ago for the first time in history of mankind an artificial satellite was delivered into orbit by Soviet Union.

This unique event was conditioned by the evolution of earthly civilization which has resulted in the qualitative growth of its energetic and informational potential in the 20th century.

Contemporaneous growth of the immensity of ecological, economical and social problems, illusions of unlimited possibilities of anthropogenic activity, low moral values, imperfection of political order are bringing the danger of uncontrolled, unpredictable scenario of events, are threatening the planet Earth with a catastrophe.

As history shows, the prime force able to prevent the destruction of society is the collective human mind whose intellectualization is growing with the enlargement of social sphere. Launch of the first artificial Earth satellite (AES) gave start to the expansion of social sphere towards the space scale.

Dialectics is teaching that the progress of society is driven not least by the features immanent to mankind such as competition, rivalry and unfortunately military opposition. It is those factors that have determined the advent of the first Sputnik and the

following impetuous progress of cosmonautics. By launching the first Sputnik Russians have thrown out a challenge in the field of science — and of military power.

For estimating the historical value of the first AES launch it is obviously expedient to refrain from panegyrizing the first spacefaring nation, and having spotlighted the history, to try to get a sense of purposefulness of the space activity in our country and abroad. One should remember meanwhile that judging the past is easier than the present.

1. FLIGHTS TO SPACE

The dilemma of utilization of material properties and shapes of space in the social sphere is far from trivial, requires rather significant resources, stipulates the integration of various fields of knowledge and technologies on a global basis.

Presently the ideas of K.E. Tsiolkovsky about spreading the earthly forms of life throughout the Universe appear to be merely figurative. At the same time the indirect and direct appearance of Man in space is already qualitatively enlarging the social sphere today.

The space activity penetrates both material and spiritual sides of human life. Its value for the social mentality, ethic, moral is high.

'*Two things fill the mind with ever new and increasing wonder and awe '— the starry heavens above me and the moral law within me.*' (I. Kant)

The space activity is multidisciplinary and as any complex problem requires the system approach.

During the past 50 years the main directions of space activity have been shaped: exploration, research and utilization of space. The complex of transportation and information tasks is being solved meanwhile.

The transportation task before and during the launch of first AES was identical to the final purpose. Solving it gave start to the whole space activity and provided the delivery of the first spacecraft (S/C) into orbit.

The beginning of space age is conditioned by the advances of the Soviet military industrial complex in the rocket engineering area. Works on jet propulsion problems have obtained the state support in Soviet Union in early 1930's in the framework of solving the weapon tasks. The center of gravity was shifted towards the solid missilery which was, by the way, forgotten in the post-war years with USA taking over the leadership in the development of solid-fuel intercontinental missiles.

As to the prehistory of the first space flight, it is related to Germany. In the mid-1930's, when the military department has appreciated the prospects of the rocket weapons, the full-range activity has started here on the development of liquid fuel vehicles. In 1942 a rocket was sent beyond atmosphere which has crossed the space boundary at the height of 100 km.

It was yet before Second World War that Germany actively developed radio-technical industry whose products were world-renowned, which has created the background for building the automated controlled rockets.

The industrial manufacturing of ballistic missiles established in Germany during the war has became not just the base for the future works on the rocket-space technology in the whole world, but has also shown the advantages of system approach to the complex problem, ability to mobilize the resources and the competence in management of achieving the specified goal.

It was only USA and Soviet Union with their scientific and technical potential that were able to make use of the results obtained by Germany in the field of rocket making after the war. The Soviet Union has fully utilized these possibilities. The world's first intercontinental missile created in USSR with the main purpose of putting an end to USA invulnerability in case of nuclear war has provided the breakthrough to space.

The historical value of this event consists in the fact that first orbital velocity was achieved. Intercontinental ballistic missile has played a role of the first launch vehicle.

A complex of scientific, technical and management problems has been solved, with the lag in radio-technical industry and automated instrument-making engineering removed, though it appearing later again and becoming 'chronical'.

It is hard to imagine now the intensity of works in the area of rocket making that were carried in the country: 16 types of liquid fuel vehicles with a flight range up to 1200 km and height over 200 km were manufactured and tested since 1948 to 1956.

The historic success of Soviet Union is explained by a number of reasons:

- the people of our country having survived the devastating war were ready to any self-sacrifice for the sake of providing independence and world prestige of their country. The population was convinced in the need of creating the perfect weapon systems, and after the launch of the first AES — in the necessity of space flight;
- Soviet state machine had the ability to mobilize huge resources for achieving the goal, though using illogical and sometimes criminal methods. It is of big importance that the goals set by the Soviet order were flawless: social justice and state independence;
- the political management of country and its highest officials have adequately responded to the German successes in rocket building, showed system approach to solving the problem of creating the rocket-nuclear weapon, and later supported the space flights. The role of N.S. Khrushchev was very important;
- the distinguishing feature of Soviet scientific and technical elite was the fact that their creative work – the meaning of life – was directed toward the specific technical result to the benefit of state; it had inherent collectivism and the sense of personal responsibility before the state, as well as combination of individual creativity with the managing activity;
- our remarkable compatriots stood at the outset of cosmonautics: K. Tsiolkovsky, F. Tsander;
- the program of penetrating the space was headed by the most talented scientist, engineer, manager and in the same time – dreamer Sergey Pavlovich Korolev. He was able not just to solve global problems, but also to set them; the creators of rocket-space technology were the giants like Valentin Petrovich Glushko, Mstislav Vsevolodovich Keldysh, Vladimir Nikolaevich Chelomey, Mikhail Kuzmich Yangel.

2. FIRST RESULTS IN SPACE

With the launch of the first AES the research of space has begun. In the space research the goal is set of handling the information in order to investigate the nature of space and Earth as its constituent part with the aid of the space based technical facilities. The direct presence of measuring devices in the explored medium is qualitatively changing the information about it.

The first direct measurements of several parameters in space were performed by the third Soviet AES with 12 scientific devices onboard. But even during the operation checkouts of the first AES some data about space were obtained indirectly.

The preparations and launch of the first AES of the simplest design with the mass under 100 kg have simultaneously served as the beginning of spacecraft manufacturing. A year after the first satellite launch the utilization of space has begun which includes the direct satisfying the needs of society with the aid of the space based technical facilities.

The design of the spacecraft (artificial Earth satellites, interplanetary stations, space ships) is differing from the launch vehicles due to their goals, environmental impact factors and lifetime which determine the characteristic approach to their manufacturing and usage.

The spacecraft manufacturing in Soviet Union has been developed under the auspices of Sergey Pavlovich Korolev in his collective, as well as in the institutions led by Georgiy Nikolaevich Babakin, Dmitry Ilyich Kozlov, Mikhail Fedorovich Reshetnev.

The goals of space research and utilization have stipulated the creation of the appropriate space rockets (launch vehicles and boosters).

In this conditions the programs of modifying the military rockets R-7, R-14 and others were carried out. However, the system approach was not always followed.

The dependence of launch facilities outlook on the assigned information task has clearly shown up in the 'moon race'. Its fuzziness has lead to the serious difficulties, and perhaps to the failure of creating the N-1 rocket.

The *Proton* launch vehicle developed without matching to specific payloads was lying there doing nothing for decades until finally finding its application. More tragical was the fate of heavy *Energia* launcher rocket devised by V.P. Glushko which has left without payloads. As a result only one of its blocks is being used today as *Zenit* launch vehicle.

Angara launch vehicle despite the 50-years old experience is designed again without the program of usage and utilization in space, on the basis of general reasoning as it is commonly in the space industry now.

The first decades of the space age were rich with the events. During this period dozens of Soviet and American satellites of the scientific and applied destination were residing in orbit. Missions to the Moon and the Solar system planets have started.

Soviet Union was retaining the leadership thanks to the intellect and the moralities of the wide range of the space activity participants with the huge strain of the industrial potential of the country.

During the race for the priority in achieving the data about the Moon and Solar system planets which had both the informatory and advertising nature, 24 autonomous Lunar stations and 16 *Venera* stations were launched in Soviet Union, seven flights for studying the system of Mars were performed. The back side of the Moon was photographed for the first time (1959), soft landing on our satellite performed (1966), atmosphere of Venus explored (1967), lunar soil delivered to Earth by automated facilities (1970), soft landing on Venus realized (1970) and its surface imaged (1975).

Four years after the launch of the first AES in space Soviet Union became the homeland of the first cosmonaut. This was the second epoch-making event in cosmonautics and the beginning of on-the-scene stay of Man in space.

The apogee of space activity was the landing of American astronauts to the Moon in 1969. The ‘Moon race’ was lost by the Soviet Union, and there are solid grounds for that.

Americans piqued by the victories of our country in space have declared the Lunar program as the national priority in 1961. In the next eight years this project was realized, by the way with the participation of dozens German rocket specialists headed by Wernher von Braun.

These were the days when the considerably superior economics has allowed USA to get twenty-fold predominance over Soviet Union in the nuclear potential. Our country, in order to provide its safety, was forced to enter the more difficult and hard race than the lunar one. As a result, by 1975 the gap was reduced to the 3:1 ratio.

Due to the above mentioned reason the political management of the country has not timely and clearly stated the goal of piloted flight to the Moon. The change of leaders itself has made effect which was followed by the poor funding and unreal terms of plan realization.

There were also subjective factors. Besides S.P. Korolev, there were also V.N. Chelomey and M.K. Yangel involved into the competitive battle. Principal disagreements have appeared between S.P. Korolev and V.P. Glushko. It was not without the latter’s participation that no serious developments on the hydrogen fuel were held in USSR by the start of lunar race. S.P. Korolev has made serious mistakes in the strategy of ground testing of launch facilities.

Having lost the leadership after the lunar triumph of USA, Soviet Union has reached the priority results in the manned flight on the low orbits, rocket engines manufacturing, creation of automated operation systems, satellite radio communication and in other fields.

3. RESEARCH AND UTILIZATION OF SPACE

During all fifty years since the launch of the first AES the vector of direction of space activity by the states involved in cosmonautics is pointed towards providing the national safety in the political, military and economical aspects. The space research is indirectly influencing all aspects of national security. Since the launch of the first Sputnik and until the landing of the man to the Moon the political aspect was prevailing in space activity.

This has to be taken into account while analyzing the space activity at the global and state levels.

After the successful completion of the lunar program in USA, the realization of similar program in USSR has been aborted: the stimulus to competition was gone. Due to the absence of the large-scale ideas of human stay in space, the ‘space’ quarters of USA and Russia are feeling some perplexity in setting the next goals of cosmonautics.

The on-site stay of the man in space has become the flag of the space activity thanks to its social and political significance, and it should be considered while developing the strategies of space activity.

Human flight around the Earth and to the Moon were epoch-making events and have displayed its big potential possibilities. The huge popularity of the manned flights can be explained by the mental features immanent to the man, such as ambitions, competition, striving to knowledge. The piloted flights have got the support of the political elite and the wide public in the whole world.

But it should be noted that the flights of spacecraft with the human onboard are in principle solving a very narrow task of exploring the space as a living environment, and their contribution to the space sciences is less important compared to the automated spacecraft. The role of the manned flights in the utilization of space appears to be limited to the servicing of complicated technical devices in space and, probably, transportation of cargoes, though the productivity of the latter is rather doubtful.

After the euphoria of the first space years the interest to manned flights started to vanish due to absence of sensations, which could not but have affected the popularity of the space activity as a whole. In the end of 20th century the interest of the wide public to human presence in space has been reanimated for a while due to the programs of the Soviet transport vehicles and long-term habitable orbital stations, as well as the American recoverable *Shuttle* space ships, despite the absence of the global goals for them.

On the same time, the most important are becoming the specific tasks of global informatization which implies a higher level of the access to information in society on the basis of computerization and the modern communication facilities.

The global informatization constitutes the main dedicated goal of space utilization which can also include in the nearest future the implementation in limited amounts of the tasks of space tourism, materials manufacturing and biological technologies, building the solar power plants and others.

The activities on manufacturing the satellites in the goals of global informatization were started by Soviet Union and USA soon after the launch of the first AES:

1958 — American communication satellite *Atlas*-SCORE

1960 — American meteorological satellite TIROS-1

1964 — Soviet personal satellite communication service *Strela-1*

1964 — American navigation satellite *Transit*

1967 — Soviet satellite retranslation system *Molniya-Orbita*

1967 — Soviet object motion control satellite (navigation+communication) *Tsiklon*

1976 — direct broadcasting system through AES *Ekran*.

The whole class of space information systems is used in the interests of global informatization for the satellite radio communication, spatial and temporal positioning of the cooperated objects; monitoring of terrestrial objects and phenomena.

The most valuable contribution from the space activity into the global informatization is provided by the satellite navigation.

Its primary instrument today is American Global Positioning System (GPS) composed of more than 24 satellites providing the measurements of coordinates (to 1 m), velocity, time calibration. To improve the measurement accuracy the extending navigation systems are used with the additional involvement of ground based transmitters. Russian orbital group of GLONASS system is being reanimated which is similar to GPS in its goals and design.

The range of practical utilization of satellite navigation systems can be judged by the manufacturing plans of GPS and GLONASS receivers for all kinds of transport, construction works, agriculture and so on. According to the information of American experts, 16 million receivers will need to be manufactured until 2008, half of them — for cars. By the optimistic forecasts of Ministry of Energetics, the Russian market is estimated in 50...70 mln US dollars a year.

'*Social impacts of communication satellites can become no less important than those which advent of newspapers and magazines have made to mankind...*' (Arthur C. Clarke).

Currently 7 thousand onboard retranslators with the average bandpass of 36 MHz are operating on geostationary orbits only which is twice the today needs (Russia is using 286 retranslators on 12 S/C with its share of market being 1.5 %). 700 thousand VSAT terminals – stations with small-aperture antennas and IP-technologies — are utilized (Russian share is 0.36 %).

More than 1 million user stations of personal communication system are deployed on low orbits with 1 thousand stations being in Russia.

Monitoring and diagnostics of terrestrial objects and phenomena from space (remote sensing) includes the global hydro-meteorological coverage, environmental monitoring, mapping the surface of Earth. Of high importance is the application of this area of space activity to solving the problems of ecology, Earth climate forecast and counteracting the natural disasters.

The remote sensing involves satellite system of environment monitoring; research S/C with the multi-spectral instruments of active and passive sensing of high, medium and low resolution; detailed resolution spacecraft.

By 2010 the remote sensing fleet will count up to 130 spacecraft, including about 20 of them for the developing countries.

The space exploration is going on actively. World astrophysical and planetary researches are being performed with the aid of automated interplanetary stations. American rovers *Spirit* and *Opportunity*, in their fourth year of operation of Mars, are studying the Martian surface. European orbiting spacecraft *Venus-Express* is performing the program of scientific research since June 2006 and delivering the images of the Morning star.

American *Cassini* probe is continuing its successful mission and obtaining the images of space system of Saturn since 2004. Another American probe, *New Horizons* has

approached Jupiter (first images of this planet were taken in September, 2006) and obtained the first images of its main goal — Pluto to which it should arrive in 2015.

European interplanetary spacecraft *Ulysses* on the solar orbit is continuing the study of heliosphere since 1990. Two heliophysical *Stereo* spacecraft launched from USA in 2006 are preparing to receive real-time stereoscopic images of the Sun.

The historical landmark of the world cosmonautics was the creation of the serviced *Hubble Space Telescope* which was launched into orbit around Earth in 1990 and still continues to enrich the fundamental science with the unique information about the Universe.

4. RUSSIAN SPACE ACTIVITY

Taking into account its large scale, the role and place of space activity is considered at two levels: global and national.

One can judge on its current status, in the first approach, based on amount of financing whose sources are state military and civilian budgets, as well as commercial one. In 2005 they totaled in the whole world to more than 180 bln US dollars. The market volume of space services in 2005 amounted to 110 bln US dollars.

The space activity in the whole world is mostly developing at the expense of state budgets. American governmental structures have invested to the space activity 57 bln US dollars in 2005, with 41 bln US dollars from Pentagon.

The space budgets of Europe, India and China have numbered in 2005, respectively, about: 4 bln US dollars, 700 mln US dollars, 500 mln US dollars. Roscosmos budget for 2006 counted 1 bln US dollars.

From year to year Russia is giving up its positions of the space market. Now it is only significantly present (about 40 %) in the segment of space launches, whose yearly world turnover is estimated as 2.5...3 bln US dollars. On the same time the world share of commercial satellites manufacturing amounts to about 10 bln US dollars, navigation facilities and services approach 20 bln US dollars, satellite communication share is at the level of 60 bln US dollars.

Space research with using automatic stations of domestic production has stopped in Russia. There are no remote sensing spacecraft on orbits. The programs of low Earth orbit (LEO) manned flights are low-effective and non-perspective.

Russia has turned into a recognized 'space carrier', whose rocket launchers deliver to orbits foreign spacecraft, basically, and space vehicles carry foreign tourists.

Space commercialization and granting of space services are accepted as a general objective of space activity in Russia, instead of producing effective space means for maintaining the national safety of the country. Such a situation contradicts the world practice.

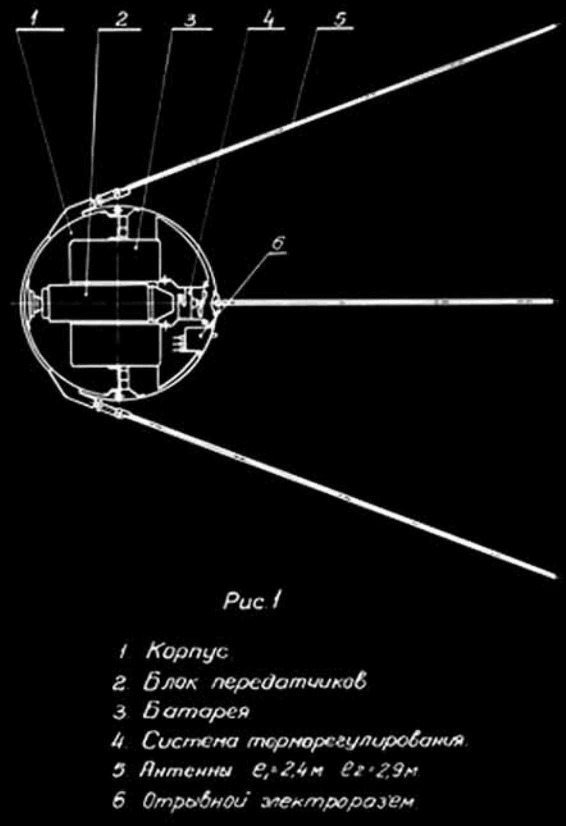
The continuity of space activity in Russia is not supported by appropriate material and intellectual resources.

Even with regard to world tendencies in astronautics development, it is rather hard to forecast the ways of development of space activity in Russia under vagueness of state policy in this area.

At the same time, the number of conditions seems to exist, which non-observance threatens to destruct the space branch. These conditions include:

- guiding by basic principles of the system approach (purposefulness, continuity, acceptability);
- declaring, at the state level, the production of effective space means for maintaining the national safety of the country as the general objective of space activity;
- correspondence of the nomenclature of space activity's target tasks. Including the manned flight programs, to the real resource restrictions;
- sufficient state financing of space activity;
- participation in ambitious planetary research projects jointly with foreign partners or on competitive basis.

AES-1 assembling

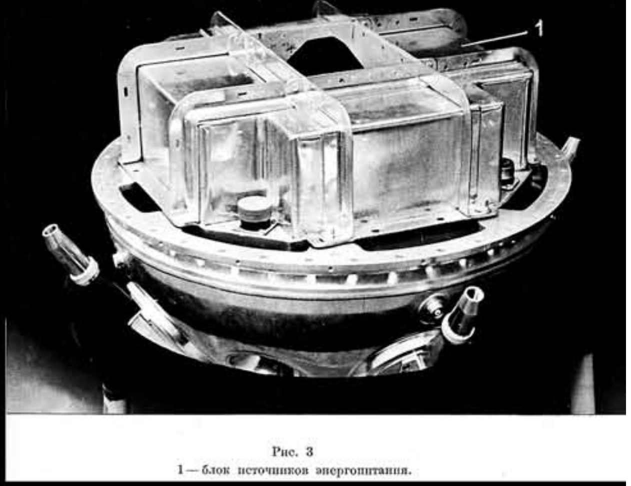


AES-1 scheme. General view

AES-1 assembling

AES-1 inner composition

AES-1 power sources



Emmanuel T. SARRIS
GREECE

Director of the Space Research Laboratory of the Democritus University, Thrace.

Committee on Space Research (COSPAR) Commission D1 Chairman, 1992–1998. National Space Committee, Deputy Chairman.

Born in 1945. Diploma in Physics, University of Athens (1967). Ph.D. in Space Physics, the University of Iowa (1973). Post Doctoral Fellow, the Applied Physics Laboratory of the Johns Hopkins University (1974–1976). Research Scientist in the Max-Planck-Institute (1976–1977).

Professor of Electrodynamics at the Department of Electrical Engineering of the University of Thrace and Director of the Space Research Laboratory since 1977.

Director of the Institute of Ionospheric and Space Physics of the National Observatory of Athens in 1990–1996.

Johns Hopkins Scholar Award 1992. Award for Academic Excellence 1994. Corresponding Member of the Academy of Athens, elected 2003. ESA and/or NASA Awards for outstanding contributions to the *Ulysses* and *Geotail* Missions.

SPUTNIK: OPENING THE STAGE FOR SPACE IN-SITU

REFLECTIONS ON THE PAST 50 YEARS IN SPACE

Up to only five decades ago the space above 50 kilometres from the Earth's surface was inaccessible and basically unknown. Today, numerous satellites and spacecraft have performed extensive observations of the near-earth space environment and explored many region of planetary bodies and the interplanetary medium all the way to the limits of the heliosphere. Furthermore, space research has been established as one of the major sources by which many scientific disciplines proceed towards new knowledge. Using the unique conditions offered by observation from space and by *in-situ* experimentation in previously inaccessible regions, research in space is serving a variety of scientific fields and applications, including: Astronomy and Astrophysics, Planetology, Plasma Physics, Particle Physics, Atmospheric Physics and Chemistry, Meteorology, Geodesy and Geophysics, Oceanography, Material Sciences, Telecommunications, Navigation, Life Sciences, etc.

Space flights offer today great capabilities for:

- *in-situ* measurements of plasmas, the fourth state of matter filling the heliosphere in exotic conditions not encountered in laboratories on Earth as well direct observations of Solar system bodies and their environments.

- Observations above the Earth's atmosphere of the whole spectrum of the electromagnetic radiation emitted by the Sun, galactic and extra-galactic objects and the Universe itself, free from atmospheric absorption and other effects.
- Making global observations of the Earth as a planet and monitoring from space its atmosphere, oceans, land and biosphere.
- Performing unique experiments in life sciences, biology and material sciences in weightlessness for extended periods of time.

The benefit of all these disciplines and applications from the advantages offered by space flights is beyond any doubt. However in terms of pure space research there is a single contribution, which touches the core of scientific methodology. This is, in my view, the immense contribution of *in-situ* measurements to space science. Those involved with space research realize how many assumptions were necessarily introduced prior to accessing space in order to comprehend and interpret the only available remote sensing observations from certain bands of wavelengths. The accumulated experience of 50 years of space research has shown that, following the *in-situ* exploration of a region or an object or a phenomenon in space, we are usually faced with great surprises, which are richer than our imagination and force us to rethink and revise our perceptions and theoretical understanding.

Sputnik on the historical day of October 4, 1957, opened the stage to space flight. The fifty busy years of *in-situ* space observations, which followed *Sputnik*, have provided many brilliant scientists with the unique opportunity to expand the limits of our understanding of our space environment and at the same time have led the scientific community to contain some of our weakly founded perceptions.

Thus the well known statement that 'the impact of *in-situ* research in space to our understanding of the space environment is comparable to the impact produced by the advent of the telescope to Astronomy and the microscope to Biology in the 17th century' is more than justified.

REFLECTIONS ON THE FUTURE

Space Weather

The fifty years of exploration and detailed observations of the terrestrial space environment have unraveled a good picture of its morphology and structure. Measurements of the various states of the hot ionized gas (plasma) and the associated magnetic and electric fields filling the Earth's magnetosphere and interplanetary space have provided a basic understanding of their dynamics. One of the most important discoveries of the space era was that of the existence of a close solar-terrestrial relationship, whereby it was realized that there is a strong coupling of violent electrodynamic effects in the solar atmosphere, the interplanetary medium and the geomagnetosphere all the way to the Earth's ground. These effects, called 'space weather', have serious and occasionally damaging consequences on space and ground systems. Further investigation of the complex dynamics of the solar-terrestrial coupling is needed in order to understand the detailed mechanisms by which the various plasma regimes are led to explosive instabilities resulting to the heating and transport of plasma and the acceleration of energetic particles. In the

next decades we expect to see dedicated constellations of spacecraft at vantage points of the solar-terrestrial environment monitoring 'space weather' much like the meteorological forecasts.

Miniaturization and the Nano-Satellite Revolution

Space research is exceptionally demanding in technological advancements, since it is carried out in a harsh environment, with damaging energetic particle radiation and extreme temperatures, while spacecraft systems and instruments must meet high energy requirements, extreme communication requirements for the transport of enormous volume of data, etc. Furthermore all this must be achieved under the doctrine that 'Space in not forgiving'. One and only mistake can be catastrophic for the whole mission.

Today we have entered a phase of explosive growth of new edge technologies aiming mainly at the miniaturization of space subsystems. Particularly important is the growth of advanced Micro-Electro-Mechanical Systems (MEMS) and Systems-on-a-Chip (SoC) based on dedicated integrated circuits tolerant to the conditions of space, which are of exceptionally small weight and power dissipation. The same is also true for the technologies of advanced microsensors. The spacecraft electronics, which used to occupy big space and weight, could now be contained in a microchip.

In the next decades we will see hundreds or even thousands of micro- and nanosatellites (Nanosatellite Revolution) with exceptionally advanced technical characteristics and low launching cost to fill simultaneously many critical regions of space for the understanding of the complicated and dynamic solar-terrestrial environment and the exploration of unknown and inaccessible regions of the heliosphere and the planetary system. With the rapid development of systems of micropropulsion, microsensors, microgyros, intersatellite links, etc., we expect to see even picosatellites with weight < 1 kg and dimensions just 10 cm carrying payload capable of important observations.

With the growth and wide use of micro- and nanosatellites, the operations of big and complicated spacecraft can be distributed to a number of smaller ones (coordinated semi-autonomous operations). Constellations of miniature satellites released from a mother spacecraft could function as a single entity undertaking coordinated operations and flight formation. They will constitute a distributed constellation, which will provide flexibility and possibility of rearrangement for adaptation in special missions and the performance of simultaneous measurements of a complex space regime at different locations. This is as close as one could get to a 'dream space lab' for *in-situ* observations continuing the legacy of *Sputnik* with its achievement of the first 'space *in-situ*'.

The unexplored regions of the heliosphere

Despite the legacy of the *Pioneers* and the *Voyagers* in the exploration of outer space very important regimes of the heliosphere — our large scale space environment — remain unexplored and present a permanent challenge to our Space Science Strategies for the 21st century:

- The *Inner Solar System* inside the orbit of Mercury and the solar atmosphere near the surface of the Sun, which is the source of the solar wind and all the dynamic effects on the complex solar-terrestrial coupling.
- The *Outer Limits of the Heliosphere*, where the solar wind is contained by the Stellar Magnetoplasma.
- The *Near Interstellar Space*, where deep space probes are expected to enter crossing the heliopause. A fascinating achievement which is anticipated for its symbolic as well as its unquestionable scientific value.

Following the Water

The 21st century for space science will be mainly the century for the exploration of planets, satellites and asteroids, where one of the main scientific targets will be the search for water in the Solar system, which may provide answers to the fundamental question on the presence of life forms beyond Earth. Existing as well as planned space missions to Mars, the Jovian moon Europa and the Saturnian moon Enceladus are on route to 'Following the Water'

Robotics and Human Space Flight

The space activities of the 21st century will be dominated by intensive preparations for the colonization of the 'accessible' Solar system bodies and the adaptation of man in the foreseen 'friendly' artificial Space Environments. Until then the detailed exploration of these bodies and all the necessary preparations will be done with robots, from which a lot is to be gained. There is nothing at the level of collecting data and conducting observations under exceptionally harsh conditions that robots cannot make better and more reliably than man. Robots are the extensions of our senses. However the analysis, interpretation and the conclusions are exclusively our own responsibility and privilege, as well as the decision for the appropriate time when ourselves 'in wisdom' will leave the mother planet for extended periods of time to distant space bodies.

For the materialization of manned missions to large distances, the technology needed must still wait for major advances. Especially primitive and expensive are still the existing propulsion systems, which today do not allow for any optimism for distant space missions not even to the near planets. More promising is the growth of Systems of information technology and robotics, which have already given a big impulse to space exploration and have created the required mature conditions for dramatic advances in the creation of near real-time data processing units for the development of intelligent systems and advanced robots.

'Colonies of Robots' will set the ground for future visits of the Moon and the neighbouring planets by man with the establishment of communication links, computing power, navigation and remote sensing stations, plants for the production and storage of fuel and oxygen, etc. The 'Colonies of Robots' are the missing step, which is necessary to ensure a subsequent exploration by man. Particularly impressive are the concepts on the production of raw material and the development of structures *in-situ* on the Moon for use in orbit around the Earth and outer space; as well as the concepts for the scientific exploitation of a Lunar Base for research of the Moon itself and the Solar system, research in biology and microgravity, use of telescopes in the far side of the Moon, etc.

EPILOGUE

The exploration of the Solar system in our times will be marked for thousands of years in the future as one of the leading achievements of human kind, much like the Greek philosophy and thought has imprinted its stamp on our civilization over the last millennia. However, while today we speak with some 'hybris' of the 'conquest of our space environment' and the explosive increase of our knowledge for space, at the same time we realize that the magnitude of our ignorance is enormous. Those deeply involved with the adventure of space research know with appreciation and modesty that they only have the utmost privilege of barely touching the vastness of what was previously inaccessible.

Roald SAGDEEV
RUSSIA

Academician of the Russian Academy of Sciences.

Graduated from the Lomonosov Moscow State University in 1955. Worked in the Kurchatov Institute of Nuclear Energy in 1956–1961. Head of the laboratory in the Institute of Nuclear Physics (Siberian Department of the USSR Academy of Sciences, 1961–1970). Head of the laboratory in the Institute of High Temperature Physics (the USSR Academy of Sciences, 1970–1973). Director of the Space Research Institute in 1973–1988. One of the founder of the modern plasma physics.

Works in the Maryland University (USA) since 1989. Simultaneously, holds the position of Chief Researcher in the Space Research Institute (Russia). Max-Planck Society Fellow. Foreign Member of the National Academy of Sciences, USA.

Hero of Socialist Labour. Awarded the Lenin Prize, Order of Lenin (twice), Order of October Revolution and the Red Banner.

DISCOVERY OF A NEW WORLD

For those, whose life is, to this or that extent, directly related to space, the 50th Anniversary of Space Era is not just an event belonging to the common heritage of mankind — it is also a very personal experience. At the time when space exploration made its first step forward, I was very far away from this field of activity, perceiving everything taking place in it only through the perspective of mass media.

My own scientific interests had to do with plasma physics and controlled thermonuclear fusion, being a new field of active research at that time, evoking a wide international public response as well. This happened after the famous lecture, delivered by I.V. Kurchatov in England, when N.S. Khruschev allowed the research work in the field of 'termoyad' (a short for 'thermonuclear fusion' in Russian) and pinch effect to be disclosed.

Thus, just in a wink, we, the research fellows from the Kurchatov Institute of Atomic Energy and other similar classified institutions, were allowed to call things by their proper names instead of using encoded secret ones. The 'syrup of high altitude' turned out to be merely 'high-temperature plasma'. My first scientific publications were devoted to its basic physical properties. Those articles dealt with theoretical predictions of various instabilities in plasma and with propagation of waves (with an attempt at comprehending the dynamics of high-amplitude waves). In one of the first publications (still in the form of a classified report, as of 1956, written in collaboration with L. Rudakov), we described 'mirror' instability of discharged magnetized plasma. By the way, at that time we called it 'diamagnetic instability', which reflected its physical mechanism more adequately.

At the same time, almost immediately after that classified report, I developed an idea about the existence of collisionless shock waves, which later resulted in a special type of waves in plasma – solitons. It is doubtful that at that time I could seriously contemplate about actual applications of these effects to extraterrestrial plasma. An attempt to reproduce these phenomena under laboratory conditions seemed to be of greater interest. Eventually, in a few years we were successful in generating similar shock waves in a lab plasma experiment. For that purpose, I had to move to the Akademgorodok City in Novosibirsk, where I managed to persuade a team of remarkable experimentators to tackle this problem and study how to generate such waves. As it turned out, space was our unexpected 'competitor' in this field, namely, the 'syrup' of solar wind. It was Konstantin Gringauz, who was one of the first to discover it but I personally got to know him much later (from 1973 at the IKI* Institute).

The notion that 99 percent of all the matter is initially in a plasma state flattered the vanity of my generation of plasma physicists. As well as the idea that it would take us, 'the masters of the Universe', just twenty years to develop a thermonuclear reactor. Alas, by the moment I went to work at the IKI, I was much less optimistic about the 'termoyad'. Even before I began to work at the IKI and even before my departure for the Akademgorodok City, my communication with Boris Tverskoy had become a bridge between general plasma physics and its implementation under the conditions of space. Boris became a staff member of the university team, led by Sergey Vernov**, engaged in search for energy particles on satellite orbits. Tverskoy introduced me to Vernov and we seriously discussed the question whether instabilities of the 'mirror' type could influence dynamics of radiation belts. Somewhat later, back in 1960, in collaboration with V. Shafranov (currently, Academician, the Emeritus Head of the Department of Plasma Theory at the Kurchatov Institute***), we predicted 'cyclotron' instability of anisotropic plasma. It was later applied to the description of both the radiation belts and a number of other phenomena, which seemingly went far away outside the scope of conventional plasma-physical concepts (as, e.g., the so-called galactic shock waves of cosmic rays).

In 1958, the discovery of radiation belts turned out to be a real space drama (and for some people, perhaps, a tragedy of lost priority). Konstantin Gringauz, one of those who directly participated in those events, told that in the spring of that fateful year Sergey Korolev was verifying the launch readiness of *Sputnik-3* instrumentation at the very last moment before the launch (it was the first satellite to carry scientific equipment). All the 'science' payload, including the Vernov's detector of cosmic rays, were ready for flight. However, the problem was that a tape-recorder used to record the instruments' data failed. Nevertheless, Korolev gave 'go' to launch. The instruments orbited the Earth many times but the data were downlinked only within the Baikonur communication pass zone. And, alas — it was precisely on this section of the orbit that an abnormal presence of cosmic rays was recorded but there was 'damned obscurity' on the rest of the orbit.

In a couple of months, a similar instrument of James Van Allen, installed on a US satellite, captured all the geometry of radiation belts and paved the way for a whole

* Space Research Institute of USSR Academy of Sciences (then; now Russian Academy of Sciences).

** At D.N. Skobeltsyn Institute of Nuclear Research of the Moscow State University (SINP MSU).

*** Russian Scientific Center 'Kurchatov Institute' series of discoveries, falling as if from a ‘cornucopia’, in the field of cosmic plasma and, in general, in the physics of the near-earth space.

Years have passed and ‘handling’ with cosmic plasma turned into a pretty routine business. Many effects, which were predicted theoretically but required to create rather exotic conditions to perform laboratory experiments, were much easier observed in space experiments. For example, the VEGA spacecraft’ instruments detected localized depressions of the magnetic field where it was appropriate (even when flying next to the Halley’s comet) — being evident results of that very ‘mirror’ instability, the effects of cyclotron instability of ions of the comet origin, when captured by the solar wind, and the comet-related front edge of collisionless impact waves.

Going back to the story of the *Sputnik-3* — no doubt, the Chief Designer* understood everything. A few years thereafter, having once met Konstantin Gringauz, he disclosed the secret of that unfortunate decision. In the morning on the launch day, he received a telephone call from N.S. Khruschev. He passed a request from Italian communists to launch something for their party to be able to add a few million of votes during the parliamentary elections in Italy. Since then, space and science were held hostage by politics for a long time! As a result, that evident advantage in time, which could have been used by the Soviet space science more than once, was lost to a great extent.

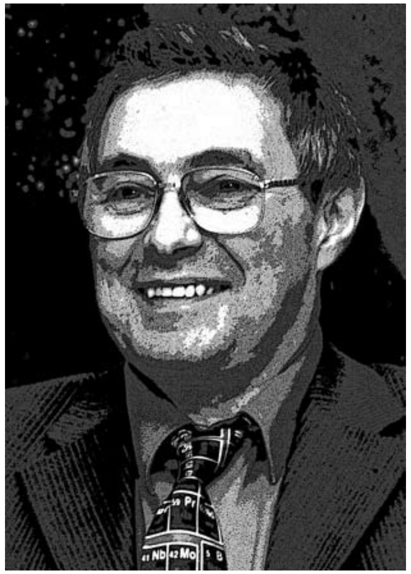
However, it should have become evident, where the bet would be placed, on the *Sputnik-2* example. The priority was placed on the dog Laika rather than on science (or even any practical applications). Wasn’t it a clear indication of a future endless chain of manned flights for the sake of political prestige? The fact that, in the field of manned flights, the USA with their shuttles went squash even to a greater extent could be just a relative consolation for some people. But, in any case, incomparably greater financial resources allowed the USA to pursue a serious scientific program in parallel. Besides, the USA succeeded in investing a lot into the applied (including military) and commercial use of space.

While for us, at the IKI, with its relatively small scientific outreach within our own country, a broad international cooperation became a way out of a crisis at a certain time period. Within the VEGA Project, we were successful in making use of scientific payloads developed in nine countries. Its Joint Managing Board was able to affect even the engineering and technical decisions made on the Project as a whole.

Nowadays, fifty years after the launch of the First Sputnik, the leading front of fundamental space science has moved far beyond near-earth space. Everything that has to do with radiation belts, magnetospheres and solar wind has become a subject for applied studies. The search for signs of exolife on Mars, in the Solar system and, hence, everywhere has currently become a focal point of science interests. This topic will be attracting the attention of research workers for a long time, as long as intelligent life survives on our own planet. And within the framework of space astronomy, the Hubble space telescope showed how processes taking place in the Universe can be visualized.

Those of us, who remain ‘the Guardian Angels’ of plasma physics, had to withstand the strokes of fate on the ‘prestige of our profession’ already twice: at first, it was the discovery of Dark Matter and then, relatively recently, of Dark Energy, being the main dominant of the Universe, which left a very modest fraction of merely 4 percent for the plasma state of matter.

* S.P. Korolev.



Lev ZELENY
RUSSIA

Director of the Space Research Institute of the Russian Academy of Sciences. Corresponding member of RAS. Professor of the Moscow Institute of Physics and Technology. Doctor of Sciences (1987).

Born in 1948. Graduated the Moscow Institute of Physics and Technology in 1972 and works in the Space Research Institute since 1972. Top scientist in the theory of collisionless plasma, magnetic field reconnection, dynamics of charged particles, magnetospheric physics.

Deputy head of the Interball project (1995–2000). Chairman of the Working group on Solar-Terrestrial Physics of the Inter-Agency Consultative Group for Space Science (IACG, 1997–2000). Member of the Bureau of COSPAR.

Awarded by State fellowship in the frame of support of prominent scientists of Russian Federation (1993 and 1997). Award of Alexander von Humboldt Foundation. Awarded Officer’s Cross (Poland) for establishing scientific contacts between Russian and Poland. Laureate of the Russian Federation President Award in the field of education.

‘FIZTEKH’ – IKI – FURTHER ON, TO THE OUTER SPACE

It took me long to begin writing this article. I have been struggling with answering the first question: ‘*What memories do you have about the day of October 4, 1957?*’ I even peeked into my 3rd-form school day-book, which I miraculously still retained, but that historically memorable week did not have any records other than conventional teacher’s remarks: ‘*Got in the teacher’s way*’, ‘*Was fidgeting during the lesson*’. So, I have to admit that the event which shaped my future, as well as that of billions of the Earth inhabitants, more or less escaped my attention.

A real interest to the outer space was aroused later. It should be noted that the books written by Ivan Efremov, Stanislaw Lem, Ray Bradbury and brothers Strugatskiye were no less important in doing that than the actual events. The life of a pupil from School No. 167, the Degtyarny Pereulok, Moscow, was running happily and smoothly (or did it only seem so?) and I heard the first ‘reverberations’ of my future only in April, 1961, when having returned home after classes, I saw a smiling face of a man wearing a pilot’s helmet on the screen of an old ‘KVN’ TV set. I remember being surprised by his family name Gagarin, which belonged to a prince rather than to a proletarian.

By and large, by the moment of my graduation from another, already specialized mathematical school, I had no doubts about which university to enter. Surely, it should be the ‘Fiztekh’ (the MPIT, short for the Moscow Institute of Physical and

Technology) – the famous 'Rocket' Faculty of Aerophysics and Space Research. That was not the best year for entering a university. The year of 1966 was the last one for Khruschev's experiment on eleven-year secondary-school education and the 10^{th}- and 11^{th}-form pupils simultaneously finished school and competition (though usually high enough) was doubled. Some people tried to scare me off by a 'percent rate', advised to enter 'Mekhmat' (the Mechanical and Mathematical Department) but, somehow, I instinctively understood that one cannot cheat one's fate and went to submit my documents to a comfy, provincial town of Dolgoprudny, which looked like anything but a sanctuary of science.

Since that time my life was closely related to the 'Fiztekh': at first, as a student, then as an lecturer and, currently, as a Head of one of it's Chairs. In fact, during all the subsequent years I have been a staff member of only two institutions: the MPIT and the IKI Space Research Institute.

Georgy Ivanovich Petrov

The Space Physics Department was founded on the basis of the IKI Space Research Institute in 1969 due to the efforts of Georgy Ivanovich Petrov, the then director of the IKI Institute and Prof. Leonid Lvovich Vanyan, a Division Deputy Head. The IKI Institute, founded in 1965, was in need of young specialists and, it should be mentioned, the 'Fiztekh' Chair fulfilled that task successfully (and still continues to do it). I believe that, at least, half of the staff members of the Institute are the 'Fiztekh' alumni of different years.

It would be interesting to describe how I came to work at that Department and the IKI Institute (to characterize the manners of those times). As it often happens, the big-politics zigzags also changed the future of ordinary small people. On April 14, 1969, my friend Volodya Parshev and I went for a walk down spring Moscow. I recollected that on that day — the day of Mayakovsky's tragical death — poets get together in the square named after him, recite poems, and sing songs. It had always been a legal, almost formally authorized event. But the times had changed already — after the 'Czechoslovak Spring' the authorities set to 'tighten the screws' and the militia men started to scatter the illegal 'mob' of poets and their listeners. Parshev and I got into trouble. We were arrested, taken into a militia station, they captured our identification data and let us go with amity but, as it turned out, not exactly.

That autumn, there appeared a letter, addressed to the 'Fiztekh', sent by corresponding official authorities containing a long list of the MPIT students, engaged in the anti-Soviet activities. Our names did not miss to land into that list. At that time I was a student of a department at the Scientific Research Institute of Thermal Processes

(NIITP, currently, the M.V. Keldysh Research Center), mostly engaged in classified projects. There I began to deal with nuclear rocket engines — the most interesting project in the world, as it seemed to me at that time.

The Dean's Office had to react to a letter issued by such a serious organization. A few students mentioned in the list were sent down but Parshev and I got incredibly lucky: we were allowed to choose if we want to leave or go over from the classified 'base' to a brand new 'unclassified' Chair of Space Physics organized by IKI which had just began to recruit students.

Very unwillingly, missing the NIITP Institute, we set forth in search for that new 'base' lost in an industrial zone, surrounding the 'Kaluzhskoye' subway depot at that time.

Probably, it was only after the first lectures about solar wind (which unexpectedly immediately captured my imagination) that I stopped to feel distressed about that almost forced transition and fully plunged into new tasks. The careers of those students from my 'Fiztekh' group who remained at the NIITP did not end up very successfully — nuclear rocket engines, being so wonderful in drawings, turned out to be practically impossible to test. Only now this trend has taken momentum again, trying to undertake a second attempt.

The very first months at the IKI Institute amazed me by free manners prevailing in academician institutions, by sharp discussions conducted at seminars, being almost on the verge of correctness, by some strange atmosphere of fragmentation an different clans which we, students, were able to feel immediately. Georgy Ivanovich Petrov, the then Director of the IKI Institute, had a few meetings with us. He impressed us strongly enough. Unfortunately, he did not deliver lectures to us and I have almost no personal recollections about G.I. Petrov*.

During its first years, the Institute was dwelling in hastily constructed 'glass' buildings – four small glass-covered buildings, usually intended at that time to house hairdresser's parlors or dry-cleaners. These buildings are still present in the yard of the Institute. One of them houses the Moscow Branch of the Department of Physics and Energetics of the MPIT, where our base department was transferred in 1976.

Construction of the large building, currently occupied by the Institute, was undertaken in the same years but, after N.S. Khruschev left his position, the 'Golden Age' of space research in the USSR was over, it began to be financed in the same way as other fields of science, and the construction of the new building proceeded at a snail's pace. Legend has it that M.V. Keldysh, President of the Russian Academy of Sciences (at that time we only began to suspect that he was that legendary 'Chief Theoretician of Cosmonautics', referred to in the newspapers), cut that knot with resoluteness inherent in him: 1/5 of the building was given over to the Institute of Applied Mathematics and another 1/5, to another organisation. As a result, by 1973 the construction was completed and the staff members moved to new spacious offices.

The first precursors of 'tectonic shifts' were felt in the spring of 1973, there were many different rumors but soon everything was clear: P.Z. Sagdeev was appointed a new director of the IKI Institute (at those time directors were not elected yet) and the glorious era of 'Sturm und Drang' began.

* N.M. Astafyeva wrote about him in a book recently published by IKI Institute called *Countdown*.

One could very quickly feel the wind of change in the Institute. At that time, I was the chairman of the Council of Young Scientists (CYS), managed to see the new Director and asked him to deliver a lecture for young scientists. Before that, at the request of the CYS, such lectures were delivered by I.S. Shklovsky and Ya.B. Zeldovich. It seemed to me that Roald Zinnurovich (R.Z.) got enthusiastic about that idea and in a few days he delivered a lecture entitled *Specific Nature of Space Research* in a conference room crammed full by young scientists, as well as by old-aged ones.

Roald Zinnurovich Sagdeev

The audience was taken aback by many aspects of that delivery — the Institute was to become quite a different, powerful, dynamic center of space science, an initiator of new and bold space projects, requiring self-sacrificing work and challenging efficiency of all the staff members. I still have snatches of the lecture notes and, reviewing them now, I got surprised once again — Institute managed to successfully implement almost everything out of all that was planned then by R.Z.

Gradually, as I understand now, overcoming the tenacious resistance of bureaucrats of different levels and authorities, R.Z. managed to turn the Institute into a center of international collaboration. It began from the *Soyuz-Apollo* Project, in which the Institute mostly played the role of an 'unclassified' umbrella for those space industry figures whose names and activity

were secret at that time, while the *Vega* Project was its culminating point. It still rates as the topmost scientific achievement of our space experiments.

When R.Z. came to head the Institute, it almost immediately brought about a sharp turn in my scientific career: in 1974 I became a postgraduate student of Albert Abubakirovich Galeev who came to the Institute with R.Z. Until that I dealt with rather 'dryish' problems of space electrodynamics but already in my fifth or sixth years at the university I was charmed by the then rapidly developing nonlinear plasma physics. I scrutinized the books by V.N. Tsytovich, the legendary Trieste article by A.A. Galeev and R.Z. Sagdeev, articles published by Coppi and Rosenbluth. Our encounter with A.A. Galeev was another good luck event, the more so that at the beginning it did not look very promising at all.

A.A. Galeev was appointed a head of a big new department of space physics at that time. At the end of 1973, he made a presentation for his new team members. I have no idea what got into me but, having just undertaken a close study of a recently published review by A.A. Galeev and R.Z. Sagdeev, I decided to prove that 'we were not tarred with the same brush'. As a result, I attacked the speaker aggressively enough (by the way, it was quite in line with the IKI manners) and asked him questions which, as it then seemed to me, were very intricate.

Presentation with Order of Honour to Academician A.A. Galeev
by President of Russian Federation V.V. Putin

Perhaps, it was something more than just my imprudence that attracted the interest of Albert Abubakirovich (A.A.), since a couple of months later he invited me to his office and gave me an interesting task to solve about ion-cyclotron instability in recently discovered magnetospheric polar cusps. A.A. had never specifically taught anything either me or his other students: Volodya Krasnoselsky, Alexander Natanzon, and Andrey Sadovsky. We merely watched, listened and adopted both his scientific and human ways of working. Interestingly, recently enough, at one of conferences, our US colleague, who did not know that V. Krasnoselsky used to work at the IKI Institute, came up to me to share his surprise: '*It's strange that you and Volodya are so similar in making your presentations, as if you were taught by one and the same person*'.

I was totally enthralled by the work with A.A. Galeev so that I paid almost no attention to other projects led by IKI Institute (missions to Mars and Venus to name just few). It was only in the middle of 80's that I began to be interested (thanks to Oleg Vaisberg) in other planets of Solar system.

It was not easy to work with A.A. He captured 'in the air'. After listening about a new result, obtained after weekly or even monthly struggles, he guessed the answer in a few minutes, which one could see in his eyes.

A.A. Galeev became a director in 1988, while I was elected (new 'democratic' times had come) a chairman of the space physics department. Galeev happened to become a director in the most difficult times: fourteen years which coincided with the end of the 'perestroika' and disintegration of the USSR, accompanied by numerous tragedies and disasters. The space industry suffered great damages as well. No wonder, it had an unfavorable effect on the Institute. 'Brain Drain' began, the number of space projects implemented at the IKI Institute, went down noticeably. The market economy brought the majority of scientists on the brink of poverty.

In August, 1991, due to A.A. Galeev the Institute adopted an unambiguous attitude during the putsch, having refused to fulfill the 'GKChP' (the State Committee for National Emergency) directions.

The next years were shadowed by a loss of the *Mars-96* automatic mission, into which A.A. funneled a lot of his efforts. Under the leadership of A.A., the Institute managed to achieve serious successes. During those years, a few projects were successfully realized — the X-ray astronomy studies were performed by using the GRANAT spacecraft, while the solar-terrestrial physics research was implemented by four spacecraft of the *Interball* Project.

The *Interball* Project became an important part of my scientific career. Already in 1980, at the earliest stage of the project, A.A. invited me to participate in selection of scientific experiments for it. In 1982, at his request, I organized a scientific workshop in Plovdiv, devoted to the Project tasks, measurement procedures and selection of the most optimal orbits. The launch of the *Interball* satellites was being constantly delayed. After the Soviet era was over, the Project was inherited by Russia, survived during the breakdowns and unifications of the participating countries but the Project scientific and human potential turned out to be so strong that, eventually, in 1995, having overcome all the financial and organizational obstacles, the first two spacecraft: *Interball-1* and the Czech *Magion-4* sub satellite were launched from the Plessetsk launching pad**.** It became a big victory of scientists, engineers, technicians, preparing the Project in the most difficult post-'perestroika' years. Deputy Director of IKI Gennady Mikhaylovich Tamkovich played a most important part in this struggle for launch of the first *Interball* Project spacecraft in 1995, and in that of the second couple in 1996. Without his vital power, his drive and extensive contacts both among the Russian and the Ukrainian space Big Leagues, the satellites could have never left the shops of the S.A. Lavochkin NPO Scientific-Production Association.

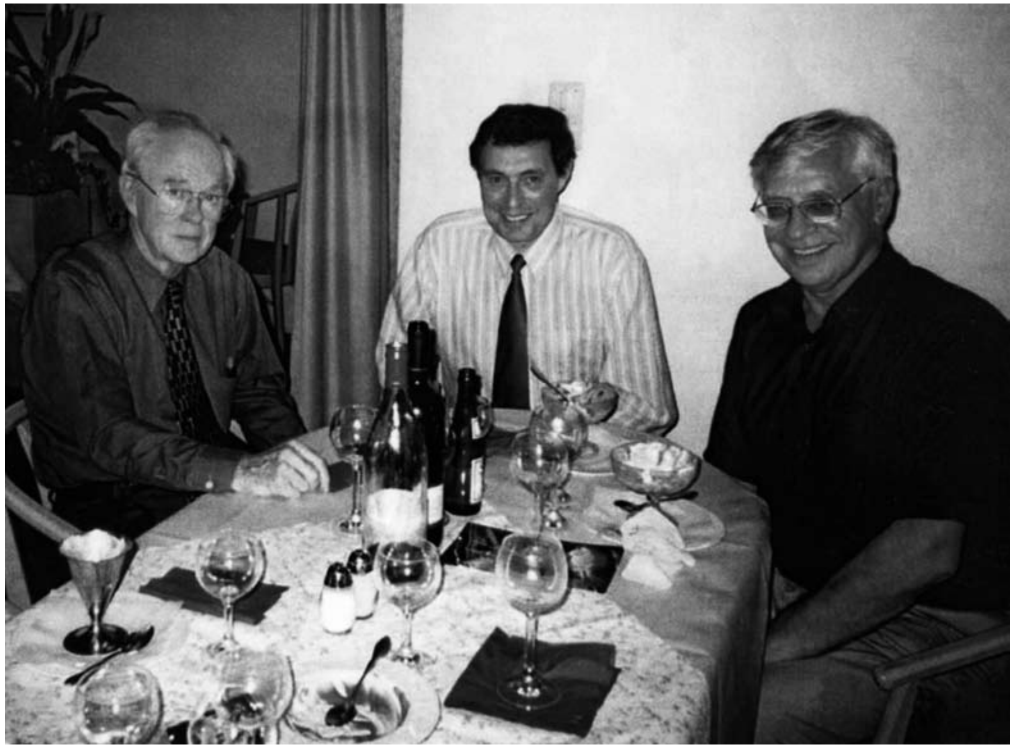
Near the launch pad before *Interball* spacecraft launch

The subsequent years turned out to be no less difficult — the Project financing got suspended a few times, staff members of a subcontractor, responsible for receiving downlinked data at the Center of Deep Space Communication in Eupatoria, went on strikes. Once again, the driving energy of G.M. Tamkovich and the status of the Project State Commission, headed by him, assisted in overcoming these difficulties, as well. The Project was successfully completed in 2001. The *Interball* satellites became a part of the international fleet of the ISTP Program (*International Solar and Terrestrial Physics Program*) and, in collaboration with the Japanese *Geotail* satellite and the US *Wind* and *Polar* spacecraft, allowed a unique number of new scientific results to be obtained.

Beginning from 1988, I got an exit permit to travel abroad. My collaboration with specialists from the Max-Planck-Institut (J. Buchner) and the California University (Maha Ashour-Abdalla, Ray Walker, Vahe Peroomian) was very fruitful. Meeting two living classics, E.N. Parker, the 'Father' of the solar wind theory, and J. Axford, one of the co-authors of classical theory of magnetospheric convection, was un unforgettable experience. At the end of 2002, I became a Director of the IKI Institute after elections held at the Institute and being authorized by the Department of Physical Sciences of the Russian Academy of Sciences. Almost 5 years have passed since that time. As usual, we have managed to achieve much less than we wanted and planned. The main mischief being that our main projects: *Fobos-Sample Return*, *Spectr-RG*, and *Resonance* are being postponed non-stop to still further due dates. The hardware is getting obsolete, people are loosing their enthusiasm, and our friends-rivals from other countries catch up on us and get ahead of us. As the new ten-year Federal Space Program was launched, there appeared new hopes that during these years our instruments, installed on the vehicles being prepared at the S.A. Lavochkin NPO Scientific-Production Association, would finally start working in space.

How will the space science be developing further on? In an anti-utopia *Return From the Stars* by Stanislaw Lem mankind got disappointed about space exploration and set forth to create a full and calm life on the Earth. It is not quite science fiction – in fact, that was exactly how space and science in general were treated in 90's (to tell the truth, it did not help the majority of out citizens to achieve happy life). A human being is a complicated creature, for whom just bread would never be enough and, as counted off from October 4, 1957, space has become a new (and achievable) horizon, a boundary of unexplored and challenging worlds for the human race.

But, besides the Space, which is a symbol of challenge, giving romantic feelings of novelty and mystery, being of vital importance if not for each individual but for



E.N. Parker, L.M. Zeleny, I. Axford

mankind as a whole, there is space, in particular, our 'Earthly' near-the-earth one, which will become still more and more a stage of activity where practical and even humdrum events will be taking place. Here, there is a certain deep-seated dialectical relationship between high-style romanticism and earthly pragmatics. The former always pays back (but not immediately) and brings about real practical results. Those countries, which lay a claim to leadership, also need ambitious space projects. It is not for nothing that during the recent decade there were a few countries which simultaneously announced their plans of exploration and even colonization of the Moon and Mars.

It is doubtful that there would be any space tasks that robots of tomorrow (at least, the day after tomorrow) would not be able to solve. But there would also be a place for a man there. Because the mere fact that the chess world champion suffers a defeat from a chess supercomputer does not stop people from playing chess! Without competing with robots but relying on their assistance, people would launch still more risky space missions, perhaps, not for the sake of science so much but rather for themselves, for their own self-affirmation. Therefore, I treat space tourism, which is negated by my many colleagues, with understanding. It 'humanizes' space, make is closer and more understandable. But it would be incorrect to let only multimillionaires enjoy this opportunity. Each Earth inhabitant is eligible to his/her own chance, even a tiny one, to perform such a flight. Maybe, it would be worthwhile to consider a system of lotteries, contests, and youth Olympiads, the champions of which would win the right (after appropriate medical examinations) to such a travel, even if it is a short one.

As for research carried by automatic space stations, they would become still more and more specialized. I believe that with time almost all the space experiments on infrared, ultraviolet, X-ray and radio astronomy would be implemented from a permanent base installed on the Moon. Here, my opinion differs from that of some of my colleagues, since I can see no incentive for extraction of rare metals on the Moon, the less so, for freezing of microscopic amounts of helium-3 isotope out of lunar soil. But the Moon Polar Regions, apparently, containing considerable amounts of water ice, might become a wonderful platform for an international astrophysical observatory.

Another trend in developing research space vehicles (in particular, those intended for local measurements) will deal with miniaturization. Perhaps, nanotechnologies, which have become particularly popular now, would play its part here. But, it should be mentioned that space engineering specialists have been discussing nanosatellites (≤ 10 kg) for a very long time. This class of satellites would form the basis for a space meteorological fleet (~ a few hundreds of SC), intended for monitoring and forecasting of 'space weather'. So far, we still manage to arrange a reasonably sufficient nomenclature of instruments only on a somewhat heavier class of SC, being microsatellites. The *Chibis* microsatellite (≤ 50 kg), being prepared for the next-year launch by specialists of the IKI Institute, the Moscow State University (MSU) and the P.N. Lebedev Physical Institute, also belongs to this class. It's chief goal will be to study very fine physical processes, accompanying the onset of a lightning discharge and generation of sufficiently powerful surges of the 'Earth' gamma-radiation.

There is another field, which I believe would pass through a rebirth in the nearest years — I mean active experiments in the near-earth space. The near-earth space is a perfect plasma-physics laboratory filled with hot, almost collisionless plasma. Here it is possible to study many physical processes, which are of principal importance for creation of controlled thermonuclear fusion reactors, e.g. abnormal transfer processes playing a very important part at the boundary of the Earth magnetosphere, as well. Now, when we understand the structure and dynamics of the whole near-earth plasma configuration much better than in the 70's, perhaps, it is high time to go back to performing controlled experiments in it: injection of beams of particles, wave packages and gas clouds.

And, finally, the last component of the inventory of future science space platforms – complicated multifunctional systems for studying atmospheres, surfaces and internal properties of all yet unknown small and large bodies of the Solar system. In this case, one cannot get along with small vehicles and remote methods. The S.A. Lavochkin NPO Scientific-Production Association has undertaken development of landing modules once again. I hope that, already during the lifetime of the current generation, these landing modules would bring us new data from the surfaces of Mercury, Europe, Io and other intriguing planets and satellites of our Solar system.

Mikhail PANASYUK
RUSSIA

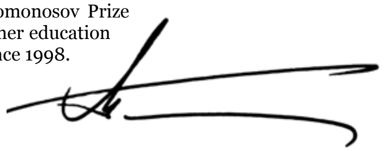
Director of the Skobeltsyn Institute for Nuclear Physics, Lomonosov Moscow State University (SINP MSU), since 1992. Doctor of Science.

Born in Moscow in 1945.

A diploma in Physics (MSU, 1969). Doctorate thesis on ring currents and Earth ion radiation belt (1988).

Expert in physics of cosmic rays and magnetosphere of the Earth. Chairman of the Space Physics Department at the Faculty of Physics, MSU.

Awarded the MSU Lomonosov Prize (1999). Honoured higher education executive of Russia since 1998.



RADIATION REFLECTIONS

Our car dashed along the new ‘concrete’ road — a beltroad round Moscow. The Indian summer surrounding us was charming. Quite of a sudden, there thundered from the speaker, ‘Moscow speaking... TASS announcement...’ That was Levitan communicating hot news of the Second artificial Earth satellite (*Sputnik-2*) launch. My father stopped the car and we became all ears.

No more than a few weeks passed after the First Sputnik launch, so the news sounded incredible. It took Soviet designers about thirty days to fly another man-made device into space carrying a dog inside. The life in the country seemed to be on the eve of great changes, we felt ready to witness the most daring fantasts’ dreams of space-flights coming true.

Now that I look back at the past trying to figure out how it could happen that just twelve years after a devastating war, with empty stores and total lack of comfort, boldest enterprises that might be beyond the present generation’s capacity proved to be possible. The main of various answers is that in those times people lived in a special atmosphere imbued with hope, expectations and enthusiasm. They strongly believed that their knowledge and labour were able to transform their country, to make it a state worth being proud of.

There is no doubt that the First Sputnik launch — as well as nuclear and hydrogen bomb explosions, the first jetliner flight, nuclear submarine and nuclear ice-breaker (all these — within one decade!) – encouraged our people’s lofty spirits. I am sure it was this spirit of creation that generated all incredible achievements of the fifties. People felt proud of their country.

I was in the 5th grade then and certainly couldn’t seriously think over my future profession. However, the fact that my father was a physicist, along with really stunning

space events of the late fifties and early sixties, determined my occupational choice. It was a blessed time for the science of physics: the nuclear program, thermonuclear researches, space achievements — school students could hardly remain indifferent to all these. A few years passed, and when Sergey Vernov (he was then Corresponding Member and later became Academician of the Academy of Sciences), head of Cosmic Ray Chair at the Physical Department of Moscow State University, asked me (while I was applying to join his chair), ‘*What would you like to do?*’ — I answered, ‘*Primary cosmic rays*’, being naively positive that since they were ‘primary’, they existed in some place faraway from the Earth — and I would be allowed to participate in satellite experiments.

And that was the case — I was allowed. But as soon as I got absorbed in the work, I realized how far I was from understanding the cosmic ray classical studies. I set about radiation belts.

I was lucky, because coryphaei of this science — B.A. Tverskoy and V.P. Shabansky — worked in Moscow University Institute of Nuclear Physics, while S.N. Vernov with his irrepressible energy provided atmosphere most favorable for creative activities. Vernov’s seminars alone were invaluable — in his fuggy office, with chronically disputing theorists and experimenters striving to enrich everybody with new empiric results.

I’ll never forget the years of my post-graduate study. It was my second post-graduate year that I managed to launch my first instrument on board of the spacecraft. My first visit to the launching site — Plesetsk, to preflight-readiness test, was also etched forever in my memory. In my suit-case I had my own radiation measuring device that in a couple of days was to be in space. High spirits is not the word for my condition — I felt really euphoric. And of course I couldn’t complete my program without encountering adventures...

...A fresh morning, ground and trees are frosty white. Two figures are sneaking up to the rocket launch site. That’s my partner and me – against the rules, we decided to avoid compulsory pre-launch evacuation from the hotel and witness the huge *Soyuz* take-off.

We stood on a steep river bank leaning against a giant pine-tree. The Yemtsa-river flew underneath. It began dawning. In front of us, as close as 300 meters or so, on the launch pad, the rocket in the rising skein of fire-smoke dominated over the whole place. It was an unforgettable view...

Count-down started. A couple of minutes before launch we began to move back trying to hide behind the pine-tree... But... the rocket did not take off. Soon we realized that something was wrong with it. It struck us: what if it blows up? But nothing happened: the launch failed. My device did not fly. Leaving the taiga we ran into a patrol. Hours of questioning and explanations in the military secret service office lay ahead. Later on, sleeping in my hotel room, I suddenly felt that my bed was... moving. It was – at last – the rocket launch...

* * *

If now we try to analyze events of the early space era, they look shockingly amazing — believe me, I do not exaggerate! I am not talking of technical achievements — they will be assessed by experts: designers and engineers. Scientific results obtained at the earliest stage of space research were on the highest world level. Just recall: radiation belts, solar wind, magnetosphere... All these were accomplished within a few years after the First Sputnik launch. Moreover, considering initial researches of, say, the Earth radiation belts, we will see that theoretical comprehension of their nature (main source origin and particle acceleration mechanisms) was achieved in an unexampled short period of time. The first mechanism of trapped radiation formation based on albedo particle generation by cosmic rays was hypothesized almost at the same time by Soviet (S. Vernov, A. Lebedinsky) and American (F. Singer) scientists within a few months after the trapped radiation discovery. And comprehensive theory of particle transport and acceleration in a geomagnetic trapping region was developed just a few years after the first satellites had been launched. All radiation belt physics accomplishments achieved since then are no more than additions and specifications to experimental and theoretical results of the first years of space exploration. Even though some of those additions and specifications were very important and impressive.

The Earth magnetosphere exploration during the first fifteen years of space era made a good basis for further planet explorations. *Pioneer* and *Voyager* flights to the Solar system outer planets made it possible to discover mighty magnetospheres of the giant planets: Jupiter, Saturn, Neptune and Uranus. They all have huge magnetospheres and of course radiation belts – much bigger than those of the Earth. But how different they proved to be! This was one of the most remarkable discoveries of the seventies and the eighties.

But our planet, too, kept a number of large-scale blank spots for researchers to ‘cover’ during those years. For example, discovery of terrestrial (ionospheric) trapped particle source could be mentioned in this context. It emerged that along with albedo particles and solar plasma, the ionosphere also fills the magnetosphere cavity with particles, thus competing with another mighty source – the Sun. This fact had been well comprehended much later, in the seventies – eighties.

But nevertheless, we can say that the main stage of developing the physics of particles captured in the near-earth magnet trap fell on the middle of sixties, within just a few years after the space era began.

Why did it become possible? One — and in my opinion the principal — reason has already been mentioned here. It is everybody’s enthusiasm that was an integral part of both Soviet and American scientists’ work.

The second reason is that the new space science — space physics — attracted, both in the Soviet Union and in the United States, a lot of thoroughly educated and highly qualified experts in plasma physics, and more specifically — in nuclear and thermonuclear fields. The mentioned circumstances undoubtedly contributed to impetuous progress of space physics.

But there is one more aspect — the military one. Throughout the first years of the space era, fundamental investigations proceeded in parallel with the arms race both countries — the USSR and the USA — were involved in. And interdependence of these two vectors, their reciprocal support and exchange of results played a significant part in extraordinarily fast progress of both scientific studies and armed forces of the two rival countries.

This is astonishing, but true: it was nothing but atomic bomb space explosion of 1958 that armed physics with the first cogent experimental confirmation of possibility of

charged particle capture in the magnetic trapping region. Unfortunately, the first atomic weapon test broke the existing environmental balance for years — the natural inner radiation belt remained beyond the reach of explorers for several years following those explosions.

Professor J. Van Allen recollected that up to 1959 American physicists had not taken it improbable that all radiation belts were actually after-effects of the USSR and the USA nuclear tests.

I would also like to mention another remarkable example of close connection between defense industry and fundamental researches seemingly quite irrelative to it.

Unexpectedly, in the sixties Soviet scientists were afforded an opportunity to use military rockets for cosmic ray exploration. That was the period when nuclear-missile potential of the two super-states – the USSR and the USA – increased in especially furious pace. Ballistic missile tests were conducted one after another.

And it was during the ‘cold war’ that two Moscow University scientists — S. Vernov and N. Grigorov — succeeded in persuading the military authorities to use experimental equipment (ionization calorimeters) instead of simulated nuclear war-heads. Their proposal was accepted, and scientists gained a really unique and unexampled opportunity to launch several tons of hardware for high energy particle exploration. They did not fail to take advantage — Soviet scientists flew four different modifications of *Proton* experimental spacecraft. Till sixties there had remained a blank spot in the cosmic ray energy spectrum: an area not filled with experimental data — the one for energy values below 10^{15} eV. *Proton* experiments for the first time covered broad bandwidth particle spectrum — 10^{11} to 10^{15} eV. It was a great triumph of the Soviet science. No one has ever conducted similar experiment so far!

...The first discovery of Soviet and American scientists that goes back to the very beginning of space exploration, namely the Earth radiation belt discovery, essentially changed the conception of the outer space. Its history, as I see it, is a real drama of space pioneering. In November, 1957 in the Soviet Union and in January–February 1958 in the United States, physicists received the first information from near-earth orbits, but both Vernov’s, and Van Allen’s groups failed to correctly interpret the observed phenomenon based on the first experimental data. In their space experimental work they encountered an absolutely unknown natural phenomenon — high energy charged particle flux trapped in geomagnetic field. But they did not realize that during their first experiments. Vernov wrote of solar flare particles, while Van Allen spoke of low-energy auroral radiation. It often happens that the original experiment eventually leads to quite unexpected results, but interpretation of the results is sometimes influenced by the existing scientific notions.

Nevertheless, by the middle of 1958, i.e. just a few months after the beginning of space experimentation, we better understood physics of the new phenomenon. Actually, it was the third Soviet satellite and American *Explorer* experiments as well as the discovery of the first physical mechanism (albedo neutron decay) that made it possible to explain the phenomenon of a giant trap capturing charged particles near the Earth.

Aboard the third Soviet satellite launched on May 15, 1958, a scintillation detector flew along with other Moscow University Institute of Nuclear Physics hardware. It was the detector that proved the existence of two separate areas in the near-earth space: outer electron belt filled with electrons of about 100 keV or higher, and inner proton belt, its energy being much higher than that of the outer one (about 100 MeV). Besides, an altitude dependence of the streams was discovered, proving that the particles are captured in the magnetic trap.

Nowadays it seems obvious that the first Soviet and American space experiments mutually complemented each other. But in view of specific international relations of those days, any international cooperation was out of question, and space physics was springing up in the environment of vehement competition between scientists of the two super-states. It was undoubtedly a Nobel result, but the history picked its own way.

I have a recollection of debates at Vernov's office — for me, a young student then, it was actually kind of familiarization with 'big science'. A decade passed after the Earth radiation belt discovery, and scientists involved in *Mars* interplanetary space probe experiment met at the office of Institute of Nuclear Physics director. They reviewed radiation data obtained on the stage of approach to the red planet. No Mars radiation belts were found — the planet magnetic field is too weak.

Now, after a lapse of many years, I think I can understand emotions and expectations of those who were then at Vernov's office — as well as of Vernov himself. And indeed, if at least traces of Mars radiation belts had been discovered then, it would have been a sufficient 'compensation' for Soviet scientists after their not quite successful experiment aboard the second satellite in 1957. Nature, however, didn't give our Solar system mate a mighty magnetic field capable to hold charged particles.

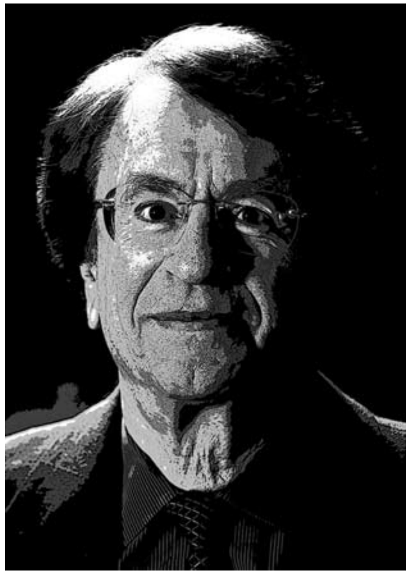
In this regard, Van Allen — strange as it may seem — proved to be luckier: in the middle of seventies he launched (once again, years after *Explorer-1*!) Geiger counter aboard *Pioneer-10* and discovered Jupiter radiation belts — the second after the Earth's ones. Anyway, their existence was pretty predictable — Jupiter possesses a very strong magnetic field, and it had been kind of common knowledge.

* * *

What are future development trends for the space physics — and in particular for radiation field and cosmic ray investigations I have been reflecting upon in this article? By no means am I going to prophesy that the Golden Age of this science will be followed by exponent of recession. I believe that an equally interesting phase began — a phase of applications. Indeed, we know a lot about radiation environment nearby our planet, in the vicinity of other planets and in interplanetary space. We know characteristics of radiation belts, galactic and solar cosmic rays. But potential of future mission radiation condition estimation, i.e. of forecast, is still limited. The problem is that radiation field temporal variation patterns have been insufficiently explored so fare — weather we speak of charged particles trapped by magnetic field, or energetic particles accelerated during solar flares. Exhaustive solution of this problem can be rather creation of global spacecraft network — radiation hazard monitors located on different distances within the heliosphere, than interpretation of experimental data and making physical models. This task is only adequate for several states. Without this cooperation neither long-term Mars expeditions, nor settling the Moon seem to be possible.

Nor can I regard as complete the space physics section related to its fundamental part. The theme of particle acceleration as well as correlation between active phenomena on the Sun and inside planet magnetospheres, i.e. solar-magnetosphere interrelation, should start sounding differently. This part remains 'immature' and it will require years of investigations and favourable environment to come nearer to the next stage of perceiving this tiny part of the Universe — our Solar system with its planets going round the star closest to us — the Sun.

SPACE IN-SITU

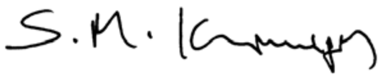


Stamatios M. KRIMIGIS
USA

Academician, Chair of Science of the Space Academy of Athens, Greece. Emeritus Department Head, Space Department, Applied Physics Laboratory/Johns Hopkins University, USA.

Principal Investigator on several NASA spacecraft, including *Voyagers-1* and *-2* to the Outer Planets and the *Voyager Interstellar Mission*, and the *Cassini* mission to Saturn and Titan.

Dr. Stamatios Krimigis received his M.Sc. (1963) and Ph.D. (1965) in Physics from the University of Iowa. He is recipient of NASA's Exceptional Scientific Achievement Medal twice, is a Fellow of the American Physical Society, American Geophysical Union, American Association for the Advancement of Science, and American Institute of Aeronautics and Astronautics, recipient of COSPAR's Space Science Award in 2002, a recipient of the Basic Sciences Award of the International Academy of Astronautics where he chairs the Board of Trustees for Basic Sciences.



YEARS OF REMARKABLE ACHIEVEMENTS

– W*hat do you remember about the 4th day of October, 1957, and what were your feelings and thoughts? How has this event affected your life?*

In the fall of 1957, I was an incoming first year student in Electrical Engineering at the University of Minnesota Institute of Technology, not knowing much about engineering, and even less about rockets, other than what I had read in Comics books. Everything was new and different, and fascinating about the world of technology. So, I was ill-prepared to understand what an artificial satellite was, let alone comprehend and appreciate its significance.

I was, however, most impressed with the newspaper headlines. 'SOVIET FIRES EARTH SATELLITE INTO SPACE; IT IS CIRCLING THE GLOBE AT 18,000 M.P.H.; SPHERE TRACKED IN 4 CROSSINGS OVER US' screamed the *New York Times* on Saturday, October 5, 1957. The launch was top news on all television networks, all radio stations, and in every gathering on the campus, including the classrooms and lecture halls. Needless to say, I began to read everything about the subject that I could find, and before long, I had become a space enthusiast, without really recognizing what a historic step in human history this was. Soon, I was attracted to the balloon investigations of high altitude radiation being conducted in the Physics Department by Professors John Winckler and Edward Ney, and transferred to that Department. Within another year, I was building ion chambers as a member of Professor Winckler's research team that was engaged in the study of solar cosmic rays through balloons, flown from the abandoned Anoka airport near Minneapolis. It was an exhilarating experience and provided me the initial tools that served me well in designing and building detectors for space experiments within the next few years.

My real opportunity came when a student committee invited, at my suggestion, Professor James Van Allen from the neighboring State University of Iowa (SUI) to give a public lecture on the newly discovered Radiation Belts encircling Earth. He gave a captivating lecture and then visited Professor Winckler's laboratory where I was sitting at my bench assembling an ion chamber. He stopped by, asked me to explain what I was doing, and then inquired if I had considered going to Graduate School. I said that I had, and he suggested that I apply to the State University of Iowa. That's how I arrived in Iowa City in September, 1961 and began my graduate work in physics.

The University's Physics Department was a very exciting place to work at the time. There were several data sets from spacecraft to work on, and new mission opportunities for answering many of the scientific questions that were generated from the analyses of the early data. I finished my Masters thesis in late 1962 on data collected from a detector flown by the Space Physics Group at the Applied Physics Laboratory (APL) of the Johns Hopkins University (George Pieper and Carl Bostrom) on the first SUI-built satellite (*Injun-1*). Immediately thereafter, Dr. Van Allen asked me to build a 'solid state' detector for the first NASA missions to Mars (*Mariners-3* and *-4*) to look for Martian radiation belts. In addition, there was an opportunity to fly an instrument on the SUI-built *Injun-4* (*Explorer-25*) satellite and I thought of designing a detector to attempt to answer the question of the source of the Van Allen Belts: was it the solar wind, the ionosphere, or some combination of the two? All three spacecraft were launched in November, 1964 – an amazingly short time by today's standards. The shroud of *Mariner-3* did not detach, and the mission was a failure (my first and only disappointment for many years); *Mariner-4* succeeded and reached Mars in July 1965 (no radiation belts*, but did discover solar electron emissions**); *Injun-4* succeeded and did discover trapped He nuclei***.

Well, after many more missions at Iowa (*Mariner-5*, *OGO-4*, *Injun-5*, *Explorers-33* (*IMP-D*) and *-35* (*IMP-E*) and since the fall of 1968 at APL (*Explorers-43*, *-45*, *Voyagers-1*, *-2*, *AMPTE Charge Composition Explorer*, *Galileo*, *Ulysses*, NEAR, ACE, TIMED, MESSENGER, *New Horizons*, STEREO), I can truly say that the *Sputnik* launch indeed *changed my life*. I was fortunate to be at the *right place*, *at the right time* to engage in one of mankind's greatest adventures, the exploration of the space frontier. This was a terrific privilege, for someone born on a small island in Greece (Chios), to participate in the adventure of exploring every one of the (eight) planets, and with a mission going to the ninth (until recently) planet, Pluto. None could ask for a more fulfilling dream to come true.

'— *How was this event reflected in different spheres of human activity; our worldview, scientific and technical progress, international relations, conditions of life, human psychology, culture?*

One could write an essay about each of these subjects. For the sake of brevity, I will comment on only some of these. Clearly, humanity's world view has been changed forever. *Sputnik* and its successor spacecraft demonstrated that borders are meaning-

* *Allen Van J.A.*, *Frank L.A.*, *Krimigis S.M.*, *Hills H.K.* Absence of Martian radiation belts and implications thereof // Science 1965. V. 149. P. 1228–1233.

** *Allen Van J.A.*, *Krimigis S.M.* Impulsive emission of ~40 keV electrons from the sun // J. Geophys. Res. 1965. V. 70. P. 5737–5751.

*** *Krimigis S.M.*, *Allen Van J.A.* Geomagnetically trapped alpha particles // J. Geophys. Res. 1967. V. 72. P. 5779–5797.

less when viewed from 300 kilometers altitude, and there was nothing anyone could do about that. Our vulnerability and *nakedness* to the peering eyes from the sky and to listening ears demonstrated the global context of humanity's existence. Overall it exacerbated the sense of insecurity, especially in the United States.

The first reaction at the governmental level was actually very positive. The Soviet Union had demonstrated its technological prowess, and the US felt the need to redouble its efforts in scientific and technical education at all levels. I was one of thousands of beneficiaries by being selected for a National Defense Education Fellowship (NDEA) to continue my graduate studies in physics at the Ph.D. level. Opportunities for graduates in engineering, mathematics, physics, and technical fields in general were plentiful. Government-funded research programs proliferated, not just for space but also for many technical areas across all disciplines. Thus, the launch of *Sputnik* caused a great leap in research and development that would not have occurred otherwise. The resulting technological progress is at the foundation of today's economic development throughout the world.

But the most profound impact was that on international relations, especially among the then superpowers, the US and the USSR. Each was vying for supremacy, and each viewed demonstrations of technology as a tool in asserting their superiority as a social and economic system. The USSR's accomplishment with *Sputnik* caused a re-examination in the US of many assumptions on its capabilities. The sense of invulnerability, being on a different continent, was shattered; the potential for nuclear weapon delivery through high speed rockets was now a near-term reality for both sides of the cold war conflict. The inability to hide force buildups and military bases from space imaging had a sobering effect on the conduct of international affairs. Although these assessments were slow in being realized, they ultimately contributed to stability in the nuclear standoff, in that neither side would develop an advantage without the other's knowledge. Thus space became a substitute as an avenue for competition and diplomacy became the only viable avenue in conflict resolution for the remainder of the 20th century. It also opened up scientific exchanges between the USSR and the US. I remember well my first visit to the USSR in 1969 at the invitation of Academician S.N. Vernov for a conference at the Ioffe Physico-Technical Institute in (then) Leningrad. There were only a few scientists from the west (H. Alfvén, K.G. McCracken, W.R. Webber, J.R. Winckler, D.J. Williams) and we had an excellent set of discussions and the first comparisons of solar energetic particle data from US* and USSR satellites.

Finally, the impact on the lives of people everywhere was profound. It was manifested first in satellite communications, but it spread quickly to other applications such as weather forecasting and navigation, to name just a few. Images could travel around the world at nearly the speed of light, and watching sport events a continent away became commonplace. Live dispatches changed the way broadcast news was delivered, and the world became a 'global village' indeed. Developing storms were tracked from space, and people on their projected path were evacuated safely. Ships at sea no longer needed the sun and the stars to navigate with great precision. Distance education learning was established for many of the world's remote areas. No person on the globe needed to feel isolated anymore.

* *Krimigis S.M.* Observations of low energy solar protons with Mariners-4 and -5 // Trudi Mezdunarodnovo Seminara, Proc. of the Ioffe Physico-Technical Institute, Academy of Sciences of the USSR / Ed. G.E. Kocharov. Leningrad. 1969. P. 43–86.

SPACE IN-SITU

Conversation with Academician S.N. Vernov outside the Ioffe Physico-Technical Institute in Leningrad during the meeting June 3–7, 1969. From left, front row: G. Kocharov, K. Gringauz, J. Winckler, I. Podgorny, D.J. Williams, S.N. Vernov, S.M. Krimigis, K.G. McCracken

What I have cited above are a few of the direct applications of space, without reference to innovations of all types enabled by space technologies ranging from earth-based communications to medical devices, computers, wireless phones, and microchips of all kinds. Thus, the impact of *Sputnik's* launch has affected a multitude of human activities and has become a powerful, but seemingly ordinary component of our everyday lives.

'— *What has mankind gained and lost from having begun space research?*

In thinking back to images from space, I recall one taken by astronauts on the Moon as the Earth's blue sphere rises above the moon's horizon. It is a beautiful picture, not just because of the blue Earth, but because it shows humanity's home as a single entity in the vastness of space. No human being could look at that picture and still feel that their neighbor or person in another country or another continent is somehow a *foreigner* or an *enemy*. It is really hard to miss the message of *unity* and *oneness* that is conveyed from this image for all humanity to see. This, I believe, is the one key message that mankind has *gained* from the space program. What mankind has *lost* is our ignorance and superstitions: our knowledge of the world around us has increased immensely, from the surface of the Earth to the edge of the Universe. The most vivid demonstration is that even popular books today are totally different from those of the decade of the 1950's. For example in Goodwin's book (*The Real Book About Space Travel*, by Hal Goodwin), Venus is described as '*a young planet, probably covered by hot swamps teeming with the kind of life that vanished from earth millions of years ago*', together with an illustration of a '*Venusian swamp*' with a monster walking through. Even the first flight of *Venera-4* in 1967 to Venus provided the physical measurements that did away with those speculations that had misled people for many centuries. Canals on Mars are another example referred to in the same book.

'— *How will space technologies be developed in the near and long-term future?*

Unfortunately, the collective budgets of space-faring nations have decreased substantially from the peaks of the 1960's. This decrease reflects the fact that space research is viewed as *routine* and politicians do not seek the necessary popular support to advance space activities. This is very unfortunate, and has slowed down substantially the development of space technologies in the near term. The end of the 'cold war' has contributed to this trend. So, the outlook for the foreseeable future is not encouraging, because the necessary investments are made elsewhere, driven by the clear need for energy resources, environmental cleanup, and health research, among other things.

Never the less the space enterprise continues to capture people's imaginations, and there may well be a revival of interest in the intermediate term. The technologies needed for modeling new and bold initiatives, such as human travel to Mars, comprehensive exploration of Europa, Titan, or Triton, an *Interstellar Probe*, etc. involve nuclear power and propulsion. Because of both funding and safety concerns, I do not believe these technologies will be seriously developed until 2020–2030. So, there may be another burst of exploration by the middle of this century. Hopefully, humanity will have solved a lot of its chronic and pressing problems, such as poverty, disease, energy, environment, overpopulation so as to become more interested in looking outward again. Perhaps, entrepreneurs will find ways to make profits from space, and they will begin to push the frontier. That seems like a forlorn hope!

Concluding Remarks

In reflecting on the onset of the space age, one is struck by the fact that the 'cold war' played a pivotal role. It is hard to imagine that the heavy-lift rockets that enabled the launch of satellites and space probes would have been developed, absent the arms race driven by superpower competition. Perhaps such rockets would have been built eventually even without the 'cold war', but it may have taken many more years, and the beginning of the space era would have been delayed. Thus, in a strange way, space science has been the beneficiary of the 'cold war', strange as that may sound. There is no question, however, that the space age was an inevitable next step in the development of human civilization, and that it has been tremendously beneficial for all of humanity. Thus, we must salute the visionaries and pioneers of the age: **Korolev, von Braun, Van Allen, Vernov,** and all their colleagues who pursued their dream and possessed the imagination and skills to make it come true.

Finally, it is worth contemplating humanity's steps in aeronautics and space during the past one hundred years. The flight of the Wright brothers at Kitty Hawk, North Carolina, on December 17, 1903 to an altitude of a few meters; some fifty years later, the launch of *Sputnik* to orbit Earth at 946 km altitude; and recently*, the exit of *Voyager-1* from the Sun's atmosphere at the Termination Shock on December 16, 2004 at a distance of 14.1 billion km from our home planet. What a remarkable one hundred years these have been!

* *Decker R.B., Krimigis S.M., Roelof E.C., Hill M.E., Armstrong T.P., Gloeckler G., Hamilton D.C., Lanzerotti L.J.* Voyager-1 in the Foreshock, Termination Shock and Heliosheath // Science. 2005. V. 309. P. 2020–2024.

Anatoly Cherepaschuk
RUSSIA

Director of the Sternberg Astronomical Institute, Lomonosov Moscow State University (SAI MSU). Doctor of Science. Academician of the Russian Academy of Sciences. Expert in astrophysics.

Department Deputy Chairman in the Faculty of Physics, MSU

Head of Russian leading scientific school in physics of close binary stellar systems.

Deputy Editor-in-Chief of Astronomy Magazine and international magazine Astrophysics and Space Science, Fellow of the International Astronomical Union, vice-president of the European Astronomy Society (2000–2005), Fellow of the Royal Astronomical Society, Deputy Chairman of the Astronomy Council (Russian Academy of Sciences).

Awarded the Lomonosov award at MSU, the Belopolsky award from the Russian Academy of Sciences

STERNBERG ASTRONOMICAL INSTITUTE AND THE BEGINNING OF SPACE EXPLORATION ERA

In the beginning of the International Geophysical Year (1957–1958) the launch of a scientific satellite was announced. A net of ground observation stations was build which enabled to monitor the flight of the satellite, to predict its motion and calculate its orbit.*

Astronomers were always attracted by the idea and possibility to study radiation from astronomical objects in the entire specter of electromagnetic waves with no interference from our atmosphere which is actually transparent only in the visual part of the specter open to human eye. The launch of the satellite unfolded a new era in astronomy.

Iosif Samuilovich Shklovsky, in charge of radio astronomy department of the P.K. Sternberg Astronomic Institute (SAI) Lomonosov Moscow State University, was among the first scientists who realized the wide prospects of satellite launches in terms of their use for observations outside atmosphere. His young colleagues from newly organized Department of radioastronomy supported him enthusiastically.

The first step was to develop procedures and equipment for observation of the satellite. The launch proved that the rocket carrier was bright enough for filming, and that was done by P.V. Shcheglov who used *Exacta* camera with 1:1.5 relative focal length. The first picture of a space object was published in *Soviet Union* monthly.

* Co-authorship with V.F. Yessipov and V.V. Shevchenko.

NAFA-25/3c aerocamera was the first device they used. The case with a photofilm was replaced with a case with an astronomical photoplate, and a new system of shutter opening/closing control time was designed. Infrared lamp was put in front of the lens and next to the photoplate there was a photocell which signal was registered by a loop oscillograph with accuracy of 0.01 s. The camera was mounted on a big photo holder and was capable of rotating and targeting at the carrier and satellite trajectory path. The observation was successful. The use of the photoplate enabled the scientists to measure objects' coordinates with accuracy of 5 seconds of the arc. Two more devices were produced to observe the satellite: one using two-stage image converter for hardly visible satellites and the other using photoelectric multiplier and photoplate with a slit to register exact moment of the satellite passing through the slit with coordinates being determined using the stars.

The results of the work were made available at the meeting of Scientific and Technical Council for Space Research headed by Mstislav Keldysh. After the completion of control tests in Tashkent the report covering those activities was approved my Mikhail K. Tikhonravov, Sergei P. Korolev's First Deputy (Fig. 1).

Fully aware of SAI potential Korolev visited the institute on March 22, 1958. Having taken a close look at the device for observation of weak astronomical objects (using multistage image converter) he dwelled on various tasks of space exploration which could be joined by I. Shklovsky and his radioastronomy team. Korolev set a task to perform observation of the vehicles flying to the Moon. For this purpose Shklovsky suggested to use the so-called artificial comet method — evaporation of sodium at the flight path to the Moon. SAI developed observation facilities while Specialized Design Bureau No. 1 (OKB-1) equipped the rocket with the sodium evaporator which was supposed to create an artificial comet at a certain time. The observation was intended to determine coordinates of the comet, i.e. of the spacecraft, and verify its trajectory.

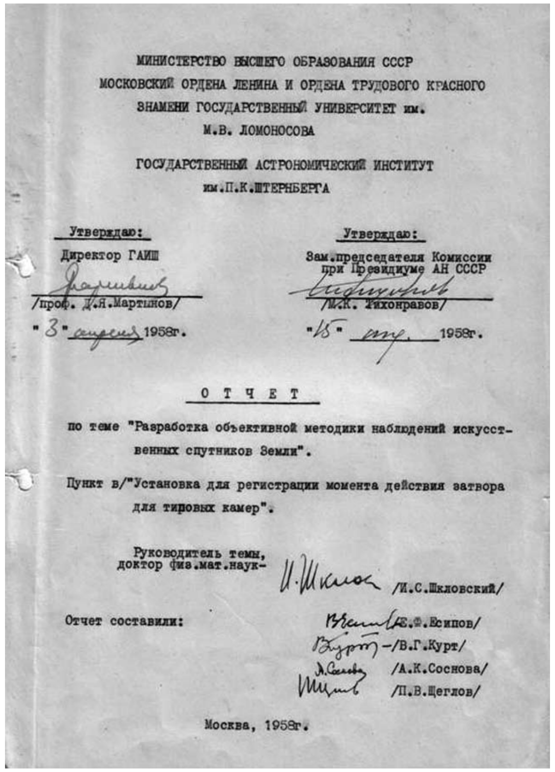
Soviet industry promptly produced hardware designed at SAI: double photographic camera with an orange filter to get a shot of the comet among the stars and a set with a three-stage image converter designed to get a picture of sodium cloud dispersion. For the second unit the Optics Department Faculty of the Physical Faculty of the Moscow State University manufactured dielectric multilayer interference light filters (Fig. 2) for the yellow line of sodium doublet. The method proved to be a success: the coordinates of the spacecraft were obtained, and the comet evolution process was registered.

Image converters allowed displaying artificial comet evolution on the screen and taking pictures.

All the members of the department involved in this work (P.V. Shcheglov, V.I. Moroz, V.G. Kurt, V.F. Yessipov, I.S. Shklovsky) received gifts from S. Korolev — pendants analogous to the ones launched on *Luna-1* and *Luna-2* spacecraft. Moreover, I. Shklovsky was granted the Lenin Award in 1960 (Fig. 3).

The sixth space craft successfully launched in the USSR was supposed to solve the Moon's enigma of the century and survey its far side. *Luna-3* automatic interplanetary station after having rounded the Moon on October 7, 1959 took the first pictures of the far side of the Moon. The were downlinked using photo/TV system from various distances up to 470,000 km. The initial pictures were heavily affected by interference which necessitated the development of a special procedure to get rid of them. One should keep in mind that no computers or imagery processing methods now commonly used existed then.

SPACE IN-SITU


МИНИСТЕРСТВО ВЫСШЕГО ОБРАЗОВАНИЯ СССР
МОСКОВСКИЙ ОРДЕНА ЛЕНИНА И ОРДЕНА ТРУДОВОГО КРАСНОГО ЗНАМЕНИ ГОСУДАРСТВЕННЫЙ УНИВЕРСИТЕТ им. М.В. ЛОМОНОСОВА

ГОСУДАРСТВЕННЫЙ АСТРОНОМИЧЕСКИЙ ИНСТИТУТ им.П.К.ШТЕРНБЕРГА

Утверждаю:
Директор ГАИШ
/проф. Д.Я.Мартынов/
"3" [illegible] 1958г.

Утверждаю:
Зам.председателя Комиссии при Президиуме АН СССР
/М.К. Тихонравов/
"15" [illegible] 1958г.

О Т Ч Е Т

по теме "Разработка объективной методики наблюдений искусственных спутников Земли".

Пункт в/"Установка для регистрации момента действия затвора для тировых камер".

Руководитель темы,
доктор физ.мат.наук- /И.С.Шкловский/

Отчет составили: /Е.Ф.Есипов/
/В.Г.Курт/
/А.К.Соснова/
/П.В.Щеглов/

Москва, 1958г.

Fig. 1

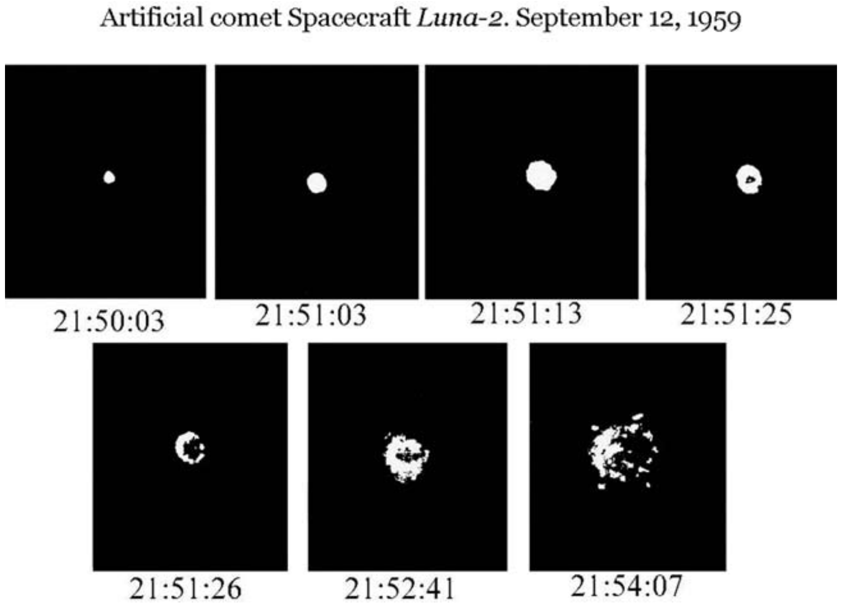
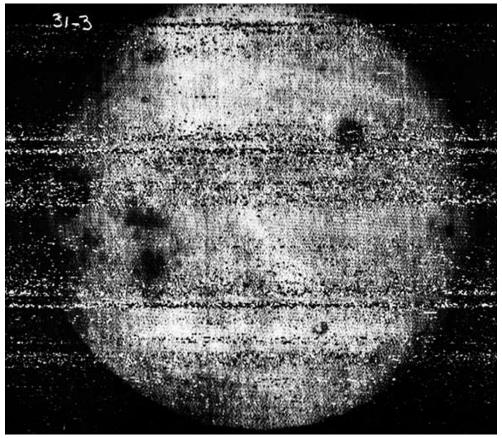
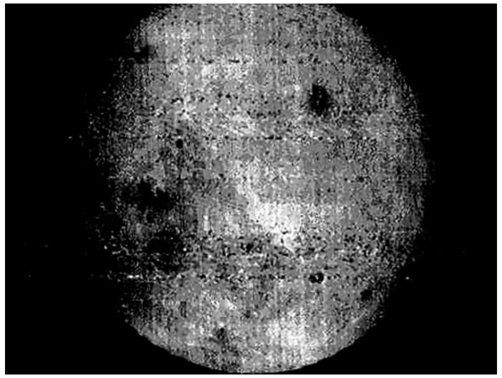


Fig. 2

Fig. 3. From left to right: V.I. Moroz, V.F. Yessipov, I.S. Shklovsky, V.G Kurt, P.V. Shcheglov

The pictures were to be processed by a team of SAI scientists headed by Professor Yu.N. Lipsky. The task was successfully accomplished and the results supplemented the first *Atlas of the Far Side of the Moon* published by the USSR Academy of Sciences in 1960 (Fig. 4).





a) b)

Fig. 4. Left — the picture taken by *Luna-3* spacecraft, right — the same picture after the processing

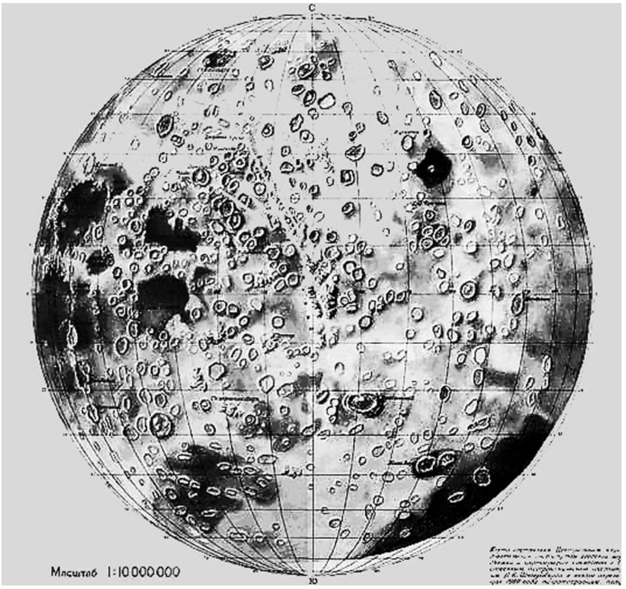


Fig. 5

Fig. 6

Also, at that time the first map of the far side of the Moon was published and the first Moon globe was created. The globe was updated later using the pictures obtained by from *Zond-3* in 1965 (Fig. 5, 6).

Analysis of the first space pictures of the Moon formed a team of specialists which later, in mid-sixties was transformed by initiative of Academician S. Korolev into SAI Department of physics of the Moon and planets with Professor Yu. Lipsky at the head. Within the next 13 years SAI in cooperation with other specialized organizations prepared and published 7 editions of various lunar maps, 5 editions of the Moon globe and completed a 3 volume edition of *The Atlas of Far Side of the Moon*.

At the same time the Department of physics of the Moon and planets cooperated with the Design Bureau headed by G. Babakin. Yu. Lipsky and V. Shevchenko designed, prepared and carried out a photometric experiment on *Lunokhod-2* Moon rover in 1973. The goal of this work was to study photometric characteristics of thin soil fraction in its natural laying (Fig. 7, 8).

In 1990 Russian-French project called *Spectral Observation of the Moon* started. A number of interesting investigations of the Moon's diffusive structures were carried out in 1994 using ground and space (*Clementine* spacecraft) spectral images. Later those works were followed up by SMART-1 launched by ESA in 2005–2006.

In 2004 a team of scientists from the Space Research Institute under the Russian Academy of Sciences, Academician R. Sagdeev and his colleagues (University of Maryland), NASA Goddard Space Flight Center, SAI and some other institutions won the NASA tender for a new polar lunar satellite (*Lunar Reconnaissance Orbiter* or LRO) which is scheduled to be launched in 2008. In preparation of the experiment the scientists of Moon and planetary Department (SAI) studied the conditions of the Moon's polar regions. The work resulted in identification of the so-called 'cold traps', i.e. continuously shaded regions which might contain volatiles, including water ice. These regions got the status of first priority tasks in LRO-LEND experiment.

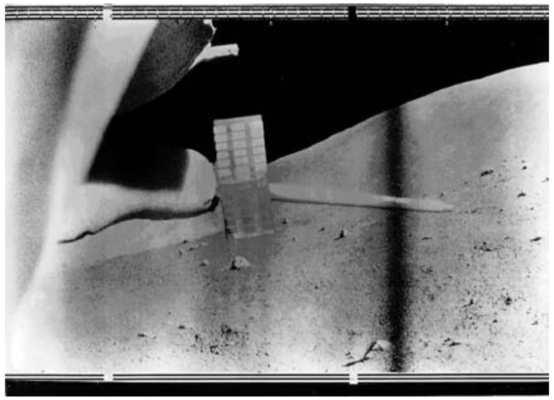


Fig. 7. Photometric standard on *Lunokhod-2*

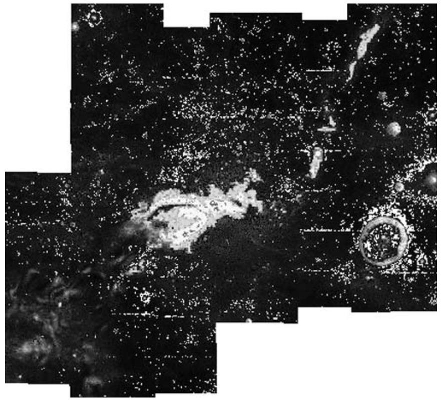


Fig. 8. Spectral pictures from *Clementine* spacecraft

SAI also organized a continuous scientific workshop, called Joint Astrophysical Workshop. It was launched in 1967 by initiative of three outstanding scientists: Academician Vitaly Ginzburg, Academician Yakov Zeldovich and Corresponding Member of the USSR Academy of Sciences Iosif Shklovsky. Owing to its interesting topics and very high scientific level the workshop gained solid national and international recognition.

The workshop was held once in two weeks on Thursday. It was attended by almost the entire Moscow physical and astronomical community. SAI conference room was always crowded when the workshop was on, exciting discussions going on in the lobby during the breaks. Yakov Zeldovich was the soul and the main driving force of the workshop up to his death in 1987.

Outstanding Soviet and foreign scientists presented their projects at the workshop. Its participants discussed latest discoveries in astronomy: quasars, relict microwave radiation, pulsars, space masers, compact X-ray sources — accretive neutron stars, black holes, etc.

Owing to space explorations astronomy had become all-wave in 1960–1970, which expanded a scope of astronomical observations and made their interpretation more reliable. Although the workshop was originally designed as a theoretical seminar its work got in direct touch with space experiments and enriched them with new theoretical findings.

Brilliant presentations on various aspects of X-ray astronomy made by Soviet scientists caused special attention of the participants. The era of systematic X-ray observations of the sky began in 1972 with the launch of UHURU, US orbital X-ray observatory. Its scientific supervisor was Nobel Prize winner R. Giacconi. UHURU made it possible to discover about 100 compact X-ray sources in binary star systems which function as accreting neutron stars and black holes. Therefore, discovery of black holes is closely connected with X-ray astronomy.

A series of theoretical papers preceded these discoveries in the field of X-ray astronomy. Many of them were presented at the workshop and allowed to understand the nature of compact X-ray sources as accreting relativistic objects in close binary systems. Back in 1964 Ya. Zeldovich and E. Salpeter (USA) predicted powerful release

of energy during non-spherical accretion of the matter to a black hole. The theory of disk accretion of matter to relativistic objects was further developed by N. Shakura, R. Sunyaev, D.J. Pringle and M. Rees, I. Novikov and K.S. Thorn in their works.

In 1973 N. Shakura and R. Sunyaev developed the theory of disc accretion of the matter in binary system to a black hole (including supercritical behavior). They calculated a specter of X-ray radiation with due account of comptonization effects and put forward standard model of α-disc. It is still the most frequently quoted paper in the world astronomical literature.

All these works reviewed at the workshop were carried out before systematic study of compact X-ray sources began. Their theoretical predictions were fully substantiated in the course of further X-ray survey of the sky by specialized space observatories. Further launches of space X-ray observatories (such as HEAO-2, *Ginga*, *Roentgen* on *Kvant* module of the *Mir* space station, *Granat*, ROSAT, ASCA, RXTE, *Chandra*, XMM-Newton, INTEGRAL and others) resulted in discovery of more than a 1,000 X-ray binary systems which enabled the community to put the search of black holes on a solid observation basis. Further optical identification and investigation of X-ray binary systems made it possible to develop powerful methods for determination of black holes masses in binary systems. By now masses of about two dozens of black holes have been determined in X-ray binary systems.

S. Fred SINGER
USA

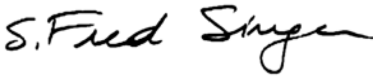
Atmospheric and space physicist, Professor Emeritus at the University of Virginia.

He received an electrical engineering degree from the Ohio State University and earned a Ph.D. in physics at the Princeton University.

The first director of the US Weather Satellite Service (now part of NOAA) and a former vice-chairman of the US National Advisory Committee on Oceans and Atmosphere. In high-altitude rocket experiments with J.A. Van Allen, he determined the energy spectrum of the Galactic Cosmic Radiation and demonstrated the existence of the Elecrojet Current flowing in the equatorial ionosphere. Later he served as principal investigator on the LDEF interplanetary dust experiment, which discovered the existence of artificial debris clouds in Earth orbit.

He has held a number of university and governmental positions and conducted research at the Institute of the Physics of the Earth (Moscow) in 1972 as a guest of the Soviet Academy of Sciences.

He devised the cosmic-ray method of dating meteorite ages. More recently, he has been studying causes of global warming and published several books – including *Unstoppable Global warming – Every 1500 Years*, which was listed as *New York Times* bestseller in 2007.



THE PRE-SPUTNIK YEARS AND EARLY SPUTNIK DISCOVERIES

ABSTRACT

Beginning in 1946, space research with captured German V-2 rockets (and later US-made *Aerobee* rockets) produced results on primary cosmic radiation, ozone distribution, the solar ultraviolet spectrum, and magnetic fields and ionospheric currents. The limited time of exposure, of the order of minutes, led to the desire for instrumented Earth satellites for extended scientific applications, with eventual applications to meteorology, communications, and navigation.

The rocket experience also taught experimenters how to build miniaturized instrumentations. By 1954, the concept of an instrumented unmanned satellite began to take shape, in competition with popular accounts of space stations housing dozens of astronauts. In 1954 also, international scientific organizations like IUGG and URSI adopted resolutions promoting the use of satellites during the 1957–1958 International Geophysical Year.

Still, it came as a great surprise to the world community when the USSR launched the first satellite, *Sputnik-1*, on October 4, 1957 at the beginning of the IGY. It was soon followed by *Sputnik-2*, which carried important scientific instrumentation, included cosmic-ray detectors built by Sergey Nikolaevich Vernov and Aleksandr Evgenyevich Chudakov. These instruments detected for the first time the protons of the inner radiation belt, although the discovery was not recognized at that time because of a series of circumstances. The US satellite *Explorer-I*, carrying Geiger counters to measure cosmic rays did encounter the high counting rates typical of the large flux of radiation trapped in the geomagnetic field. To explain these results, the author developed the 'neutron-albedo' theory, and so did S. Vernov and A. Chudakov quite independently.

The outer radiation belt consisting of energetic electrons, was also seen by Valerian Ivanovich Krassovskii and Yury Ilyich Galperin, and studied extensively in later *Sputnik* satellites.

INTRODUCTION: PERSONAL RECOLLECTIONS

Starting in 1946, after having served in the US Navy during World War-II, I was intimately involved in developments in space science in the pre-Sputnik years. At the Applied Physics Laboratory (APL) of Johns Hopkins University in Silver Spring, Maryland, James A. Van Allen and I determined the energy spectrum of the primary protons of the galactic cosmic radiation before these primaries were modified by nuclear reactions in the upper atmosphere[*]. Using the Earth's magnetic field as a spectrometer we interpreted the increase in measured flux with geomagnetic latitude in terms of primary energy. I was aware of the fact that our measurements of the primary protons were contaminated by an unknown contribution from 'albedo protons' that emanated from nuclear reactions of the primaries in the atmosphere below our instruments. Guided by the Earth's magnetic field, these protons would emerge above the atmosphere but then reenter the atmosphere and disappear. Early efforts to distinguish primary protons from albedo protons are described in a review article on Cosmic Rays[**].

Our research group at APL also measured the concentration of ozone at high altitudes, and later I was successful in locating the strong electric currents in the lower ionosphere that produce the long-predicted 'equatorial Electrojet'[***]. Our research group also took the first pictures of Earth's cloud systems from altitudes of up to 100 km, which gave us a first inkling of the value of space meteorology (By a fortunate set of circumstances, 15 years later, I became the founding director of the US Weather Satellite Service[****]).

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* *Allen Van J.A., Singer S.F.*//Phys. Rev. 1950. V. 78. P. 819; V. 80. P. 116; Idem//Nature. 1952. V. 170. P. 62.

** *Singer S.F.* The Primary Cosmic Radiation and its Time Variations//Progress in Elementary Particle and Cosmic Ray Physics/Ed. by J.G. Wilson, S.A. Wouthuysen. No.-Holland Publ. Co., Amsterdam, 1958. V. 4. P. 203–335.

*** *Singer S.F.* Dynamo Currents and Conductivities in the Earth's Upper Atmosphere//Nature. 1952. V. 170. P. 1093–1094.

**** Singer SF., Rao P.K. History of Weather Satellites//Wiley Space Encyclopedia/Ed. H. Mark. N.Y.: John Wiley, 2002.

INSTRUMENTED SATELLITES

One of the great handicaps of high-altitude rockets was the fact that the exposure time above the appreciable atmosphere was only a few minutes, which limited many experiments in an important way. In addition, the rocket and all the instruments were generally destroyed on impact. Therefore, the idea of a satellite carrying the same kind of instrumentation came about in a very natural way. Since the public view of Earth satellites was dominated by futuristic descriptions of manned spaceships circling the Earth, which were clearly out of reach of the then-current technology, it became important to emphasize the unmanned feature — hence the designation of MOUSE (Minimum Orbiting Unmanned Satellite of the Earth). First published in the *Journal of the British Interplanetary Society*[*], the concept gained public exposure in a space symposium held at the Hayden Planetarium in New York City in 1954. Prominent geoscientists like Lloyd Berkner and Athelstan Spilhaus championed the concept, and with their help resolutions were passed in the summer of 1954 at the international meetings of URSI (International Radio Science Union) and IUGG (International Union of Geodesy and Geophysics). These resolutions recommended the use of instrumented satellites during the IGY (International Geophysical Year) 1957–1958[**].

There was also opposition to satellites and a turf battle between the Naval Research Laboratory, favoring the *Vanguard* design, and the US Army *Redstone Arsenal*, favoring a design based on the *Redstone* ballistic missile. President Eisenhower, anxious to avoid any military connotations to satellites and to the IGY, gave the nod to the *Vanguard* project, which was based on a yet-to-be-developed booster rocket. Ultimately, however, it was the Army concept, based on the *Redstone* missile, which put the first US satellite into orbit in 1958. One may speculate that had the White House favored the *Redstone* proposal, the US might have launched a satellite in 1957, more or less at the same time as *Sputnik*. In any case, the launch of *Sputnik* came as a huge surprise and shock to some people — and had a great impact on world opinion. I well remember the announcement of the *Sputnik* launch by Academician Leonid Ivanovich Sedov at the 1957 conference of the International Astronautical Federation (IAF) in Barcelona[***].

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* *Singer S.F.* A Minimum Orbiting Unmanned Satellite of the Earth (MOUSE)//J. Brit. Interplan. Soc. 1952. V. 11. P. 61.

** *Green C.M.*, *Lomask M.* Vanguard: A history. Washington, DC.: Smithsonian Institution Press, 1971. P. 22.

*** Sedov and I became good friends over the years, meeting at various IAF conferences, which he attended as the chief of the Soviet delegation. Earlier, it had included Blagonravov and Ogorodnikov, later also Krassovskii, Galperin, Gringauz, Kurt and many others. When the IAF met in Washington DC, Sedov and Krassovskii visited my laboratory at the nearby University of Maryland where we were preparing miniaturized instrumentation to be launched in small two-stage rockets (Terrapin), one-and-a-half stage rockets (Oriole), and aircraft-launched meteorological rockets (Rock-Air). After admiring our efforts to build a complete instrument package for cosmic-ray measurement to fit into the FARSIDE rocket vehicle, Sedov invited me to submit it to fly in a future Soviet satellite. I never knew whether he was serious but often wondered what might have happened if it had flown on Sputnik. I last saw Sedov in 1997 (in the company of Vladimir Kurt) when we were both invited to Barcelona to celebrate the 40-year anniversary of the Sputnik announcement.

EARLY SPACE SCIENCE

In 1956, I published a review paper that described various scientific projects that might be done by an unmanned instrumented Earth satellite[*]. Earlier, I had contributed several studies to a book[**] that discussed possible experiments that might be flown in satellites. It is of some interest to review the many possible scientific applications and to see which ones have actually been carried out. My topics dealt with measurements of the exosphere, solar ultraviolet radiation and X-rays, ionospheric currents through their magnetic field effects, interplanetary dust, and even meteorology and climate studies, such as the earth's radiation balance and cloud albedo. For our purposes here, the most interesting measurement related to the detection of geomagnetically trapped radiation. By 1956 I had developed a theory of geomagnetic storms[***] that relied on trapped radiation to form a 'ring current' around the earth to produce one of the major features of a magnetic storm, a decrease in the magnetic field lasting for several days[****].

The concept of geomagnetically trapped radiation was difficult to propagate. My first full research paper on the subject, submitted to the *Journal of Geophysical Research*, was rejected by referees and the editor. But it was published in the *Transactions of the American Geophysical Union*[*****]. I was then able to persuade the Air Force Office of Scientific Research in 1955 that an experiment to detect and measure trapped radiation was worthwhile. We set up a project, termed FARSIDE, basically an extreme-high-altitude rocket. It consisted of a 4-stage rocket system, launched from a high-altitude balloon to avoid the atmospheric drag losses of the lower atmosphere[******]. I prepared instrumentation using the same instrument that Van Allen used in *Explorer-1*, a thin-walled Geiger counter and scaling circuit, plus a simple telemetry system. The instrumentation package would have reached an altitude of one Earth radius, or 6400 km above the Earth's surface. Following the launch of *Sputnik*, the AFOSR tried to launch FARSIDE from the Pacific island of Eniwetok. Unfortunately, their hurried attempts to launch this complicated system failed and no scientific results were ever obtained.

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* *Singer S.F.* Geophysical Research with Artificial Earth Satellites//Advances in Geophysics/Ed. H.E Landsberg. N.Y.: Academic Press, 1956. V. 3. P. 302–367.

** *Van Allen J.A.*//Ed. Scientific Uses of Earth Satellites. University of Michigan Press, Ann Arbor, 1956.

*** *Singer S.F.* My Adventures in the Magnetosphere (with Addendum: A Student's Story, by R.C. Wentworth)//Discovery of the Magnetosphere/Eds. C. Steward Gillmor, J.R. Spreiter, History of Geophysics 7, Amer. Geophys. Union, Washington D.C., 1997. P. 165–184.

**** During such magnetic storms one often measured a decrease in the cosmic ray flux, the so called 'Forbush decrease'. There was much debate at the time whether the magnetic ring current would be responsible for the cosmic ray effect. This debate was settled conclusively by data that showed a Forbush decrease occurring at the geomagnetic pole where outward going lines of magnetic force would not intersect the ring current. I therefore formulated a theory that called for the deceleration of cosmic rays by magnetic field scattering centers carried outward by the solar wind. This theory has now found application to help explain the influence of cosmic rays on climate changes.

***** *Singer S.F.* A new Model of Magnetic Storms and Aurorae//Trans. Am. Geophys. Union, 1957. V. 38. P. 175.

****** *Singer S.F.* Project Far Side//Missiles and Rockets. Oct. 1957. V. 2. P. 120–128.

The neutron albedo theory arose in 1958, following the launch of *Explorer-1* and its discovery of extremely high fluxes of ionizing particles at altitudes of 1000 km above the Earth's surface. The instrument could not identify their nature or energy, but it became obvious to some of us that they must be protons having a large range so as to survive for long times in the tenuous exosphere. But how could protons, presumably 'albedo' particles, be trapped? Coming up from the outer atmosphere they would have to re-enter again, guided by the geomagnetic field. The only possibility would be if they were albedo neutrons from the same nuclear reactions. These would not be affected by a magnetic field. But the lifetime of neutrons against decay into protons is quite long — and therefore the fraction of neutrons decaying while within the geomagnetic field is extremely small. However, the range of the decay proton is large and so is its lifetime. Therefore, it should be possible to obtain sizable fluxes of protons in the energy range of 100 million electron volts. The complete neutron albedo theory, giving the energy spectrum and spatial distribution of these trapped protons, was completed and published while the detailed examination of the data was still in progress[*]. In developing the theory I benefited from a seminal review paper by V. Ginzburg, which discussed the theory of diffusion in energy space. It is of interest that Vernov and Chudakov developed the concept of neutron albedo independently and at about the same time. They published their work later but should be given equal priority[**].

One might raise the question why *Sputnik-2* did not discover the radiation belt. I asked this question of Professor Harry Messel of the University of Sydney, Australia, at a cosmic-ray conference in Moscow in 1960. *Sputnik-2*, launched from Kazakhstan had its perigee over the USSR and its apogee over Australia. Vernov and Chudakov did see an increase in counting rate in their data collected over the USSR and evidently penetrated the lower edge of the radiation belt. But the high counting rates that would have led them to the discovery occurred over Australia and were recorded by Messel in his radio receivers. However, as he told it to me, he could not obtain the code for interpreting the radio signals and therefore refused to transmit his data to the Soviet experimenters. So it seems that the undue emphasis on secrecy prevented Vernov and Chudakov from making the discovery and receiving credit for their pioneering work[***].

CONCLUSION

Space science in satellites started as a natural extension of high-altitude rocket research and drew on similar techniques of instrumentation. It went on to space astronomy, which exploited the whole electromagnetic spectrum and to planetary and solar exploration with advanced instruments and robots. Progress has been remarkably swift and may expand further with manned missions to the Moon and Mars. In particular, a manned base and laboratory on

* *Singer S.F.* Radiation Belt and Trapped Cosmic Ray Albedo//Phys. Rev. Letters. 1958. V. 1. P. 171–173; Idem. Trapped Albedo Theory of the Radiation Belt//Op. cit. 1958. V. 1. P. 181–183.

** For more detailed discussion, see *Singer S.F.*, *Lenchek A.M.* Geomagnetically Trapped Radiation // Progress in Elementary Particle and Cosmic Ray Physics. V. 6 / Ed. J.G. Wilson, S.A. Wouthuysen. North Holland Publishing Company, Amsterdam, 1962. P. 245–335.

*** *Dessler A.J.* The Vernov Radiation Belt (Almost) // Science. 1984. V. 226. P. 915.

the Martian moon Deimos may allow a more efficient study of the planet Mars than either a series of unmanned missions or a manned base on the surface of the planet[*].

Acknowledgments: I am indebted to Prof. Joseph Lemaire for contributing important information[**] and to Alex Dessler, Martin Walt, and Robert Wentworth for useful discussion[***].

Copy of a letter written by S.F. Singer to A.J. Dessler
George Mason University, 15 September 1986

Dr. A. J. Dessler
Department of Space Physics. Rice University. Houston, TX 77005

Dear Alex:

For nearly two years now I have been meaning to write you and commend you on the editorial *The Vernov Radiation Belt* (*Almost*), which appeared in the Nov 23, 1984 issue of Science.

Your point is absolutely correct. Vernov lost his priority to the discovery of the radiation belt because of Russian secrecy. Vernov's instrument on *Sputnik-2* recorded radiation belt particles six months before Van Allen's in *Explorer-l*. But the *Sputnik's* elliptic orbit penetrated the belt significantly only in the Southern hemisphere, and the Russians did not release the telemetry code to anyone.

Prof. Harry Messel, a noted cosmic-ray researcher and head of the School of Physics at the University of Sidney, told me the whole story in a Moscow hotel room (the Hotel Moskva, I believe) during the Cosmic Ray Congress in 1959. He recorded the *Sputnik* signal every time it passed over Australia, but they wouldn't send him the code. When they finally asked for a copy of the recorded data, he told them to go to hell (as only Harry Messel could). Harry, you must remember, is a Ukrainian from Canada; he told the story with great glee.

But the full story is a little more complicated. Vernov **did** record the radiation belt but never interpreted his results properly. I have analyzed the matter in a review article on *Geomagnetically Trapped Radiation*, published in *Progress in Elementary Particle and Cosmic Ray Physics* Vol. VI. (North Holland Publ., Amsterdam, 1962). I enclose pp. 249–258, 'Historical Introduction,' and draw your attention to p. 254. Vernov et al. reported in 1958 a 40 % increase in count rate between 500 and 700 km. But only 12 % can be due to cosmic rays; the rest must be radiation belt particles. Of course, had they gotten data up to *Sputnik's* apogee altitude of 1680 km, then there would have been no doubt.

But Vernov is not the only one who missed discovering the trapped radiation. I don't know about others, but I am certainly one of them — four times to be exact!

1) In a 1950 *Aerobee* firing off Peru, I measured the east-west asymmetry of cosmic ray primaries, mostly relativistic protons. But I also measured the ionizing efficiency of the particles and found a component of high ion densities (presumably low-energy protons) with a reversed E-W asymmetry. (These were trapped protons; I later developed a theory for their E—W asymmetry (see p. 274), eventually confirmed by Heckman's observations.)

* *Singer S.F.* Manned Laboratories in Space // Reidel. July 1969. ISBN 9027701407; Manned Missions to the Moons of Mars // Cosmos. 2002–2003. V. 12; The Ph-D Project: Manned Expedition to the Moons of Mars // Space Technology and Applications International Forum-2000 / Ed. M.S. El-Genk. American Institute of Physics, 2000.

** *Lemaire J.F.* From the Discovery of Radiation Belts to Space Weather Perspectives//Space Storms and Space Weather Hazards/Ed. by I.A. Daglis. Kluwer Academic Publishers, Dordrecht, 2001. P. 79–102.

*** For more details see also: *Panasyuk M.I.*, *Vernov S.N.* At the foundation of national space physics// Acta Astronomica. 1998. V. 43. P. 51–56; *Panasyuk M.I.* Breakthrough into outer space//Science. 2000. V. 4. P. 61–66 (in Russia).

My 1950 notebook indicates that I considered albedo protons emanating from and curving back into the atmosphere as an explanation. But statistics of the data were not good enough to draw firm conclusions. Some details are given in another review article on *The Primary Cosmic Radiation and its Time Variation in Progress*... Vol. IV (1958), pp. 263–276. (See esp. p. 264).

2) In the summer of 1950 I flew thin-walled Geiger counters in balloons launched from an icebreaker between Boston and Thule. In the auroral zone, off Labrador, the count rate went crazy. I concluded that I was seeing noise from high-voltage discharge in the instrument, as the air pressure reached a certain low value. I never published the results; but evidently I was seeing trapped electrons of the outer belt. I should have either had a student like Carl McIlwain, or flown thick-walled counters along with the thin-walled variety.

3) By 1956 I was quite sure about the existence of trapped radiation (although I had not yet thought of the neutron albedo mechanism). I designed a 4-stage balloon-launched rocket for the Air Force OSR, to go to 4000 miles altitude. I then got the contract to supply a scientific payload, a simple Geiger counter. The Air Force called the project *Far Side* and diddled a lot. But right after *Sputnik* they tried to launch it in a great hurry from Eniwetok. I never learned officially why the project failed; all I know is that I never received any data from my instrument. Too bad; because I had published an article in *Missiles and Rockets* magazine, around 1957, that we would measure trapped radiation in the *Far Side* project.

I was one of the contenders for a spot on *Explorer-l*, with an experiment to measure meteoric erosion, using a Geiger counter. It would have seen trapped radiation, but the experiment got bumped**.** End of story.

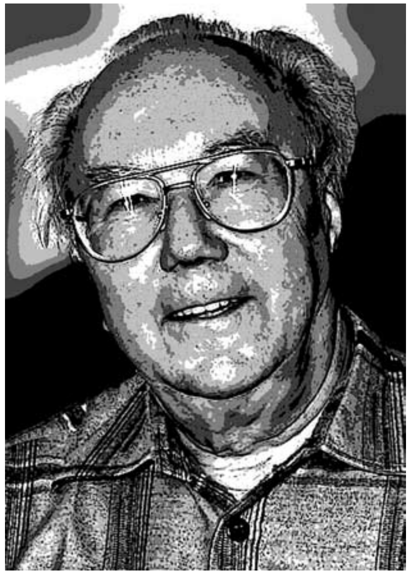
I think this is the first time I have written all this down, or even thought about it in a coherent way. Your editorial stimulated all this; I know how Vernov must have felt.

I suppose I owe most of my radiation belt insights to Hannes Alfven, from whom I learned a great deal about charged particle motion. Even earlier, John Wheeler at Princeton taught me some useful things about ergodic motion of particles in a trapping region. Someday I'll document the evolution of the ideas and theory a little better. For the time being, the enclosed will have to do.

My best wishes to you,

Cordially

S. Fred Singer, Visiting Eminent Scholar



Yuri LOGACHEV
RUSSIA

Chief Research Fellow of the Skobeltsyn Institute of Nuclear Physics, Lomonosov Moscow State University (SINP MSU).

Born in Leningrad in 1926.

Graduated from Faculty of Physics of the MSU in 1952.

Doctor of Science. Professor. Author of lectures on experimental space physics for students of the Cosmic Rays Department at the Faculty of Physics MSU in 1982–1992. Researcher in fields of magnetospheric physics, physics of inner space, galactic and solar cosmic rays. While involved in the project of the 3d Earth satellite (May 1958), the outer radiation belt of the Earth was observed. Participated in several experiments at the PROGNOZ satellites on research of cosmic rays, generated by solar-flares.

Awarded Sign of Honor and State Award of the USSR.

THE BEGINNING OF SPACE ERA AT THE SKOBELTSYN INSTITUTE OF NUCLEAR PHYSICS

To commemorate the 50th anniversary of the first Earth satellite launch

In the spring of 1956, Sergey Nikolaevich Vernov, Director of the Skobeltsyn Institute of Nuclear Physics of the Moscow State University (SINP MSU), then a corresponding member of the USSR Academy of Sciences, proposed that I should develop an instrument to be installed on an artificial Earth satellite. Probably, I was chosen, since I had already had some experience with automated instruments installed on planes. I agreed without the slightest hesitation, although, I understood that I would face serious difficulties and that I would have to say 'farewell' my dissertation theses. It should be noted immediately that everything was totally classified: I was given a room behind closed doors, all the negotiations were classified as secret, etc. Later, that secrecy cost us very much but I will come to that later.

The first trip to the Design Bureau OKB-1 headed by Sergey Pavlovich Korolev did not impress me at all: we were not allowed to go anywhere, just some people came into a room and set their requirements — the instrument mass should not exceed 2.5 kg, the power consumption — 2 W, the telemetry — one 'dry' channel with a scan rate of 50 Hz (a 'dry' channel means that a relay installed at the instrument output makes and breaks a contact with no voltage applied, while the telemetry records the making-breaking time). The instrument should be able to work for a few months. Similar 'input' data were given to other participants of our project. It was planned to launch an orbital laboratory with a large set of research instruments to explore the atmosphere, magnetic and electric fields, ionosphere, cosmic rays and a number of other problems.

Besides us, it was also a group led by L.V. Kurnosova from the Physical Institute of the USSR Academy of Sciences (FIAN). They intended to measure fluxes of lithium, beryllium and boron nuclei abundances of cosmic rays, which was of paramount importance at that time. Their instrument had a much bigger mass and greater capabilities, since the study of variations of cosmic rays (being our speciality) was treated as much less important.

Such an orbital laboratory with a full scope of instruments was launched into space on May 15, 1958 (the third Soviet artificial Earth satellite).

During a meeting chaired by S.N. Vernov, a work strategy was chosen. It was decided that a Geiger counter tube would be a detector of cosmic particles and the count of its pulses, originating, as it was then assumed, only under the effect of cosmic rays particles, would be recorded. As for recording electronics, three main options were considered: the use of miniature low-power electronic tubes, no-filament thyratrons (MTKh-90) and semiconductor elements. It should be mentioned that at that time the semiconductor technology was at the very beginning of its development (back in 1956) and we were vaguely aware of it. Therefore, great efforts were undertaken by us to use no-filament thyratrons. Almost immediately, it was decided not to use electronic tubes for the instrument, since it was shown by calculations: their power consumption was so high that we would not be able to stay within the allocated limits under any conditions. An instrument model was built around thyratrons MTKh-90, which satisfied us, as far as the mass and energy consumption were concerned, but it turned out to be absolutely inappropriate due to a very unstable operation of thyratrons. And exactly at that time we finally obtained the long-awaited semiconductor triodes and diodes and began the most interesting work: it was required to build an instrument similar to electronic-tube counters, using these elements. And — we were successful! It was practically an electronic-tube-based schematic circuit but using semiconductors instead of tubes. It worked well, very stable, in a broad temperature range, was not at all affected by vibrations and had a very low power consumption. I remember discussing this situation with Sergey Nikolaevich. None of us clearly understood how a semiconductor worked, therefore it was somewhat scary to trust this technology but we took our chance. We had carried out an extensive cycle of tests, recorded all failures, found the stable operation temperature boundary.

After that, setting aside all our doubts, we finalized the use of semiconductors. By that time, S.N. Vernov had already invited the 'Fizpribor' Plant (Physical Instruments Plant) to participate in this work, where the first instruments were manufactured and called KC-5: version-5 of our instrument. The first four versions (built around tubes, thyratrons, etc.) were turned down for the reasons mentioned above. It is curious that the very first version of the instrument was classified as secret and it was transported, protected by armed security guards. It was such a nuisance then and even after, when we withdrew the secrecy label from the rest of our developments.

In September, 1957, the instruments were practically ready. Only the service life tests remained to be performed, after that the instrument would be ready for flight. But on October 4, the whole world, including us, learnt that the first satellite (*Sputnik-1*) was launched in the USSR. There were no scientific instruments on the satellite — more

than 60 kg of storage batteries and a transmitter with non-stop '*beep-beep-beep*' signals. Just imagine our indignation and resentment of Sergey Nikolaevich: we have our instrument ready for flight with the mass of just 2.5 kg, while the satellite is flying empty, informing the whole world that it is alive and moving. This signal was received all over the world and, had our instrument been installed, — radiation belts would have been discovered already at that time, without any doubt.

After a short meeting, it was decided to try to get more complete information about the plans of our rocket specialists. Then we found out that they are preparing for another launch with a dog on board. They failed to keep it secret, since large teams participated in that work: medical biologists, headed by O.G. Gazenko (Academician), solar physicists, headed by Professor S.L. Mandelshtam from the FIAN, and their colleagues. After that, Sergey Nikolaevich 'fought his way' to be received by K.D. Bushuev, S.P. Korolev's Deputy, and we went to the town of Podlipki with the instrument's drawings. We explained the situation, emphasized the importance of our intents, reliability of the instrument and obtained a directive resolution addressed to the designers to 'work on' our issue.

Sergey Nikolaevich was very happy but K.D. Bushuev somewhat cooled his ardour: 'I didn't say 'to upgrade' the vehicle but 'to explore' the possibility of installing the instrument and it makes a great difference. Only if the designers tell me that the hardware allows its installation, we shall go to S.P. to resolve a political issue – whether we install the instrument or not'. But there were three weeks left before the launch. And here the energy of Sergey Nikolaevich was manifested: he 'mounted' the designers and technical specialists gave their 'go' already in three days.

They visited S.P. without me, I only know that Korolev did not give his consent immediately but the arguments that radiation should be measured to increase flights safety convinced him. There was a command issued – to upgrade the vehicle, i.e. to arrange the seats for mounting the instrument and telemetry connections. We had to install a stand-alone power supply source for the instrument. It consisted of storage batteries that are currently used for pocket flashlights with the voltage of 6 V, their capacitance was enough for a month of flight.

To summarize: we got 'go' resolution for the experiment, the Chief Designer got familiar with the notion of 'penetrating radiation' and its effect on living beings and hardware, which, to a great extent, defined further space activities at the Skobeltsyn Institute of Nuclear Physics.

At the end of October, 1957 we prepared two similar instruments KC-5, fit to be installed on the intended 'vehicle', and went with it to the ballistic range. The participants of this experiment were: S.N. Vernov, N.L. Grigorov, A.E. Chudakov and the author of these memoirs. We took a special flight by a Tu-104 plane from Moscow to Tashkent. From Tashkent all the Tu-104 passengers flew to the range by small Li-2 and Il-14 planes. Our team was accommodated in a separate room in a hotel, being a single-storey wooden barracks. In the assembly and test building we were also given a room, where were allocated our 'facilities' and performed all the checks and upgrades of the instruments. Here the perseverance and foresight of Sergey Nikolaevich also manifested themselves. He anticipated that we would have much work to do and it would have been not very convenient to position ourselves in a large room, like all the other participants of the satellite launch.

The 'upgrade' of the vehicle was being carried out right next to the launch pad, at the integration and test building, and we had a chance to participate in it. Our instrument was installed in the engine compartment of the rocket second stage, which, in this case, was a satellite itself. We saw that there was quite enough space in that compartment to install our two instruments rather than one. Can you imagine how Sergey Nikolaevich responded to that 'discovery'? In less than 24 hours we got an approval to install two instruments. But there remained an issue of connecting them to one telemetry channel, to the 'dry' contact. Here it was time for A.E. Chudakov to say his word. He proposed a setup ensuring connection of two counters to one channel. I am not willing now to go into technical detail of this setup. It is enough to say that the setup required coordination of output relays' actuation times for our two instruments. It was required to match resistors and capacitors, to solder everything and check. And everything was implemented right next to the launch pad, the instruments were installed and operated perfectly. And there was no military acceptance inspection. Mind that they were the very first instruments launched to the Earth orbit, totally built semiconductors.

Our whole team shared one room of the hostel-hotel. We worked hard but not round the clock. Therefore, a part of the day was spent together in informal surroundings. This is when I was impressed by the fact that Sergey Nikolaevich and his colleagues kept talking only about science all the time. They discussed Chudakov's experiments, a network of neutron monitors that was being created at that time, the results obtained by A.N. Charakhchyan, Director of the FIAN scientific station in the town of Dolgoprudny, where cosmic rays were explored by flying balloon probes. I recollect that sometimes I was successful in directing their attention to sport games (checks, chess) but it happened very seldom. And it was very difficult to play chess with Sergey Nikolaevich, he hesitated to make the next move, kept pondering over it. Once I asked him why he was 'dragging' so. '*It takes me so long to think it over because I don't like to make weak moves*', — answered Sergey Nikolaevich. In my opinion, this trait of his also revealed itself both in everyday life and in his management of the Institute. Once I proposed to play a trap game, for which it was needed either to know the secret or to find it out in the process of playing the game. My partners were not successful in doing that and they all backed down, except for Sergey Nikolaevich. And Chudakov even said in agitation: '*There's no need to waste our wits on your whims*'. This was their decision. Once, when we had an open-hearted discussion, N.L. Grigorov mentioned that he was awfully sorry for those people who were not in love with physics: they wasted their life rather than enjoyed living it...

A whole week passed like that and the time for the launch had come. Here goes another recollection but this time about S.P. Korolev. The point is that our instruments were installed next to the engines and it was possible to access them only from the viewing point next to the engines. It was decided that we would activate the instruments at the very last moment right before the launch in order to save the batteries and I was chosen to perform the mission. To check whether the instruments did get activated, I brought a radioactive source next to them and listened if the output relays were clicking. Waiting for the right moment to activate the instruments, I walked along the railroad track on the platform, used to install the rocket, carrying a long rod with the source at the end. Another civilian participating of our epopee was also walking along the neighboring railroad track (during the preparation and launches on the range everything was done by military personnel – everywhere one could see lieutenants, captains, and majors), wearing a pilot helmet and a fur jacket. It was a cold night, I was freezing and waited impatiently till it would seem for me the right time to activate the instruments and leave. All of a sudden, my neighbor made a motion with his finger inviting me to come closer and asked what I was doing there.

I explained. '*Don't you know that it's only me who is allowed to stay here? Go to the bunker, you'll be informed when you are to do your job...*' It was Sergey Pavlovich Korolev. As it turned out, it was really only his privilege, he always secluded himself in this place before the launch – and it was not allowed to disturb him: 'he was pondering over the prospects...' When later I told about this encounter at home, my mother-in-law shared an old joke: 'A serf bragged before his friends: 'I was speaking with the landlord today....What did he tell you? Go to the dogs! – said the landlord...' It was kind of rough but reproduced the situation closely...

I did not return to the bunker but went to the rocket unnoticed (that was possible at that time!), activated the instruments and only then went to the observation platform. At that moment the rocket was being fuelled with liquid oxygen, snow flakes were falling down from the sky and everything looked unusual and exotic. The launch picture is wonderful beyond description: a satellite is born from smoke and flame, accompanied by a frightening roaring of the engines. At first there was smoke, then flame and then there appeared the rocket bow – exclamations were heard: 'Here it goes, hurray!', etc. Then there was a unique sight of separating stages: five torches at a time, diverging from one another, a glowing cross in the night sky, and, finally, one torch flying away from the central stage engines.

Nevertheless, I, apparently, got cold during these operations. The next day I had a strong throat ache and a running temperature. Sergey Nikolaevich summoned medical doctors who prepared the experiment with the dog Laika to help. O.G. Gazenko turned out to be one of them. I have no idea how he treated me but, in any case, I went home accompanied by him rather than our team, so that he could observe me during the flight. We flew to the town of Kuibyshev, and then took a train. By the way, the medical team was directly opposite to our team: they were drinking, played preference card game and discussed general topics.

In the morning of November 3, 1957, all the newspapers and radio stations informed about the launch of the second artificial satellite (Sputnik-2) in the USSR, carrying the dog Laika and some scientific instruments on board, as well. One can still see Laika's photo on packs of cigarettes, named after it, but only a few people remember the scientific achievements. Laika was alive as long as our instrument — until the power expired in the batteries, i.e. about ten days...

Then, there was a period of data receipt and processing done by the military personnel without our participation. Unfortunately, the information from that satellite was transmitted only when it was flying over the USSR territory, in the orbit perigee region (250-500 km), while at the areas, where the satellite went up to high altitudes (the apogee height of about 1670 km), there were no our receiving ground stations, while it was impossible for other countries to receive this information, since the telemetry system and wavelengths were classified: the signal went into nowhere. Thus, the second opportunity at discovering the radiation belts was also lost.

However, the information available to us was also extremely interesting. Nobody had ever performed measurements of cosmic rays at those altitudes within such a large interval of latitudes and longitudes. Instruments operated perfectly. The measured flux of particles turned out to be close to the anticipated one. Isocosms (lines of equal fluxes) of cosmic rays were built, altitude behavior was defined within the interval of 300...700 km, which was reliably explained by the Earth shielding and by decrease of geomagnetic cut off with increasing altitude. However, at the altitude of 700 km our points displayed a tendency to a higher increase than that anticipated theoretically but we disregarded it — the increase was within the measurement margin of error. As it is clear now, that increase was due to the particles of radiation belts, which just begin to manifest themselves at these altitudes over the USSR territory. In the Southern Hemisphere, at the same altitudes and, the more so, where the satellite was passing, the fluxes of radiation belts particles already exceeded the fluxes of galactic cosmic rays by many times. But, since there were no data received from our satellite there, we learnt about it only in 1958 after the flights of US Explorer satellites and our third satellite.

On November 7, 1957, our counters recorded an unusual count rate behavior on one of the orbits. Pronounced fluctuations were noted, the increase was much more at high latitudes than that anticipated due to the latitude effect. That was specified by precipitating of particles from the external radiation belt due to weak magnetic perturbation. Unfortunately, at that time these notions were not included into the scope of our interest and we interpreted the observed effect as penetration of solar particles into the Earth atmosphere. It should be noted that already at the Physical Department of the MSU we, nuclear physicists, always slightly mocked geophysicists, not treating their field of science seriously. As a result, we failed to react to this most interesting phenomenon.

Thus, despite the fact that we were the first to record the particles of the Earth radiation belts, it was James Van Allen who was the first to understand that there are intensive fluxes of charged particles in the equatorial regions around the Earth. At first, Van Allen did not understand the nature of the recorded particles either, the explanation for the detected phenomenon appeared later. The *Explorer-1* and *Explorer-3* satellites did not fly at high latitudes, while the high intensity of particles had to do with the internal belt, discovered by Van Allen in February–March, 1958. He correctly interpreted his results (although his counters got silent – were 'bogged down' due to a very high intensity). Van Allen made a presentation about the phenomenon discovered by him at the US Academy of Sciences on May 1, 1958. The orbits of our satellites allowed not only equatorial regions but also subpolar ones to be investigated, thus, making it possible to detect an external radiation belt by the third Soviet satellite (*Sputnik-3*), launched on May 15, 1958.

The results of the second Soviet satellite flight indicated that, as the instruments detected the increases of particles on November 7, 1957, besides cosmic rays, they recorded bremsstrahlung of electrons (with very low efficiency) rather than protons or electrons (the average shield thickness of the rocket walls and our instrument walls amounted to a few grams per square cm and only sufficiently energetic particles were able to penetrate this protection). Therefore, on our *Sputnik-3* we installed an instrument with a scintillation counter and a rather large (40×40 mm) crystal of sodium iodide, which was able to detect not only protons or electrons but their bremsstrahlung as well. This instrument was designed and manufactured in a short space of time. A.E. Chudakov (later an USSR Academician of the Academy of Sciences) invited his colleague P.V. Vakulov from the FIAN Institute to participate in this work. Since this work was being carried out, trying to practically catch up with the far advanced *Sputnik-3*, it was required to overcome a whole number of obstacles, while installing and connecting the instrument, being considerably larger and heavier than the KC-5 instrument.

We managed to successfully install the new instrument on the satellite outer cover, while employing the same *Mayak* transmitter, used to send only the '*beep-beep*' signals on the *Sputnik-1*, to downlink data. It was precisely this setup that ensured the

success of our experiment on *Sputnik-3*, since all the stations in the world, all the ham radio stations were able to receive the *Mayak* signals. And they did receive this information, while submitting the records to us. This was how were obtained the data from almost the whole surface over the globe, including the Southern Hemisphere. There was so much information that we had to invite new staff members to process it. E.V. Gorchakov, whose participation was particularly great, was one of them. This was how the team of the main participants was defined: S.N. Vernov, A.E. Chudakov, P.V. Vakulov, E.V. Gorchakov and me.

It became clear that our results clearly distinguished between the internal and external radiation belts: in the internal one, the energy is mainly carried by fluxes of protons with E > 100 MeV, while in the external ones, by those of electrons with E > 100 keV (our instrument allowed the energy carried by one particle to be determined). Since we were the first to fly in those regions, where the external radiation belt is located, we believed it appropriate to record the fact of discovering the external radiation belt of the Earth. The authors are the above-mentioned five people, Patent # 23 with the priority set as of June 1958 (the date when the experiment results were presented at the session of the Geophysical Union in Moscow).

At the end of 1958, three aborted attempts were made at launching a rocket to the Moon. But only the forth one was successful, on January 2, 1959. The *Luna-1* station (that was how that mission was called) carried our instruments on its board, as well. The radiation belt was crossed through – from the Earth to the utmost external areas. After that, the instruments were recording stable fluxes of cosmic rays for more than 24 hours.

For their work done on the satellites and lunar vehicles, S.N. Vernov and A.E. Chudakov were awarded the Lenin's Prize (in 1960).

This stage can be treated as that of establishment of space physics at the SINP MSU. Beginning from those launches, S.N. Vernov applied a considerable part of his efforts to exploration of the discovered radiation belts and magnetosphere of the Earth. The *Elektron* satellites were an example of this activity. They were used to perform extensive research of the Earth radiation belts. The *Elektron* satellites are an epopee in the research of the radiation belts. They were conceived by S.N. Vernov immediately after the flights of the lunar stations, when the large-scale pattern of the belt's design became evident. In order to perform a comprehensive study of the internal and external belts, S.N. Vernov and A.E. Chudakov proposed to launch two satellites at the same time, since no single trajectory of only one satellite allowed such a task to be resolved. The high credibility of Sergey Nikolaevich and the importance of the task played their important part and the designers accepted that project for development. It was implemented in 1964 (the *Elektron-1* and *Elektron-2* satellites in January, the *Elektron-3* and *Elektron-4* ones, in June). It was for the first time that two satellites were launched by using one rocket. A large set of hardware for studying the internal and external belts was installed on those satellites. As a detector of particles, use was made of gas-discharge, scintillation and, for the first time in our practice, semiconductor counters. Those instruments, the total number of which exceeded 20, worked reliably, a vast amount of information was obtained, and it took us a few years to process it. A few Ph.D., Doctorate and Bachelor degrees for the studies, based on the results of these experiments, were received.

Here I could have finished my memoirs about the first space experiments. However, it is worthwhile at least to mention those experiments that were carried at the SINP MSU thereafter.

Our specialization is cosmic rays. And it was precisely from them that we began our space exploration. On the *Proton* and *Kosmos* satellites, the contents and spectrum of particles of cosmic rays were measured up to the energies of >1015 eV, while on the *Interkosmos-6* satellite, an emulsion unit was exposed that was subsequently processed in six countries. And it was precisely in that experiment that the highest energy electron was recorded ($\approx 2 \cdot 10^{12}$ eV).

The SINP MSU was engaged in the research of Earth magnetosphere oand its radiation belts more than any other institute of the country. The *Elektron* satellites provided us with comprehensive information about the structure of the belts and some of their variations. A theory of the Earth radiation belts was developed at the Institute (by B.A. Tverskoy), explaining all the phenomena observed in them, the behavior of captured particles during geomagnetic storms was studied experimentally, particles of the ionosphere region of the Earth were also detected in the plasma layer, as its component part, in addition to those of the solar wind.

Enormous attention was paid to solar cosmic rays. We performed experiments in flights to Venus, Mars and the Moon. It was precisely during these flights to Venus, that G.P. Lyubimov, a staff member of the SINP MSU, discovered deceleration of Sun-generated shock waves as they are leaving the Sun, by using the Forbush-effects observed in cosmic rays. The solar cosmic rays were investigated on the *Prognoz* satellites, specifically created under the initiative of the SINP MSU, as well as on many satellites of the *Kosmos* series. It was already the third Soviet satellite that recorded a powerful solar flare for the first time in space. We also reviewed propagation of flare-accelerated particles and processes taking place in the flare itself, as well as the concomitant X-ray and gamma-radiation and processes of particle escape from the Sun.

From the very onset of space exploration, the SINP MSU took part in assessment of radiation hazard of space flights. Beginning from 1960, the instrumentation of the SINP MSU was/is installed on each manned spacecraft (and on some unmanned ones). A Model of Space was created at the Institute, while *A Model of Spectrum of Sun-Accelerated Particles*, developed at the SINP MSU, has the status of a COSPAR documents.

Such leading scientists as S.N. Vernov, A.E. Chudakov, who closely collaborated with us, although being a staff member of the FIAN Institute, N.L. Grigorov, theoreticians V.P. Shabansky and B.A. Tverskoy were engaged in studying particles in space at SINP MSU. It was precisely those five people, who were the ideologists and organizers of almost all the experimental and theoretical researches at the SINP MSU and who, much to our regret, are no longer with us.

Space research is the main area of scientific focus at the SINP MSU, in which from 25 to 50 % of the Institute staff members were engaged in different years. Considerable achievements gained in this area suggest that during the first 50 years after the satellite launch we have been working decently in the field of space science. We hope that the next 50 years will be still better. As shown by the above-mentioned, the launch of the first artificial Earth satellite profoundly affected the scientific program of the SINP MSU. I believe that the whole mankind experienced a similar effect.

SPACE IN-SITU

William Ian AXFORD

NEW ZEALAND

Born in 1933. Educated at the Canterbury (New Zealand), Manchester and Cambridge Universities (1951–1960). Employed in the RNZAF Defence Science Corps (1957–1963), the Canadian Defence Research Board, Theoretical Studies Group (1960–1962). Professor at the Cornell University and the University of California in 1963–1974. Director of the Max-Planck Institute for Aeronomy in 1974–2003.

Vice-President of SCOSTEP (1986–1992). President of the Committee on Space Research (COSPAR, 1986–1994) and of the European Geophysical Society (1992–1994).

Vice-Chancellor of the Victoria University of Wellington, New Zealand (1982–1985). Foreign Member of the US National Academy of Sciences, Fellow of the Royal Society of London, Honorary Fellow of the Royal Society of New Zealand. Tsiolkovsky Medal of Cosmonautical Federation (USSR, 1987). Asteroid 5097 is named after him (1993).

THE BEGINNING

In October, 1957 I was a student just beginning my doctoral research in the Mathematics Department of Manchester University in England. I had arrived only a few months previously from my home country of New Zealand where I had studied aeronautical engineering and applied mathematics and expected to continue in this general direction. By some piece of good luck, which is always to be hoped for as one's career develops, my new supervisor, James Lighthill, decided that aerodynamics did not have to be about aeroplanes and that my thesis topic would be concerned with 'cosmical' gas dynamics, involving interplanetary and interstellar space. I knew nothing about these subjects but, with the courage of the young and ignorant, was willing to learn. In fact by October 4 I had learned quite a lot but not enough to expect that anything unusual might happen in space so suddenly. Accordingly the successful launch of *Sputnik-1* was a great surprise and I sat before the television set with my eyes and ears wide open trying to make sense of what was clearly a great event.

Of course when young I was just as fascinated as any other boy with space stories. The most famous of these concerned 'Buck Rogers' as a hero of the 25th century, who, together with his curvaceous girl friend 'Wilma Deering', conducted successful battles against evil-doers in space. Their chief weapons were 'ray' guns which were used effectively against their enemies as they careered around in space with the aid of flight packs carried on their backs. Their space suits were quite minimal and they did not seem to have a problem in breathing even without helmets. In fact the stories were simply our familiar 'Cowboys and Indians' in a different environment but they were vastly popular, catering as they did to the needs of the 1930's when depressing social conditions made almost everyone want to dream about different places and different times.

The first real space traveller, the unfortunate dog Laika, did not measure up to these heroes but we felt for her all the same. The first human being in space, Yuri Gagarin, was a different matter but we cheered him for his bravery and took him to our hearts despite the tendency of our western media to downplay the significance of the events wherever possible. For me however it was the scientific aspects of the early missions into space that mattered most: my reading had brought me some knowledge of the work of Chapman and Ferraro on the magnetosphere (as it was later named by Gold), on Biermann's 'solar corpuscular radiation' (Parker's solar wind), on comet tails and on collision-free shock waves. The latter were explained by Gold in 1953 to be the explanation of the very abrupt increases ('sudden commencements') in the geomagnetic field observed at the start of a geomagnetic storm.

As a newcomer to the field I took to reading everything I could find. Each day I would pass through the University library searching for new journals and books that might offer some fresh crumbs of knowledge. There were not so many journals at that time and those that existed were much thinner than their successors today. The *Journal of Geophysical Research* for example appeared quarterly and covered all topics in a total of less than about 1000 pages per year. However the interesting journals for me were *Doklady**, *Soviet Astronomy* and *Uspekhi*** which appeared in translated form quite promptly. They contained satisfying articles on the new observations of interplanetary space and on the ideas that were being developed, particularly with regard to *in-situ* measurements of the plasma, energetic particles and fields.

It was the results obtained by the Gringauz group that I found most interesting. They involved a quite simple and robust technique based on directional ion 'traps' with modulated potentials which could be used to distinguish between positive ion and electron fluxes above a certain energy threshold. With these measurements, made from the spacecraft *Lunnik-2*, *-3* and *Venus-1*, the following discoveries were made:

1) profiles of the topside ionosphere, the plasma-sphere and plasma pause.
2) the nightside plasma sheet and the dayside transition region with the latter being interpreted as the consequence of a bow shock in the upstream supersonic plasma as first suggested by Zigulev and Romishevski.
3) in the region of the outer radiation belt, which was discovered from *Explorer-1* by Van Allen and his associates as a saturation of their Geiger counters, the particle flux did not exceed about 10^8 $cm^{-2}s^{-1}$, confirming that the particles could not be associated with the auroral phenomenon (i.e. 10…20 keV electrons), which would have required the fluxes to be many orders of magnitude greater.
4) the solar corpuscular radiation, which was found at sufficiently large distances from the Earth to be directed from the sun as a flux of positive ions ($10^8 \ldots 10^9$ $cm^{-2}s^{-1}$), presumably protons with energies greater than 40 eV.

There appeared to be no stationary component of the plasma, the flux was related to geomagnetic activity and was present whenever the spacecraft could be interrogated from the Earth. Fortunately Gringauz had taken care to publish his results in the annual *Cospar Proceedings* so that they were available in English and widely read.

Gringauz had some trouble concerning these measurements, particularly of the plasma-sphere, because his colleagues pointed out that they were not confirmed by US

* Full name: *Doklady Akademii nauk* (*Proceedings of the Russian Academy of Sciences*).

** Full name: *Uspekhi fizicheskih nauk* (Advances in Physics; published in English as *Physics-Uspekhi*)

measurements, particularly from *Explorer-1* and *-2* and *IMP-1* and *-2*. However I happened to write an extensive review* of all observations of the interplanetary plasma up to 1967 and stated that these particular US 'measurements' were clearly incorrect. As a result I became Gringauz's friend for life and was later pleased to be his collaborator in *Vegas-1* and *-2* where the plasma structure of the envelope of Comet Halley was determined for the first time.

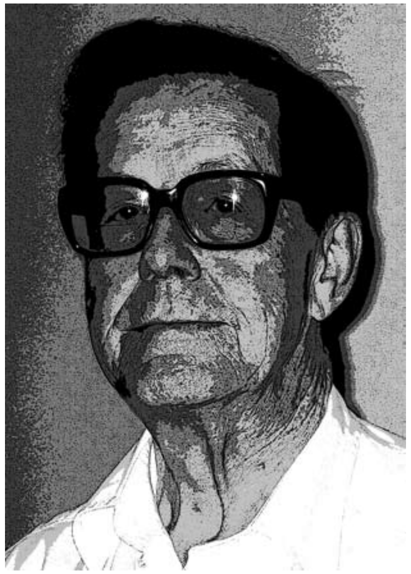
Observations of particles and fields in the magnetosphere and interplanetary space have since been carried out in extraordinary detail and have given us a wonderful appreciation of the phenomena involved. The only regions which have yet to be explored fully are close to the Sun, which will require a 'Solar Probe', and at large distances in the outer heliosphere and beyond, which are at present being traversed by *Voyagers-1* and *-2*.

Detailed observation of the planets and their satellites began with *Lunnik* observations of the far side of the Moon. Here Manchester University played a role in that Sir Alec Lovell, the Director of the University's radio observatory at Jodrell Bank, had the idea of using his new large telescope to track the *Lunnik* transmissions as something of a public relations exercise. This was understandable in view of the difficulty he had had in raising money for the telescope and the enormous public interest in lunar observations. He even 'published' the data on BBC television to the chagrin of its real owners. However he did not know how to size the pictures he had received, which consequently looked a little odd. In the end no harm and much good was done.

The advances that have been made in planetary research have been amazing – these involve the terrestrial planets, the outer planets, their satellites, asteroids and comets. There can be no question that this work should be continued and extended as far as it is possible to do so. However we should not neglect the Earth itself, especially the atmosphere. We are facing a very great danger to the existence of mankind as we know it as a result of climate change associated with global warming. There are now plenty of signs of the beginning of the expected changes from extended drought accompanied by bush fires in susceptible regions (Australia, Spain, Portugal, California and so on), storms and extreme weather (with Hurricane Katrina a clear example) and loss of snow cover in favourite ski resorts. There are many other effects to be expected, most of them unpleasant. Russia is in the front line and it is to be expected that, if we are lucky and the average annual global temperature anomaly is restricted to 2 °C (the limit considered acceptable by the European Union). The average temperature in Siberia will increase by about 6 °C which will cause havoc in regions of permafrost where methane clathrates will melt, emitting methane (a particularly dangerous greenhouse gas), and removing the support beneath buildings and roads built on the permafrost.

It is important that Russia should monitor and investigate the situation very carefully, in its own interests as well as those of the rest of the world, and of course many of the relevant observations should be made from space. Unfortunately I am a pessimist: in my opinion the world will fail to control greenhouse gas emissions until too late and we must therefore also prepare for the worst. This will become apparent during the next 20…30 years with unavoidably serious effects becoming widespread by 2050. We will not be saved by Buck Rogers and his girlfriend Wilma — manned space flight cannot help us — we must take all sensible measures to avert a catastrophe.

* Space Science Reviews, 8, 331–365, 1968.



Bengt HULTQVIST
SWEDEN

Secretary General of the International Association of Geomagnetism and Aeronomy (IAGA) since 2001.

In 1957–1994 — the first director of the Kiruna Geophysical Observatory in Sweden, which changed its name to Kiruna Geophysical Institute (in 1973) and to the Swedish Institute of Space Physics (in 1987). In 1995 he became one of the two first directors of the International Space Science Institute (ISSI) in Bern, Switzerland.

In the early sixties he initiated the process of having the European Sounding Rocket Range located in Kiruna, He also initiated the Swedish national satellite programme, with *Viking* as the first satellite, and the European Incoherent Scatter Facility (EISCAT).

He is a member of different Scientific Academies, a Fellow of the American Geophysical Union and has received medals from COSPAR (Committee on Space Research), European Geosciences Union (EGU), Russian Academy of Science, the King of Sweden, and several Swedish Academies and other institutions.

CONSEQUENCES OF SPUTNIK

I moved to Kiruna with my family in May, 1957 as director of the new geophysical observatory, which the Royal Swedish Academy of Science was establishing. My immediate task was to prepare for the official inauguration of Kiruna Geophysical Observatory (KGO), which took place on Monday, July 2, 1957, the first working day of the International Geophysical Year (the observatory became a governmental research institute with the name changed to Kiruna Geophysical Institute (KGI) in 1973 and to Swedish Institute of Space Physics (IRF) in 1987). We were five persons working at the observatory at the time of inauguration and the number increased to eleven by the end of the year. Johannes Ortner and I were the two scientists during the first half-year and we were preparing a number of ground-based measurements, including magnetic, optical and radio wave recordings, for investigations of physical processes in the auroral region. None of us knew anything about the Soviet plans to launch the first artificial Earth satellite as a part of the programme for the IGY.

For us in Kiruna, as for most people on Earth, the launch of the first *Sputnik* was an enormous event. We, as millions of other people around the world, were observing the little bright spot as it moved across the sky near sunrise and sunset and we also picked up the satellite '*beeps*' on the radio. We followed with great interest the enormous publicity that the event gave rise to in all sorts of media and we quickly started to plan how we could use the satellite radio emissions for scientific purposes. With the use of the Faraday effect we started measurement of the total electron content in the ionosphere and one of the first Ph.D.-theses at the observatory was based on such measurements on *Sputnik-3* transmissions.

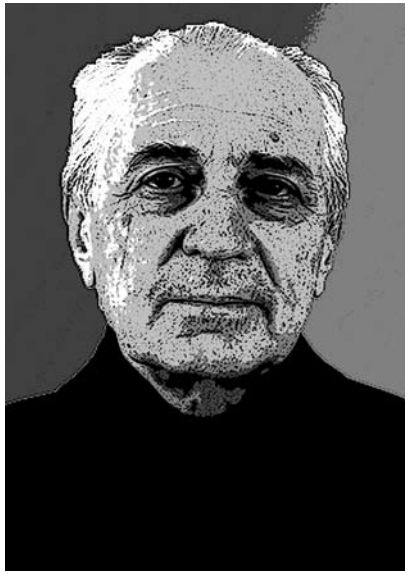
The Kiruna Geophysical Observatory was originally intended for space physics studies in the auroral zone by means of ground-based measurements of various kinds of

radiations, which carried with them information about the processes that had affected them on their way down to our antennas and detectors. *Sputnik* changed our situation profoundly. Not only became space physics suddenly a scientific field of general interest in society and the scientific community at large, but it opened up the possibility to have satellite-born instruments for measurement of physical variables in space which cannot be measured from ground. As I had a background in measurements of energetic particles, we decided to develop satellite instruments for determination of characteristics of the hot space plasma, which gives rise to aurora and many other things. We succeeded in having our first instrument accepted for the first European satellite, ESRO-1. From that on we added to our ground-based measurements the building of satellite instruments for hot plasma measurements, including ion mass spectrometers as time went on. The Kiruna group was the only scientific group in Sweden that had resources allowing participation in international satellite projects in the early space era, until the first Swedish scientific satellite, *Viking*, was developed in the 1980's. Then the electric-field measuring group in Stockholm and the plasma-wave group in Uppsala joined the satellite-instrument-building community.

Although the space research was an affair for the Soviet Union and USA in the 1950's, European scientists started to discuss rather quickly how Europe could be involved in it and space research committees were established in many European countries, among them Sweden, already in 1959. An organization for planning European space research was established in 1961 and I had the pleasure of participating in the planning work as a representative of Sweden and as member of various expert committees and later in the work of the European Space Research Organization (ESRO) and its successor European Space Agency (ESA) from 1961 to the end of the year 2000. The planning organization decided in 1961 that the European sounding rocket range (*Esrange*) should be located in Kiruna, which was very important for us. The number of persons involved in some kind of space activity (including education) in Kiruna increased from 5 at the inauguration of KGO in 1957 to about 500 when I retired from the directorship of IRF in 1994 (for whom Swedish Space Corporation is the largest employer). So in Kiruna we have really been riding on the space bandwagon through the half-century that has elapsed since *Sputnik*. Our collaboration with Space Research Institute (IKI) in Moscow has been an important part of KGI's development.

Space research has first of all opened up new fields of science but it has also changed the view of the world for the general public more than most other scientific fields. The pictures of the blue planet taken from space, with the thin layer near the surface as the only region where life of the kind we know can exist, has made it clear to most people that conditions for life are quite limited and have to be protected. Space science research has also been the driving force behind important technical developments that affect most people today (e.g. the development of microelectronics) and space applications have become important parts of the technological civilisation that dominates our planet (e.g. satellites for communication, navigation, and observation). New space technologies will certainly continue to provide new applications in the future.

Our planet Earth is the 'spaceship' where humankind lives and shall live into the distant future. It is limited in size and in resources and has to be protected so that it can remain our home in future forever. In the long run this will require that the resources of the Solar system will be exploited and that strongly disturbing activities will be taken away from Earth and brought into space. In my and many others' view, space is the main adventure of our generation and of many generations to come, an adventure that provides some hope for the future (unfortunately, in this brief note it is not possible to present and discuss the reasons for such a hope). That human beings will go into the Solar system is a necessary part of the adventure. Success certainly will require that most resourceful countries will cooperate, as the needed resources are very large. There are unfortunately many problems in the world that may hinder a large-scale cooperation, one of which is reaching a general agreement that going into the Solar system in a grand way should be a long-term high priority goal of humankind. A most serious risk is that coming to such an understanding will take such a long time that when most people finally will agree about the need to go into space in a very serious way, it will be too late because the resources will not be there any more. In spite of the problems the vision has to be kept alive.



Vladimir KURT
RUSSIA

Deputy Director of the Astrospace Center of the Lebedev Physics Institute of the Russian Academy of Sciences.

Born in 1933 in Moscow.

Graduated from Faculty of Physics of the MSU. From 1955 worked in the Sternberg Astronomical Institute in radioastronomy department. In 1967 changed for the Space Research Institute of the USSR Academy of Sciences (Head of Department of X-Ray and ultraviolet astronomy). Since 1991 has worked in the Lebedev Physics Institute of the Russian Academy of Sciences.

Expert in physics of the upper atmosphere of planets, cosmology, X-Ray and ultraviolet astronomy. Doctor of Science. Professor of Astronomy Department, Faculty of Physics, MSU.

Honoured worker of science in Russia. Awarded the Red Banner of Labour, Russian State Award.

THE FIRST STEPS OF OUR SPACE ASTRONOMY

Department No. 3 or Department of Astrophysics of Space Research Institute of USSR Academy of Sciences (IKI) was organized following the initiative of the Academy President M.V. Keldysh in 1966. Iosiph Samuilovich Shklovsky, the correspondent member of the USSR Academy of Sciences led it till his death in 1985. This was, no doubt, the brightest astronomer of our country. The base of the department was a strong and well pulled team of astronomers at P.K. Sternberg State Astronomical Institute of the Physics department of Moscow State University (SAI MSU or GAISh). It had been 10 years since the launch of the first artificial satellite, which opened our 'space' life.

It might have started by meeting the Academician, admiral and deputy Minister of Defense Axel Ivanovich Berg, a man of an extraordinary life and various talents in a wide range of scientific applications and life in general. We, I.S. Shklovsky and a few GAISh employees were introduced to him by our senior friend and mentor, professor Valerian Ivanovich Krasovsky, head of the upper atmosphere physics department at the Geophysics Institute of USSR Academy of Science (GEOFIAN). This was Axel Ivanovich who introduced, or rather recommended I.S. Shklovsky to then absolutely unknown, except a few 'initiates', Sergey Pavlovich Korolev, to work on optical observations of the artificial Earth satellite, which was then getting ready for launch. Me, P.V. Scheglov and V.F. Esipov were assigned to develop a photography method for such observations to determine the satellite coordinates and accurately relate the spherical coordinates to the time. We used aerophotographic camera NAFA for the purpose. The camera had 10 cm lens and marine chronometer with electric connections.

The camera allowed blocking the light from the satellite at precise time intervals, so the satellite track consisted of dotted lines, the tails of which were referenced with the precision down to fraction of a second. The film was developed immediately after the observation, the tracks were referenced to the stars on the measuring microscope, and for arithmometer *Felix* or *Rheinmetall* computer it took from half hour to an hour to determine six parameters of the satellite orbit (it takes a second or two for a modern PC). This method ensured at the time more accurate orbital parameters than radio measurement of the range and radial velocity of the satellite. Naturally, we could only make test observations of the stars before the launch, imitating the satellite motion by swaying the camera to get the star tracks of the required length. Vasily Ivanovich Moroz experimented with the photoelectric sensor of the satellite — photomultiplier tube and, I think, with the TV hardware.

I and P.V. Scheglov took a flight to Tashkent in a couple of days after the satellite launch (October 4, 1957), where Scheglov's father Vladimir Petrovich was the director of the astronomical observatory of the Academy of Sciences of the Uzbek SSR for photographic observations. It was the time when first passenger jet Tu-104 started regular flights, and we boarded the direct flight Moscow-Tashkent with our instruments. All passengers were treated to black caviar, the jet was flying at 11 000 m altitude at about 1000 km/h — it was like being in a science fiction movie. We could calculate the timing and the coordinates of the satellite and told this to the pilots of the jet. I remember well as we were taken to the pilots' cabin and the satellite (the last stage of the booster rocket to be more precise) passed right across our flight path against the very dark sky at dusk, which completely astounded the flight crew.

P.V. Scheglov and I made excellent photos of the *Sputnik* on the very first day and sent them to Moscow. These were the exact photos that were published in all the papers! Papers, of course, did not report how and why we needed to get the short tracks.

For about two weeks we were in Tashkent we have been making daily observations and calculated orbital parameters in order to calculate the atmospheric density at the satellite flight altitude (300…400 km). High density and significant satellite drag were a complete surprise for the geophysicists. I believe no one expected such a high density (about 10^8 atoms/cm^3) at this high altitude. The geophysicists were not even aware of the turbulent mixing in the atmosphere up to 100 km and, as a consequence, permanent molecular weight of the atmosphere at 29.9. Neither there were any data about the chemical composition of the atmosphere at the satellite flight path altitude. We soon learnt that the primary atmospheric component at the altitude was atomic oxygen, which was also a great surprise. The idea then was there was a diffusion partition almost from the Earth surface, in which case the atmosphere would be almost 100 % pure hydrogen at 400 km! Celestial mechanics at Academician D.E. Okhotsimsky's department (Drs. T.M. Eneyev, M.L. Lidov, E.L. Akim, V.S. Egorov) determined the atmosphere density. Our brilliant mechanic M.L. Lidov, with whom we extended the cooperation throughout all of his life, laid the foundation of the satellite drag theory. However, only we had the proper instruments and data processing methods.

A.G. Masevich and A.M. Lozinsky at the Astronomy Council of the USSR Academy of Sciences worked on this task in parallel with us. Their idea was to equip all astronomical observatories, universities, planetariums, teacher training universities and even astronomy armature clubs with simple 'spy glasses' mounted on the stands and star maps. When the satellite passed near some star, the observer would press a button and the chronograph would record the fact on the roll chart, and the star and its

coordinates would be recorded by hand in the observation log. Of course, this 'primitive' method was much less precise than our photographic method, but it ensured the large scale of the observations. Our optical factories promptly manufactured the 'spy glasses' and the operational manuals for the observers, and hundreds of enthusiasts have been making these observations until the radio methods provided the required precision and ensured the observations could be done in any weather and the coverage was complete from Byelorussia to Vladivostok.

However, we realized that the faint satellites and bleak booster rockets were out of reach for us. By that time, an almost 1m Bekker-Nunn mirror-lens camera was manufactured in the US, which was capable of spotting satellite tracks up to stellar magnitude 11, i.e. it was a hundred times more sensitive than our NAFA camera with 10 cm lens. We got in touch with our famous opticist, Correspondent Member of USSR Academy of Sciences D.D. Maksutov, and he made an estimate of such a camera in a surprisingly short time with, of course, with Maksutov-type mirror lens. The camera was not built at the time, but a few such serious machines (VAU) were built much later and are still used for a lot of geodesic and other purposes involving satellite observations.

After the optical observations of the satellite were successfully accomplished and their orbital parameters were identified in 1958, S.P. Korolev offered I.S. Shklovsky to accomplish the optical observations of an object on the trajectory flight to the Moon. OKB-1 was already busy working to arrange a launch a Moon station in order to fly around the Moon, take pictures of the back invisible side, land on the surface, take a sample of the Lunar soil and fly back to Earth. Three competing projects were reviewed at the meeting of Technical and Scientific Committee for Space Exploration chaired by M.V. Keldysh, who was also the Director of the Department of applied mathematics of the USSR Academy of Sciences and the President of the USSR Academy of Sciences. Our project involved building an artificial sodium comet, i.e. an evaporation of a few kilos of sodium or lithium on the orbit. This cloud was supposed to resonance scatter the solar radiation and shine the way the comets do. I.S. Shklovsky preferred sodium over lithium, although the lithium comet would shine twenty times brighter, as there is a lot of sodium on the solar surface and virtually no lithium. However, on the wavelength 6708 Å (lithium absorption line) the sensitivity of both the human eye and the photomaterials available at the time were ten times lower than at the sodium absorption lines (wavelengths 5890 and 5896 Å on the solar spectrum) and that is why we chose the 'sodium' option. Two other projects lost to us due to following reasons. The first project proposed spraying a fine aluminum powder and the second, too 'science fictional' to be true, proposed exploding a nuclear device. The basic calculations performed by I.S. Shklovsky indicated that the cloud would be expanding too slowly, would have small linear and angular size and its stellar magnitude would not be sufficient for observations. The nuclear option gave only a millisecond short flash. A huge mass of hot ionized air shines in a nuclear explosion on Earth, whereas in space a tiny mass of the evaporated space vehicle would be enough.

As the result, our project won the competition fast and easy. Right away, we started working on its implementation. Several directions were determined. The first was to develop and manufacture sodium evaporators. The second was to run a test on a geophysical missile in the upper Earth atmosphere at 400…500 km. The third was to develop and manufacture about 10 telescopes of two types with short band interference colour filter on the sodium line. One of them had a luminance amplifier — a three cascade image-converter tube. The second was a simple photo camera. Based on S.P. Korolev's request, A.N. Tupolev agreed to convert a strategic bomber Tu-4 for such observations. The designed telescopes were supposed to be mounted at the lateral window of the aircraft or could perform observations from the ground, at which the weather would be ideal when the 'comet' would go off. We were given 4 aircrafts based at a military air field at Belaya Tserkov in Ukraine. Our colleague V.F. Esipov was in charge. The academician Vassily Gavrilovich Grabin, the director of the institute that designed artillery systems, started working on the design of the sodium evaporators. S.P. Korolev assigned his deputy A.M. Petryakhin to run the tests on R-5 rocket. S.P. Korolev personally monitored the work on the project. The optics was manufactured at Krasnogorsky optical factory, image converter tubes were manufactured at NII-801 and Moscow electric lamp factory. A.N. Tupolev and his deputy L.L. Kerber monitored the aircraft conversion and telescopes installation activities.

Everything was ready 8…10 months and the evaporators were flight tested on 18th September at Kapustin Yar rocket range. The R-5 rocket carried two thermite sodium evaporators which activated at the zenith of the rocket trajectory flight at 430 km altitude. I.S. Shklovsky came to witness the launch and saw the fantastic view, which transformed his idea and estimates into the reality against the morning sky. The bright orange was shining for almost half hour until the rising sun did not outshine it. These observations allowed us to estimate the evaporator efficiency and the expected stellar magnitude of the sodium cloud at the lunar distance.

V.I. Moroz and V.F. Esipov made successful observations of the sodium comet during *Luna-2* lunar station launch on September 15, 1959. Observing the expansion of the sodium cloud at 430 km altitude allowed determining the density of the Earth atmosphere for the first time at this high altitude. Observations made by V.I. Moroz and V.F. Esipov helped developing the gas expansion to the vacuum theory and test it experimentally. I.S. Shklovsky was awarded the Lenin prize for his idea of the sodium comet and the successful execution of the project in 1960.

A close cooperation with a prominent engineer and scientist and S.P. Korolev's associate Gleb Yurievich Maksimov made it possible for us to participate in rocket launches to research the hydrogen geocorona, density, chemical composition and the temperature of the upper atmosphere, and later in experiments investigating the interplanetary media and the upper atmosphere of Venus and Mars. Our UV hardware was installed on all the stations traveling to Mars and Venus.

At the same time the future academicians of Russian Academy of Sciences began a series of successful observations of the low frequency radio emission at the bands that do not reach the Earth surface and are reflected by the ionospheric layer, i.e. below 30 MHz. For this purpose, OKB-1 designed a few meters-long antennas, unfolded like a reel tape, and the Institute headed by M.S. Ryazansky Correspondent Member of the USSR Academy of Sciences, developed the receivers for this band.

The large work scope in terms of the hardware development for satellites and interplanetary stations, processing of the incoming data and the ambitious plans of the future researches were hampered by the traditions and capabilities of GAISh. When following M.V. Keldysh's initiative the Space Research Institute at USSR Academy of Sciences was founded in 1966, it was natural that I.S. Shklovsky received a proposal to organize the department of Space Astronomy at the Institute. It got number 3, as numbers 1 and 2 were already reserved for the well known researches. Of course, not all the GAISh Radioastronomy department employees desired to get a transfer to the newly established Institute. However, the core employees received this proposal with

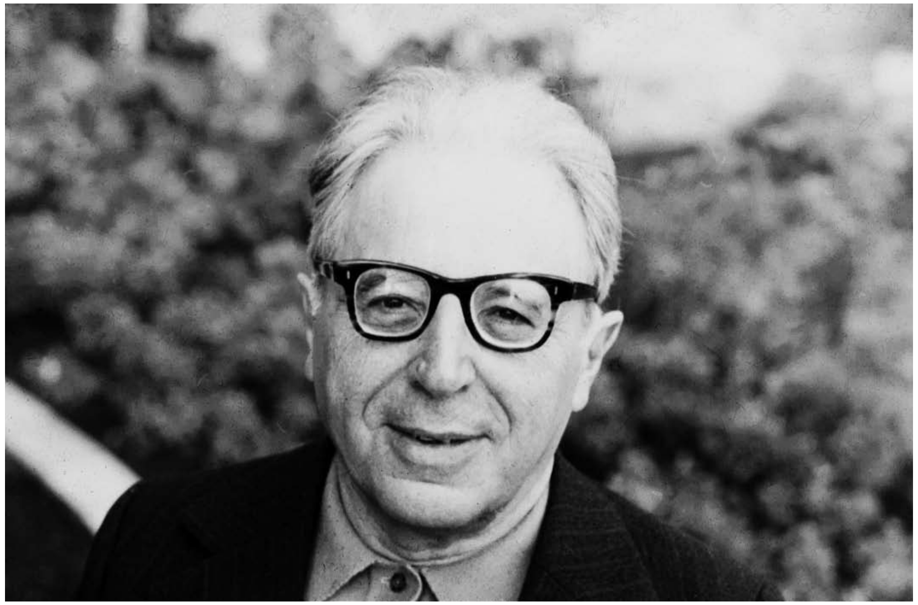
SPACE IN-SITU

Head of the laboratory V.E Nesterov, Academician R.A. Syunyaev, Academician Ya.B. Zeldovich and Head of the Department Correspondent Member I.S. Shklovsky (from left)

Head of the Astrophysics department of Space Research Institute of USSR Academy of Sciences, Correspondent Member I.S. Shklovsky, Professor Leo Goldberg (USA) and deputy director of Space Research Institute Academician N.S. Kardashev, 1970's (from left)

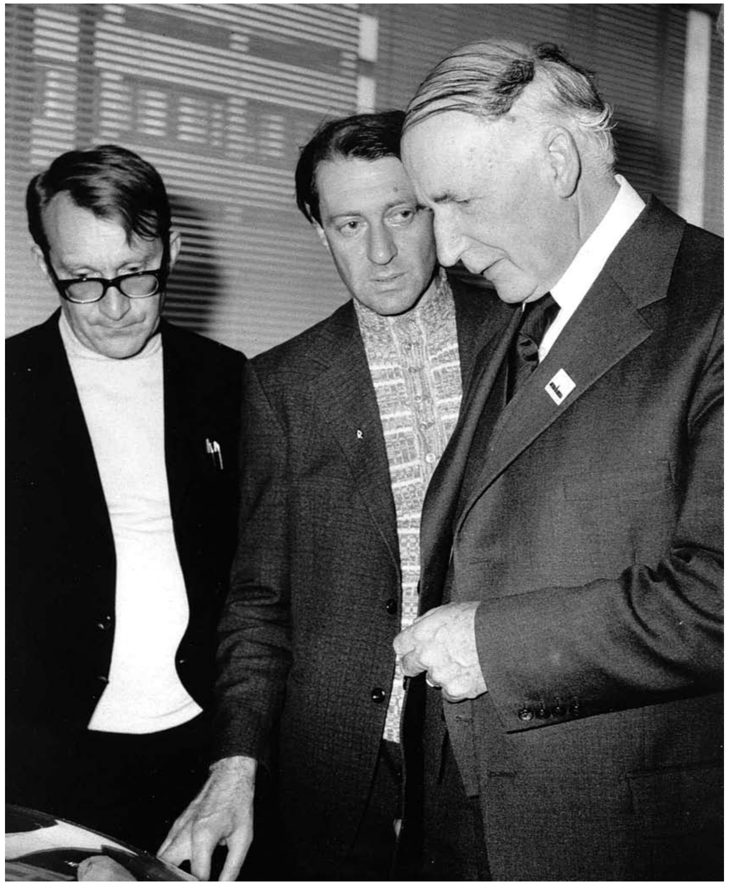
Head of the laboratory G.B. Sholomitsky, Head of the department I.S. Shklovsky, Dr. Bill Howard (National Radio Astronomical Observatory, USA). Head of the laboratory L.I. Matveenko, Head of the laboratory, Correspondent Member V.I. Slysh, 1960's (from left)

Director of Space Research Institute Academician R.Z. Sagdeev, Head of the department I.S. Shklovsky and Head of the laboratory, Prof. V.G. Kurt, 1970's (from left)



I.S. Shklovsky

Director of Space Research Institute Academician R.Z. Sagdeev, Nobel prize laureate Prof. Arno Penzias (Bell Laboratory, USA), Academician Ya.B. Zeldovich and cosmonaut V.I. Sevastyanov (from left)



Director of Space Research Institute Academician R.Z. Sagdeev, Head of the laboratory, Prof. V.G. Kurt and Director of Jodrell Bank Observatory (United Kingdom), Prof. Sir Bernard Lovell (from left)

enthusiasm. Young Doctors of Sciences N.S. Kardashev, V.I. Moroz, V.I. Slysh and the author of this article headed the respective laboratories. Other younger employees got a job at our department as well, including the future Doctors of Science M.V. Popov and G.B. Sholomitsky, with some other employees transferred from other Institutes. The department hosted 150 employees and up to 14 laboratories at the peak of its existence. We made radio observations at the antennas of the Long Range Space Communication Center in Eupatoria and Ussuriysk, the optical scientists made their observations in Crimea and Caucasus at the observatories of the USSR Academy of Sciences and the Academies of sciences of the Soyuz Republics. In other words, the years from 1968 to the end of 1980's were the heyday of the department No. 3! This is quite a term — over 20 years. N.S. Kardashev was elected the Correspondent Member of the USSR Academy of Sciences; a few employees received the State Award of the USSR (N.S. Kardashev — twice, V.S. Etkin, V.I. Moroz, V.G. Kurt), and many employees were endowed with government awards.

Back in those years, our country was launching two or even four interplanetary stations a year to Venus or Mars, not missing a single good launch window, 1-2 *Prognoz* satellites, apart from a few UOS satellites (universal orbital station) to survey ionospheric layer, earth radiation belt, magnetosphere and other geophysical phenomena. Generally we were managing and processing the data received from two or more satellites or automatic interplanetary stations, two instruments were tested at the manufacturer's plant or the test range, the new instruments were developed, manufactured or went through the acceptance tests at the manufacturer's works or on the IKI Institute grounds, where we had KIS and LIS (control and test station and flight-test center) operating. This work under pressure was nominal and routine for all experimental and engineering departments of IKI Institute. We often had no weekends or vacations, and we could be easily called back to work from the vacation in case there was a problem with an instrument at the plant or the test range, which was a routine thing back then.

Of course, one should remember this was all top secret, although no one could explain what could be so much confidential about surveying the Moon and the planets in the Solar system, interplanetary and interstellar media, galaxies and quasars. Many employees could not get a permit to go abroad, although, again, no one ever explained the reasons for this discrimination. The head of the Department, correspondent member of the USSR Academy of Sciences, the Laureate of Lenin prize, could not go outside the USSR for 19 years. To this day I am not aware of the reason for that. Our department, as well as other departments, had a 'social' and communist party activity program, we issued a wall news poster, had political training sessions, were awarded a 'red challenge banner' etc., and, finally, the whole department volunteered to work at the vegetable storage facilities, clean the streets, work at 'subbotniks' and 'voskresniks' (volunteer clean-ups). Each department was assigned the 'street pole number', where we would stand for hours on end greeting the leaders of the friendly Central African countries. Let alone week- or two-week long 'business trips' to sovkhozes to collect the beat root and regular work at the 'beloved' vegetable storage base. However, this was the way the whole country used to live before B.N. Yeltsin era, which opened in 1991.

The era which started with the launch of the *Sputnik-1*, first artificial Earth satellite was, I think, the happiest time in our lives. We were not losing the race with the USA and Europe, and often were ahead. Thanks to the efforts made by our director Academician R.Z. Sagdeev, we started a successful cooperation with the USA, all the countries of the socialist block, France, and later with the rest of the European countries. Of course, there were two sides to this cooperation. On the one hand, we got an access to the cutting-edge technology, got a chance to use foreign-manufactured elements in our on-board instruments, processors, memory, stepping motors etc. We gradually started using completely or partially foreign built instruments at our vehicles instead of the ones manufactured in our OKB or at the factory in Frunze (now Bishkek). We also had some 'intermediate' cases, when one or a few units of the instruments were manufactured in the Soviet Union, and a few were made abroad. This required a joint effort at the institutes abroad and frequent visits of the foreign specialists to IKI and even the manufacturer plant and the test ranges where we made the launches. Despite the fact that our Institute was a 'secure facility' we worked on extending the list of our employees who had a permit to travel abroad.

However, this also had a negative impact on the local instrument building industry. Of course, it was much better to go for two or three weeks to Paris, Budapest or

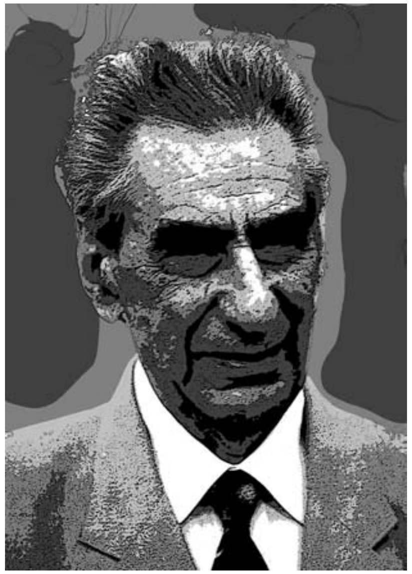
Prague, than, say, drudge along in hot Frunze or Tashkent. Besides, the instruments developed in Toulouse were more reliable than home made units, weighed less and consumed much less power. What did this lead to? Apparently, this led to displacement and demise of our local instrument building industry. This was exactly the ‘reverse of the medal’.

Certainly, I would not rate the IKI management policy back in those days. It is clear, though, that the scientific research results we got in 1970’s and 1980’s were very impressing. It would be sufficient to name a few. Venus radar map (automatic interplanetary stations *Venera-15* and *Venera-16*, 1984). Landing on Venus, starting with the first successful *Venera-4* (1967) project. Artificial satellites of Mars and Venus, delivery of the lunar soil samples to Earth (*Luna-16* in 1970 and *Luna-17*), balloon flight in Venus atmosphere. Two vehicles sent to Halley’s comet (*Vega-1* and *Vega-2*, 1986), the first in our country artificial Earth satellite for UV and X-ray astronomy (*Astron*, 1983) and *Granat* with the French made aperture grid camera (1987). The satellites which surveyed the Earth magnetosphere and solar wind effects (*Oreol-3*, 1983, *ARKAD-3*, 1981, and *Interball-2*, 1995–2000). Department No. 3’s share in these success stories was quite significant.

The laboratory of theoretical astrophysics, headed by I.D. Novikov, joined the Department in 1980. I.D. Novikov was the close associate of Ya.B. Zeldovich, Academician and tree times Hero of Socialist Labour. He was elected Correspondent Member of Russian Academy of Sciences in 2004 for his distinguished contribution to development of theoretical cosmology.

The last 50 years since the launch of the first artificial Earth satellite, as evident from the above, had a dramatic impact on the lives of all the employees of the former Department No. 3 at IKI. Most of their creative and private lives were related to space. Not all of their dreams came true, but still a lot has been accomplished. It would be good if the Government and the Management of the Academy changed their attitude to the science in general and space science in particular. The future of the whole humankind and our country, now new Russia, in particular, is closely related with this research. This is not only about the basic and clear directions, such as space communication (Internet, telephone and TV, meteosatellite), but it is more about discovering the World, the structure and the origins of the Universe, the structure and the physical properties of the superdense substance in white dwarfs and neutron stars (millions tones per cubic centimeter), superfast rotating stars rotating at tens of thousand kilometers per second at their equator, superhot plasma at billion degrees temperature etc.

Only by investing in building telescopes and accelerators, launching satellites with telescopes for all spectral ranges, our country can expect to be among the world leaders, such as USA, Japan and the European Union. Let us hope these dreams will come true!



Yan ZIMAN
RUSSIA

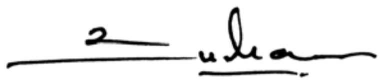
Chief Researcher of the Space Research Institute, Russia. Doctor of Science. Professor.

The optical space instruments department at IKI headed by Yan L. Ziman has prepared and implemented many space research experiments, including multi-spectral imaging of the Earth, the Halley comet and the Martian moon Phobos.

Born in 1922. Graduated from the Pilot’s Training School in 1939, the Kharkov Military Aircraft Navigation School in 1941 and the Moscow Institute for Engineers in Geodesy, Aerial Photosurveying and Cartography in 1951.

Took part in the Second World War, made 311 flights as a bombardment force pilot.

Honoured worker of science of Russia. Full member of the Tsiolkovsky Academy of Cosmonautics. Awarded by the USSR State Prize. Honoured 1st-level flight navigator of the civil aviation.



HOW THE OPTICO-PHYSICAL DEPARTMENT OVERCAME CONSEQUENCES OF ‘PERESTROIKA’

Dedicated to Yuri S. Bykov, the first chief designer in space communications systems

The rebuilding of the Russian economy, launched by Mikhail Gorbachiov and continued by Boris Yeltsin, did not leave space research untouched. Almost all the scientific programs were suspended and in fact they were terminated. Hundreds of institutions and thousands of specialists in the space research field were without work.

Our Institute*, which was established for preparing and conducting fundamental studies directly in space, found itself in a very difficult situation. In addition to the research segment the Institute also had a comprehensive computing base, highly skilled mathematicians and programmers and inventive designers as well as modern production and unique testing facilities. Moreover the Institute was awarded the status of the leading institution in the field of space research. All the projects prepared at the Institute were implemented by involving specialists from other Russian institutes and foreign states. This wide cooperation arranged and headed by the Institute was exemplified in the well-known *Venera-Halley* mission. Within the framework of this project scientific complexes for two spacecraft were created by the scientists and

* Space Research Institute of Russian Academy of Sciences, abbreviation IKI.

designers from the research and industrial institutions of our country and Hungary, Germany, France and other countries under the aegis of IKI.

Within the framework of this project in addition to the scientific instrumentation control system the Space Research Institute has created a constellation of unique space instruments for carrying out fundamental research in various fields. In particular, our Optico-Physical Department has developed three instrumentation complexes — two multi-spectral television systems together with Hungarian specialists, one with a French and another with Russian telescope, as well as two TV and two analog pointing sensors. The latter provided for targeting the three-axial platform with the television and imaging spectrometric instrumentation to the Halley comet nuclei. This unique experiment, including TV-images of the Halley comet and its nuclei as well as their scientific analysis, is sufficiently well highlighted in scientific publications. It should be noted that within this mission the so called charge coupled devices (or CCDs) were applied as photoreceivers in the TV-cameras for the first time. This made it possible to both improve the acquired imagery quality and ease this imagery transmission to Earth via the radio channel. Since then Genrikh A. Avanesov has become an irreplaceable chief designer of all our instrumentation developments.

The destructive 'perestroika' of the country's space sector, together with the tragic wreck of the *Mars-96* interplanetary space station, confronted the department with the difficult problem of how to exist in the future and how to retain the qualified scientific and engineering staff with an absence of new space missions and the avalanching funding decrease.

Professor Genrikh A. Avanesov, who headed the Department at that time, found a unique solution to this complicated situation. Based on the high device engineering experience of the Department's staff he transformed the Department into a small design bureau. By that time the Department had begun the development of star coordinators — instruments providing for both spacecraft precision (up to the units of angular seconds) attitude determination and referencing images and measurements acquired from these spacecraft. At the beginning conventional astro-sensors integrated two or three gimbaled viewing tubes. Each tube was pointed to a particular star and tracked it. As distinct from these instruments star coordinators have no moving details and fulfill frame digital imaging of arbitrary segments of the starry sky being observed for a particular moment by the coordinator's TV-camera. As a rule, the acquired images contain at least ten stars. The star coordinator's processor identifies the registered stars in the built-in star catalog for the whole celestial sphere and calculates orientation parameters. This solution has made it possible to improve the star trackers' accuracy and reliability as well as reduce their mass and power consumption.

The star coordinators developed at IKI were called BOKZ. Different modifications of this instrument have been operating in the attitude control circuits of various spacecraft since 1999. By the middle of 2007 thirteen BOKZ instruments were operating on six spacecraft, including two instruments on the *Yamal-100* spacecraft since 1999 and three BOKZ instruments on the International Space Station since 2000. Five more BOKZ instruments were prepared for launch. The Russian space industry's need for our BOKZ star coordinators has made it possible to retain almost all the department's staff as well as to provide job for the designers, production workers and test engineers of the Institute. Young specialists have begun to come to the Department.

Then the time came when our country began to drag itself out of the disaster caused by 'perestroika'. The first significant scientific mission *Phobos-Soil* appeared in the national space program. Naturally the Department is actively involved in the implementation of this mission. The star coordinator's next modification BOKZ-MF is included in the onboard instrumentation being developed for the spacecraft.

The Department continues the BOKZ instrument family modification as well as the relevant software and algorithms. The BOKZ principal change consists in integration a three-axial angular velocity sensor to significantly widen this star coordinator application field. A universal navigation instrument is being developed. It integrates a BOKZ instrument, a three-axial angular velocity sensor and the navigation satellite signal receiver in a single body. This instrument is to replace the available measuring systems of motion control systems for various destination spacecraft.

* * *

Now let us turn to the 50-year history of the star coordinator creation. At the end of 1957 there occurred an event which considerably determined my subsequent life and is probably directly connected with the star trackers being created in our department. The first chief designer of the space communications systems, a member of the Korolev's Council of Chief designers, a Hero of Socialist labor and a winner of the Lenin prize, Yuri S. Bykov, exchanged NII-1 (Research Institute No. 1) for the sub-faculty of aerial photosurveying of the Moscow Institute of Engineers in Geodesy, Aerial Photo Surveying and Cartography (MIIGAiK), where I worked at that time. Bykov offered my colleagues and me to study the problem of Earth photo-imaging from space in order to map the terrestrial surface and geo-reference the objects imaged.

The idea proposed to us by Yuri Bykov shows his genius. In fact at that time only the first two Soviet satellites had completed flights to space and he already saw multi-faceted prospects for astronautics, including mapping the terrestrial surface from space. This task was solved after his death. Yuri Bykov died in 1970 before he was 55 years old. Moreover in the last years Yuri Bykov was removed from his beloved space research for some unknown reason. He told us: 'I have injected you into orbit and burnt myself as a launcher'.

Yuri S. Bykov was a pleasant and interesting companion. It was possible to discuss with him any problems — from alpinism to which he devoted his spare time, to the political and economic problems of the world. He told many interesting things about the space segment of our country. I will never forget this remarkable man.

Yuri Bykov not only put forward the task to be solved but also found a customer for this work. An agreement was concluded and the project was implemented with enthusiasm. We considered all the aspects of photo-imaging from space, paying most attention to designing imaging instrumentation, analyzing optic-physical conditions of imaging from space and geo-referencing of the objects imaged.

Boris N. Rodionov headed the department and the work as a whole and devoted himself to the development of imaging instrumentation and simulation the imaging from space platforms. At the beginning of 1960's Yuri Chesnokov came to the department and got involved in the work. He developed a technique for obtaining images with the maximal spatial resolution. This required analysis of the optical and physical conditions of imaging as well as the optimization of both the imaging photocamera parameters and acquired imagery photo-chemical processing modes based on this analysis results.

I had to determine the geodetic coordinates of objects located in various regions of the world, based on photo imagery acquired from space. I also had to optimize the orbits for an imaging satellite to survey the specified region.

I proposed carrying out geo-referencing based on synchronous imaging of the terrestrial surface and the starry sky and a simultaneous satellite in-orbit positioning using the ground orbital measurements. This approach made it possible to solve the task — to determine the geographical coordinates of the imaged surface objects.

Boris Nepoklonov and I developed the algorithm for this task solution and got an inventor's certificate for the developed technique of coordinate determination. To my regret this certificate as well as all the reports on this theme were secret. At that time almost all the developments in space research field were not allowed to be published. For the first time we stated the principle of determining spacecraft attitude parameters based on images of a starry sky and the subsequent geo-referencing of the Earth surface images acquired from these space platforms in 1958. This was the first analytical and engineering report on the subject. Soon a similar solution appeared in western countries, where it was immediately published. I managed to publish the main ideas of this method and its algorithm in 1969 only in the *Kosmicheskie Issledovaniya* (*Space Research*) magazine.

Within the same research program, in addition to imaging stars I proposed and calculated an orbit for imaging the given region. In this orbit a satellite passed above the specified geographical latitude for the given Sun angle. Later on namely this orbit was called sun-synchronous and the majority of the Earth remote sensing satellites are launched into it. A final report on the program was published in 1961. These two developments provided the base for my Ph.D. thesis. The paper with the title '*On georeferencing space images and imaging satellite orbit choice*' had a stamp of secrecy. In 1962 I defended the thesis. Professor Aleksei S. Skiridov, a well-known photogrammetrist was my official opponent. He advised me to submit this thesis as a paper for D.Sc. in parallel. He told that I may never again have such an original idea. He was right, but I didn't want to postpone the thesis presentation. So I defended my D.Sc. thesis at IKI in 1987.

The first large-scale experiment on synchronous imaging of the Earth's surface and the starry sky with the subsequent geo-referencing of the obtained images was prepared and implemented on the first orbital station *Salyut*. This instrumentation development for this experiment was supervised by Boris Dunaev. Two aerophotocameras AFA BA-40 were redesigned. One new camera served for imaging the Earth's surface from space, the other — for imaging the starry sky. Both cameras operated in space failure-free.

The station's crew (V. Volkov, G. Dobrovolsky and V. Patsaev) came to a tragic end. However the film was preserved and our experiment was completely fulfilled. The experiment results proved the possibility of solving many tasks by synchronous imaging of the Earth and stars. In particular the night-time images revealed fires of the missiles launched and made it possible to determine coordinates of the launch pads as well as to assess accuracy of the orbital station orientation in various operation modes, including manual control by the astronauts. And finally we succeeded in solving the main task — determination of geographical coordinates of the onground objects, which were of interest. The Earth surface images acquired proved the space imaging efficiency for solving many economic, scientific and applied tasks. This became the beginning of the works on Earth research from space at our Department.

The words by Yuri S. Bykov on our injection into orbit proved to be prophetic. The studies fulfilled were positively assessed and despite the secrecy of our reports our work was acknowledged in the space sector and we got proposals to participate in other space missions.

One of the first such proposals we got from the well-noted cosmo-physicist, Professor Alexander I. Lebedinsky, who headed the laboratory of radiation at the Research Institute for Nuclear Physics.

Alexander Lebedinsky supervised the scientific program of Moon studies on behalf of the Academy of Sciences. The program was fulfilled within the mission of *Luna-9* station flight to the Moon and soft landing onto it. He charged us with developing the technique and fulfilling the photogrammetric processing of the panoramas acquired by the station. In addition we had to compile a topographic plan for the lunar surface segments having been imaged. We fulfilled this work and the results obtained were published.

Alexander Lebedinsky paved our way to the Space Research Institute. While we processed panoramas from the *Luna-9* station he acquainted us with this station designers — Yuly K. Khodyrev and Arnold S. Selivanov.

Yuly Khodarev became a Deputy Director of the Space Research Institute. He invited the leading specialists of our sub-faculty to transfer to the Institute. It was a challenge. The problem was that Vasily D. Bolshakov, the rector of MIIGAiK and I had a rather difficult relationship. So he would not allow me to leave, as I was a member of the USSR Communist Party. Thus we decided that I had to be the first to leave, as if I was leaving for nowhere. Then Rodionov and all the others, who were not party members, had no obstacles to leave. The operation was conducted and I became the laboratory head on December 27, 1967. This laboratory was the part of the department headed by B.N. Rodionov who invented for it a very strange name – the Department of Iconics and Cosmometry. 'Iconics' meant imagery acquisition from space, and 'cosmometry' — their measurement, referencing as well as determining coordinates of the objects imaged. I was to be head of the laboratory of cosmometry.

Later on B. Rodionov's and my roads parted. In addition to the traditional planetary research a new branch of studying Earth from space was formed at our Institute. We were invited to join this new field. Rodionov refused flatly but I agreed and in the beginning headed a sector for simulating Earth studies from space. Soon in 1973 by an order of Space Research Institute director Roald Z. Sagdeev I created and headed the Department for Earth studies from space. G. Avanesov and my MIIGAiK students: Yu.M. Chesnokov, B.S. Dunaev, V. Sevastianov joined me.

In 1988 I passed the Department's leadership to Genrikh Avanesov. Then in 2003 A. Forsh became head. The main merit in creating and putting into operation the BOKZ family star coordinators belongs namely to them. These developments have made it possible for the Department to overcome the serious problems of 'perestroika'.

Oleg VAISBERG
RUSSIA

Chief Researcher in the Space Research Institute of the Russian Academy of Sciences. Doctor of Science.

Principal Investigator of many space plasma experiments investigation tests with at more than 20 space missions, including *Prognoz* and *Interball* satellites, *Mars-2, -3, -5* and *Venera-9, -10, Vega-1, -2*.

Born in 1935.

Graduated from the Faculty of Mechanics and Mathematics, Department of Astronomy at Lomonosov Moscow State University in 1957. Worked in the Institute for Physics of the Atmosphere of the USSR Academy of Sciences in 1957–1967. Employee of the Space Research Institute (Russia) since 1967 (Head of the solar wind laboratory since 1976). Project Scientist of the *Solar Probe* project in 1980–1990. Worked at the Marshall Space Flight Center (USA) and in the Goddard Space Flight Center (USA) in 1999–2001. Regular research fellow in the Southwest Research Institute in San-Antonio in 2004–2006. Presently he develops plasma experiments for the *Phobos-Soil*, *BepiColombo* (ESA), and *Resonance* projects.

Full member of the International Academy of Astronautics. Awarded the Sign of Honour for work in *Venera-9* and *-10*.

SPUTNIK AND SOMETHING ELSE

To the Memory of my Teachers:
I.S. Shklovsky and V.I. Krasovsky

It so happened that my interest to space arose back in the late 1940's, when I was a pupil at a school in Nizhny Tagil, a city in the Urals. My parents would buy me popular-science books, subscribe to popular science journals such as *Tekhnika — molodezhi* (*Technologies for Young People*) and *Znanie – sila* (*Knowledge is Power*). Then I was given a book by Sternfield about space flights. I still keep this present as well as the journals with pictures of rockets on the front pages. I asked my parents to subscribe to *Astronomicheski zhurnal* (*Journal of Astronomy*) but it was too difficult a reading for an eighth grade pupil. Together with my friend, Yura Freidenzon, we made a small telescope through which we would observe the Moon. And when the postman brought journals with the description of the new building of Moscow State University and its pictures I decided to go to Moscow to enter the Astronomy Department of the University. I was somehow confident that astronomy would allow me to go to space. I cannot say that my parents were happy about my choice and departure to Moscow but they did not talk me out of it.

I count myself lucky that Petka* Shcheglov, that's how we called Petr Vladimirovich Shcheglov, who was then Professor of Moscow State University (MSU), invited me to

* A colloquial diminutive form of the Russian name Pyotr (= Peter).

join the Radioastronomy Department of the State Astronomical Institute named after P.K. Shternberg (the so-called GAISh) that functioned under the auspices of MSU. Radioastronomy department was headed by a bright and talented man, our idol, Iosif Samuilovich Shklovsky. He would walk along the corridors of GAISh and hold us spellbound by the summaries of his recent articles. Petka was in charge of our small student group that included Valentin Yesipov (he is now the head of the Radioastronomy Department of GAISh), Rudik Gulyaev, who currently works at the Institute of Geomagnetism, Ionosphere and Radio-wave Propagation of the Russian Academy of Sciences (IZMIRAN) and was an official member of the cosmonaut corps, and myself. We got a nickname of 'infrared boys' for working with then new image converters for application in infrared astronomy. Shklovsky had a gut feeling about the prospects of new spectrum ranges in physical astronomy. Our team shared great interest in space flights and I still remember our heated debates about how many years we had left before the first manned flight to space.

We graduated from MSU in 1957, the year when the space era began. Although I had a letter of recommendation signed by Shklovsky (the handwritten copy of the letter is one of the most valuable things in my collection of memorabilia) and by the GAISh Academic Council to do postgraduate position, the GAISh administration obstructed my enrollment into the postgraduate program with Iosif Samuilovich as a scientific advisor. Shklovsky introduced me then to Valerian Ivanovich Krasovsky, a prominent specialist in infrared technology and a zealous geoscientist. Shklovsky actively cooperated with him. Valerian Ivanovich headed the Department of Upper Atmosphere Physics at the Institute of Atmosphere Physics (IFA) of the USSR Academy Sciences. So I followed the advice of Iosif Samuilovich and started to work at IFA.

After the Telegraph Agency of the Soviet Union (TASS) announced that the First satellite (*Sputnik*) had been launched I was eager to see it and closely followed newspaper reports on where it would be possible to see it flying over Moscow. But the sky was overcast with clouds and it was only late at night on October 11 that it became possible to see it flying in the sky. I went out of the house and watched a flashing dot moving slowly across the dark sky. At that time the Astronomical Council of the USSR Academy of Sciences was collecting data about *Sputnik's* visual observations as it did not possess specialized optics yet. I sent the time of my observations and the approximate direction of the *Sputnik's* trajectory to the Astronomical Council and in return I received a beautiful postcard with a picture of the *Sputnik* and words of thanks. It's also part of my memorabilia.

I.S. Shklovsky and V.I. Krasovsky offered me direction of research — infrared spectra of polar aurora. I worked one observational season at the IFA station in Roshchino in the Leningrad region, within the framework of the International Geophysical Year, and one more season at the Loparskaya station near Murmansk, observing the spectra of polar aurora. These observations laid the groundwork for my Ph.D. (candidate of science) thesis.

When I returned to Moscow from the Loparskaya station I found myself in a team of very enthusiastic young scientists, members of the department headed by Valerian Ivanovich. Yuri Ilyich Galperin, Nikolai Nikolaevitch Shefov, Tatiana Makarovna Muliarchik, Nikolai Viktorovich Dzhordzhio, Valya Prokudina, Antonina Dmitrievna Boljunova, Faina Shuiskaya, my fellow student, and Vladimir Valdimirohich Temnyi — we all were carried away by Krasovsky's enthusiasm and dedicated ourselves to research of aurora polaris and airglow. Krasovsky was the only scientist in the USSR who had a rather clear understanding of the connection between polar aurora and precipitation of energetic charged particles into the Earth's upper atmosphere. They were thought to be the particle ejected by the Sun. Yu.I. Galperin and I were particularly interested in precipitation of protons into upper atmosphere. As we worked, we received a series of new results, independently from each other. I still take some pride in the fact that using my own observations, I determined the energy spectrum of protons that penetrate atmosphere in the auroral oval and showed that it is similar to the spectrum of protons flowing around the Earth's magnetosphere, as measured on satellite.

My next 'contact' with space happened in 1961, after Gagarin's flight in space. My contemporaries and I remember what a day of great rejoicing it was. Now we can see on TV these kind and happy faces of cheerful people rejoicing in the streets in these days. It's a pity that we have lost the ability to rejoice so simply and genuinely — besides there are fewer occasions to rejoice. Then I wrote a letter to Khrushchev asking him to enlist me as a member of the cosmonauts corps and received a formal letter with polite refusal.

However the opportunity to get the taste of space presented itself very soon. In 1962 *Cosmos-3* and *Cosmos-5*, two satellites missions of Valerian Ivanovich, were launched into orbit: they carried instrumentation for measurements of comparatively low-energy charged particles fluxes. Krasovsky wanted to measure the flux of particles that, in his opinion, caused polar aurora. Actually he conducted the first experiment of this kind on first space research laboratory *Sputnik-3* in 1958. As was the case with *Sputnik-3*, preparation of experiments for *Cosmos-3* and *Cosmos-5* was conducted in strict secrecy: most department members were not aware of them. Valerian Ivanovich had a special employee with assess to secrets — an engineer Svetlichny, who prepared experiments along with him. Probably, Yu.I. Galperin participated in those experiments too, at least I know that Yura took part in analyzis of data of the *Sputnik-3* experiment. After the launch of *Cosmos-3* and *Cosmos-5* most of our employees participated in the analysis of the experimental data. I couldn't stand aside either – along with my work on the thesis on polar aurora I also analyzed these data. V.I. Krasovsky gave me the task of determining satellites orientation in space. Meanwhile I got interested in electrons drift in the magnetosphere and their losses as a result of influence of ionospheric electric fields.

Nor was I able to resist the temptation of participating in the work with cosmonauts. In 1962 the Academy called for proposals of experiments to be conducted by cosmonauts. The first Soviet cosmonauts practically did not participate in controlling their spacecraft (that was Korolev's policy). I proposed an experiment to measure the upper atmosphere's emissions from the satellite. I designed a photometer, selected a photomultiplier, a voltmeter, and batteries. The box was made in the IFA shop and two electronic cards were made at the plant in Kiev, where the hardware for Krasovsky's satellites had been made before. The photometer was calibrated at the Crimean Astrophysical Observatory. I went to Zvezdny Gorodok several times to explain the experiment to two groups of cosmonauts: a group of male cosmonauts (V. Bykovsky among them) and a group of female cosmonauts (V. Tereshkova among them). In June, 1963 I was summoned to Baikonur Cosmodrome with that photometer. Those who now prepare experiments for space research will probably find it interesting that I was neither given any documentation for preparation of the experiment, nor was I required to submit any documentation for the prepared experiment. There at Baikonur Cosmodrome I saw S. Korolev, Yu. Gagarin, G. Titov, A. Nikolaev. I refused to came close to Korolev: people said that he was a very tough and exacting person.

I managed to hide twice inside the installation-test facility so as not to be taken away far from the place of the launch. I watched the launch of two manned spacecraft from the window of the facility. The impression was fantastic: the power, the noise and the extraordinary beauty of the sight.

I was promised that the photometer would go on *Vostok-5* (piloted by Bykovsky). However after the launch I was told the photometer was not launched on *Vostok-5*. I got very upset. They reassured me that instrument will be put in *Vostok-6*. Indeed, photometer was onboard the spacecraft that carried Valentina Tereshkova to space. I was not told what were the results of the experiment for a long time. Approximately in a month I received a phone call from Podlipki, a town in the Moscow region, and location of what is now Rocket-Space Corporation *Energia*. I was told that Tereshkova had made one (!) measurement with my photometer, and I was told what was the reading of voltmeter. Result of the measurement was within the expected limits but, naturally, one measurement will not make a research paper (although, following modern PR trends, I could have coauthored an article with Valentina Tereshkova).

I undertook another attempt to associate myself with space flights by responding to another call of the Academy of Sciences in 1962: 'Scientists to Become Astronauts'. I submitted an application and passed the preliminary health evaluation at the hospital on Pirogovskaya Street. Soon I was invited to a hospital in Sokolniki where our group (Boris Yegorov, future doctor–cosmonaut among them) were to go through more extensive health evaluation and performance check. I had not reached the level of the centrifuge test: I was written off because of my excess sensitivity to Barany chair rotation test of vestibular system (doctors called it an instrument of torture). Anyway, my last name hardly would allow me to be selected for space flight in those Soviet times (though, in some occasions inappropriate names were changed: Bulgarian cosmonaut Georgi Kakalov* had his last name replaced to Ivanov).

Our next space adventure was with *Elektron* project. This was the first in the world space system of two satellites placed on different orbits in the Earth magnetosphere. The system was launched twice, four satellites all in all. The satellites helped to conduct much interesting research in the 1960's. Krasovsky and we participated in studies of magnetospheric particles and performed very interesting study of ring current. We successfully competed in science with much larger research team of S.N. Vernov from the Institute of Nuclear Physics of Moscow State University (NIIYAF). After defending my Ph.D. thesis, I completely turned from polar aurora studies to space research.

After *Elektrons* Krasovsky decided to encourage the younger members of his team to lead their own projects. Yura Galperin began to prepare a project of an Earth's satellite to study polar aurora. As for me, Valerian Ivanovich advised me to think of an experiment to study the solar wind. I began reading scientific works, there were not many of them on the topic, published by Soviet and foreign scientists and thinking on new approaches to solar wind measurements. Initially I wanted to adapt Yura Galperin's experiments designs, but soon I devised my own instruments concepts. At that time, in the second half of the 1960's, the Lavochkin Research and Production Association in the town of Khimki of the Moscow region started to design satellite *Plasma*, a high-apogee satellite, which soon was renamed to *Prognoz*. Stanislaw Ivanovich Karmanov, a member of Skuridin's team, played important rule in determining the concept of the satellite. G.A. Skuridin was an assistant to Mstislav Vsevolodovich

* The last name 'Kakalov' sounds inappropriately in Russian.

Keldysh, President of the USSR Academy of Sciences and the Head of the Scientific Space Program.

We proposed solar wind experiments for *Prognoz* satellite, but encountered strong opposition to that from a team of scientists that had started to explore that area of research earlier. Together with Valerian Ivanovich and Yura I managed to show our ability to perform sensible experiments and our proposals were approved for *Prognoz* program.

Valerian Ivanovich introduced Yuri Galperin and me to Boris Isaakivich Khazanov and Lev Solomonovich Gorn, who worked at the All-Union Research Institute of Instruments Development (SNIIP) under auspices of the Ministry of Middle Engineering. B.I. Khazanov and L.S. Gorn headed two laboratories in which from 1960's to 1990's most of scientific instruments for space research were developed and fabricated. These two talented and dedicated men with their colleagues essentially laid the national space instrumentation industry. The instruments that they had developed were installed on the majority if scientific spacecraft of those decades. First to work with SNIIP was Vladimir Gdalevich Kurt, a prominent astrophysicist, and both Yura and I had the pleasure of many years of work with SNIIP engineers. My professional and personal relationship with the late Boris Isaakivich Khazanov, an extraordinary person and a great engineer (he passed away in 2006) was one of the most significant events in my life.

It was assumed that V.I. Krasovsky and his team would begin working at a newly created Space Research Institute (IKI) of the USSR Academy of Sciences. However something went wrong, and Valerian Ivanovitch decided to stay with IFA and 'hand over' to IKI the major part of his team that was involved in space research. This is how the *Polar* aurora laboratory was created in IKI with Yuri Ilyich Galperin in charge. I started working at IKI back in 1966 and on May 15, 1967 I became a staff member in G.A. Skuridin's department. Soon I was nominated the head of a sector and collected my own team. G.A. Skuridin was a great enthusiast of space research and helped researchers a lot. He came up with the initiative of comprehensive research of solar wind interaction with the Earth's magnetosphere with three simultaneously operating *Prognoz* satellites (*Russian Troika* project), long before similar multi-satellite projects appeared in the West. Unfortunately, he did not manage to implement it due to strong opposition.

Mars-69 became IKI's first scientific research project. It was an ambitious project of a Mars satellite with many scientific instruments and IKI's data processing system onboard. We enthusiastically cooperated with the Lavochkin Association and other institutes to design and test two identical spacecraft. Unfortunately, both launches were unsuccessful: one *Proton* rocket failed not far Kyzil, a city in Kazakhstan. The second rocket fell down on the launch pad. During the launch I was in the Control Center in Khamovniki, a south-western district in Moscow, and twice I left this place in a terrible mood. My chance to launch the solar wind mass-spectrometer in space before USA was lost.

Very soon, a new project, *Mars-71*, with a new scientific program was under development. Unfortunately, planetary research scientists were against the installation of plasma instruments on those satellites – they claimed that they have nothing to do with planetary research. At a meeting chaired by M.V. Keldysh I prepared a set of posters to show that our experiments were directly connected with planetary research: they allow to study atmospheric losses resulting from the solar wind flow around Mars. Keldysh listened to an audacious young man attentively and requested that plasma and magnetic field experiments should be included in the scientific program of the project. This is how Sh.Sh. Dolginov's magnetometer, our group's plasma analyzer and K.I. Gringauz team's plasma instruments were onboard of *Mars-2* and *Mars-3*. These experiments within the framework of *Mars-71* program laid the basis of what we now know about interaction of solar winds with atmospheres of planets without intrinsic magnetic field. That moment became the starting point of my independent life in space.

Mikhail MAROV
RUSSIA

Corresponding Member of the Russian Academy of Sciences.

Born in Moscow in 1933.

Graduated from the Bauman High School of Technology in 1958. Research Fellow of the Keldysh Institute of Applied Mathematics (Russian Academy of Sciences) since 1962.

Expert in mechanics of space environments, radiation hydrodynamics of multicomponent reaction mixtures, planetary physics and aeronomy.

Fellow researcher in a series of projects on Mars and Venus. Editor-in-Chief of the magazine *Solar System Research*, issued by Russian Academy of Sciences. Full member of the International Academy of Astronautics, Fellow of the British Royal Society of Astronomy.

President of the Planetary Sciences Department of the International Astronomical Union.

Member of Academic Council of the International Space University.

Awarded by the Lenin Prize and the USSR State Prize, the International Galaber Prize in Astronautics, the Sign of Honour (2003).

THE DISCOVERED SPACE

In the lifetime of every generation remarkable social and economical changes occur that are substantially influenced by the science and technology, by the scientific and technological progress. Its pace is permanently growing, with its results having a huge effect not just on the world order but also on our everyday living conditions and relationship of people. The global and local processes are becoming more and more interconnected due to the all-round penetration of information technologies, enhancing effectivity of transportation, increasing interaction of noosphere with the natural environment. Outstanding role in these processes is played by the space sciences and technologies whose initial foundation was laid by the epoch-making event — launch of the first artificial Earth satellite in USSR merely 50 years ago.

For the future generations the historical stage of going beyond the limited habitation sphere on our own planet will forever stay in memory as the largest achievement and progress of human civilization in the last century. It has marked the beginning of the systematic research and exploration of the nearest space neighborhood — Solar system, opening the principally new possibilities in the studies of constitution of matter, origin and evolution of the Universe.

The TASS message which informed the world about the launch of the first satellite has literally shocked me, the graduate student at the Mechanical faculty of the N.E. Bauman Moscow High School of Technology (now N.E. Bauman Moscow State University of Technology). And though everything was theoretically clear to the technically educated specialist, the event seemed to be incredible. It was amazing to search the night

sky for the moving artificial little star and, leaning to the radio, hear '*beep-beep-beep*' signals. This occasion has definitely influenced my choice of the follow up career, though in the conditions of the strict security I did not get to the Design Bureau (DB) called OKB-1 and lead by S.P. Korolev right after the graduation. Nonetheless, since that time my 'entering the space' has started which was not smooth but allowed me in a rather short term to get involved in a number of research projects, promoted to study new topics and seriously enlarge my knowledge of classical mechanics, gas dynamics, navigation/control, astronomy, electronics. And, perhaps, of no less importance was getting acquainted to the wonderful people from whom I learned a lot. That time I address as 'my universities', the school of life indeed. As a participant of the numerous events since nearly beginning of space exploration, I would like to share my memories at the anniversary of the first artificial satellite launch.

The deeper in history recedes the period of the second half of the past century incredibly full of daring projects and outstanding discoveries, the sharper one recognizes his happy involvement in this unforgettable time that brought together many distinguished scientists and General Designers. I've been fortunate to cooperate with those people working on solving a number of complicated scientific and technical problems. The period of my especially close cooperation with them fell on the most fruitful epoch of studying the Moon and Solar system planets in 1960–1970's. It was wonderful time when the Soviet Union government strongly supported space research and the leading positions of our country in this area was world-recognized. Occupying the position of a Head of the Department of Applied Mechanics, Planetary Sciences and Aeronomy at the Institute of Applied Mathematics (IAM, now M.V. Keldysh Institute of Applied Mathematics, or KIAM) of the USSR Academy of Sciences, I've been also deeply involved in the development and implementation of space program serving as a Scientific secretary of the Interdepartmental Scientific-Technical Council on Space Research (MNTS on KI) which was set up in the USSR Academy of Sciences body and entrusted these responsible tasks. The Council was directed by the former President of Academy of Sciences, Academician Mstislav Vsevolodovich Keldysh with the membership of such distinguished people as Sergey Pavlovich Korolev, Valentin Petrovich Glushko, Nikolay Alekseevich Pilyugin, Vladimir Pavlovich Barmin, Mikhail Sergeevich Ryazansky, Aleksey Fedorovich Bogomolov, Yuri Aleksandrovich Mozzhorin and many other outstanding heads of Design Bureaus and scientific research institutes. They can be called the space pioneers by right.

Basically, I turned out in the core of space events which are striking in retrospective by its range and power. Everything was done for the first time, the daring innovations were connected to a large risk, but the more valuable were the successes. Soon after our first *Lunniks* launches, sending to Earth the images of invisible (and therefore, previously unknown) far side of the Moon with *Luna-3*, first launches of the first spacecraft towards Mars and Venus (1M and 1VA) were performed in which I was lucky to participate. That was a period of my close relationships at S.P. Korolev's OKB-1 with many wonderful people, among those I would name first of all B.E. Chertok, V.P. Mishin, K.D. Bushuev, B.V. Rauschenbach, G.Yu. Maksimov. In due course of two years I acquired excellent experience working with the outstanding specialist in rocketry G.A. Tyulin being involved in launches of ballistic missiles and space launchers including detailed analysis of the performance and investigation of failures.

At the very beginning of 1960's I closely related with *Yuzhnoe* DB in Dnepropetrovsk headed by brilliant Chief Designer and great personality Mikhail Kuzmich Yangel. I had a chance to participate in the development of small satellites intended to investigate the near-earth space. That was the period of close cooperation with the outstanding constructors in that DB V.F. Utkin, V.M. Kovtunenko, Yu.A. Smetanin and many others. The first launch giving rise to the *Kosmos* series of satellites was performed on March 16, 1961. One year later, while preparing my Ph.D. Thesis in the Institute of Physics of Atmosphere, I was participating in the experiments onboard *Kosmos-3* and *Kosmos-5* satellites under the auspices of Professor V.I. Krasovsky who was my adviser and to whom I am obliged with my deeper knowledge in space physics.

The experience gained from the development of *Kosmos* series at *Yuzhnoe* DB gave birth later on the unified AUOS satellites which were used in particular for the international cooperation in the framework of *Intercosmos* program. The phases of successful realization of this program are related to the effective leadership of the first President of *Intercosmos* Council Boris Nikolaevich Petrov, a wonderful man whom I had a luck of knowing well. The same unforgettable trace has been left in my thankful memory after rather frequent meetings and fruitful discussions of various problems with our distinguished leaders in the field of mechanics — L.I. Sedov, A.Yu. Ishlinsky, D.E. Okhotsimsky, who were extremely dedicated to space.

But, of course, my greatest school of science and life was taken during 17 years of work under the lead of Mstislav Vsevolodovich Keldysh whom I address as my main Teacher. The life of this outstanding man cannot be separated from the epoch he was living in and creating it by himself. The close communication with him had been a true gift of heavens. Strict and unsociable outside, he was suddenly opening many sides of his powerful talent in the contact with people beside him, showing the real attention and benevolence to them. His humanness and wide range of interests were especially felt in informal setup, in particular at his home, where I visited him many times.

M.V. Keldysh was leading the space research and space utilization for the whole first twenty years of cosmonautics. Despite the enormous preoccupation at the position of the President of USSR Academy of Sciences, the space always remained the work of his life. He was caring about the most actual researches all of the time, paid a lot of attention to the issues of developing the new rocket systems and the modernization of the existing ones, upgrading the rocket engines, creating the modern control and measurement facilities, constant improvement of the overall reliability of space systems. He has supported the development of *Proton* launcher at the DB of V.N. Chelomey despite the obstruction against this project from other General Designers in the rocketry sector and even high level authorities. Thanks to his firm position we now possess this unique tool of delivering the large payloads into space. Mstislav Vsevolodovich was interested informally in problems so seemingly far from his professional interests as space biology and medicine, discussing them with the leading specialists V.I. Yazdovsky, V.V. Parin, O.G. Gazenko. On his initiative the experiments on space material science were started with B.E. Paton in charge involved by M.V. Keldysh in the area. After every flight to space he was not limited to the formal press-conferences but instead invited the cosmonauts to his place carefully listening to their opinions on flight, systems operation and spacecraft hardware.

Working with Mstislav Vsevolodovich was hard but always interesting, and having done something wrong or irresponsibly was just impossible. He was equally exacting to himself and his assistants. In his activity he was directed exceptionally by the interests of business, decidedly rejecting everything personal or issues of secondary value. He was a true leader having a huge respect and credibility, inspiring large teams of

like-minded people. He sincerely believed that the flights to space will become one of the greatest ambitions of our civilization and worked hard on making K.E. Tsiolkovsky's dream of contenting the whole circumsolar space come true. On the same time, he was well aware of the highest responsibility for the utilization of scientific achievements in peaceful purposes, to the profit of all people on Earth, and was convinced that space exploration should help in achieving this goals. '*The mankind has entered the new epoch of possessing the intimate mysteries of nature hidden in the depths of space*', M.V. Keldysh was saying. '*New phenomena we will meet on other planets will be used for improving life on Earth…*' Such was the life position of him, an outstanding scientist and citizen deeply devoted to the ideas of the peace and progress, caring about the good destiny of our planet.

On the initiative of M.V. Keldysh the Space Research Institute (IKI) of USSR Academy of Sciences was founded in 1966. Its formation was occurring literally before my eyes. For this purpose a department was first created within the IAM structure that became the embryo of IKI. Thus, first employees of the new institute were residing in the IAM staff for about a year, until the first 'temporary' buildings (of the standard hairdresser's kind of those times) were constructed on Profsoyuznaya street, 88 and by the command of Academy of Sciences this department of IAM was transferred there in May, 1967, thus having started its own existence. By the way, I was also first sent to IKI, to the newly founded department of space gas dynamics. Its other collaborators were my good colleagues — V.B. Baranov, V.V. Leonas, I.M. Yavorskaya. However, about two months later M.V. Keldysh has changed this decision and returned me back to KIAM.

The first Director of IKI (and earlier Head of the relevant IAM department) was assigned Georgy Ivanovich Petrov, a renowned scientist in the field of aero-gas dynamics, supersonic flows and heat-and-mass transfer. Surely M.V. Keldysh has made this choice not by random occasion: first of all, he was well acquainted to G.I. Petrov yet since the common work at TSAGI and then at NII-1 (later the Institute of Thermal Processes — NIITP, nowadays M.V. Keldysh Research Center), and secondly he wanted to combine the space science and technology as closely as possible. And who else but Georgy Ivanovich could have taken up for solving many nontrivial problems, critically reviewing the proposals and developments of scientists in space physics taking into account the real possibilities and the prospects of space technologies growth and constraints. But he went much further in this, completely new for him, field of activity deeply comprehending the wide topics of research, integrating theoretical and experimental concepts on the strict mathematical background and generating new ideas in planning and performing the scientific programs. I've been communicating with G.I. Petrov for many years, not only providing the connection of IKI to MNTS on KI, but also participating in his seminar on hydromechanics he regularly conducted at the Computing Center of M.V. Lomonosov Moscow State University for more than 15 years.

It has to be noted that having become the Director of IKI Georgy Ivanovich has immediately faced many problems of the management nature. The scientific and technological/production structure of the institute was created during this period based on the principal concept of collecting under the same roof the specialists of very different specialties from other related institutes either already having experience in the space research or interested in carrying them out. This seemingly good idea turned out not easy to put into practice since a rather artificial conglomerate was created of thematically unrelated groups with their own traditions, approaches and ambitions. Discontents and conflicts were appearing whose regulation was usually rest on G.I. Petrov's shoulders.

Unfortunately the authorities of Soviet Academy of Sciences did not ensured the necessary support to G.I. Petrov in solving this problems. The commission assigned in 1972 for the planned review of the five-year IKI activity has very formally approached to the evaluation of results of its work. Many positions of the strategic line and the current politics of IKI were not approved forcing G.I. Petrov to insist on leaving the post about a year later despite the requests of some Academy leaders to stay. This step has once again shown the strength of his character, honesty and high commitment to principles. Meanwhile G.I. Petrov has managed to do the main thing: he did not only create the capable collective of the institute and complete the construction of its building, but also established the new forms of interaction between Academy of Sciences with the industry, including creation of the division for the integrated tests of scientific payload with the spacecraft and the development of new progressive trends in the space hardware design. It appears to have assisted in no small measure to the successful realization of a series of space projects, first of all VEGA rendezvous with Halley comet, during the later period of the institute directorship by R.Z. Sagdeev invited to this position by M.V. Keldysh on L.A. Artsimovich advice.

Looking back today at the glorious years after the first satellite launch one can't but remember one more outstanding man whom I had a chance to know perfectly and closely communicated with – Georgy Nikolaevich Babakin. Due to tremendous efforts of him and his skilled team our country has achieved the great successes in the Moon, Venus, and Mars exploration. Babakin 'skyrocketed the space' in 1965 when the works on lunar and planetary research were transferred from S.P. Korolev's DB to the S.A. Lavochkin Association by the decree of Government, and G.N. Babakin was appointed the Chief Designer. Enormous technical experience and high production culture of the aviation DB and factory which played a huge role during the World War II and was working on the unmanned *Burya* aircraft in the post-war years allowed them to continue the lunar E-6 program and come to success in the shortest terms. It was in January, 1966 when the automated *Luna-9* spacecraft has performed the soft landing on the Moon with sending back to Earth the high-quality panoramic view of its surface, determining the mechanical properties of the lunar soil and thus putting the end to the multi-year discussion on its surface bearing capacity. The next milestone of the Moon studies after *Luna-9* was the development and successful launch of its first artificial satellite — *Luna-10* from which the nature of lunar surface rocks was determined using the idea of A.P. Vinogradov by measuring the natural radioactivity conditioned by uranium, thorium and potassium contained in those rocks. The lunar rocks turned out to be analogous to terrestrial basalts in their composition unlike the expected granites. Coupled with the data on the reflective capability (albedo) of different areas of the Moon this allowed us to improve the lunar geological map significantly.

The issues of the Soviet lunar program stood up especially sharp when it became evident that were unable to compete USA in the race of landing the man on the Moon. It was necessary to counterresist something to Americans since it was of high political value. Here the S.A. Lavochkin Association came to the first place. Following the G.N. Babakin's proposal which was actively supported by M.V. Keldysh and approved by the high level authorities, the development of a new generation of lunar spacecraft has started for the automated lunar soil delivery and self-propelled vehicles (rovers) remote controlled from the Earth. The flights of our *Luna-16*, *-20*, *-24* automated stations that delivered the lunar rock samples from the marine and continental regions of the Moon, as well as long operations of traveling lunar rovers *Lunokhod-1* and *-2* have made enormous contribution to the study of our natural satellite and the Earth-Moon system. The crafts themselves turned out to be unique in their technical excellence and were not reproduced anywhere in the world so far.

It is with admiration and proud that I remember the 24th of September, 1970 when the automated *Luna-16* station has returned back to Earth the container with the lunar rock samples from the Sea of Fertility. I remember the shining with happiness eyes of Georgy Nikolaevich who spent several unsleeping nights at his office, his slightly confused voice when he got a call with the congratulations on the success from the Secretary of CPSU Central Committee D.F. Ustinov who was supervising the defense areas of industry. And the priceless load itself, accompanied by the police escort in the night Moscow, to deliver it from S.A. Lavochkin Association to the specially pre-equipped laboratory at the V.I. Vernadsky Institute of Geochemistry and Analytical Chemistry where the container was opened in the camera filled up with neutral gas. Soon after the 'highest level authorities' had seen what the lunar soil looks like, its systematic analysis has started followed later on by the samples from the other lunar regions. These works were directed by A.P. Vinogradov, the follower of V.I. Vernadsky who was heading the Lunar-Planetary section of MNTS on KI. The close communication with him for many years has left inerasable trace in my life.

But my closest contacts with G.N. Babakin was certainly related to the program of Venus study. Its long-time successful implementation has begun with the historical flight of the *Venera-4* automated station. It was shortly before that when M.V. Keldysh assigned me the coordination of these works. In the same time he has also approved the idea of starting at IAM, along with the theoretical works, the works on performing a number of experimental research of planets. For this goal a special laboratory was set up in the structure of my department which should be carrying out these works in the close contact with NIITP. This initiative has determined for many years my fruitful cooperation in this area of space research and longstanding friendship with the distinguished scientist and the wonderful man V.S. Avduevsky. A series of unique experiments on Venus and Mars was realized by us together with close collaboration with our colleagues.

I have forever remembered the day of October 18, 1967 when the descent module of *Venera-4* automatic station for the first time in the world parachuted on other planet and transmitted the unique data of the direct measurements of the temperature, pressure, density and the chemical composition of its atmosphere not available to study from Earth. The initial analysis of the obtained information turned out, however, dramatic because the spacecraft designed for the ambient pressure of 18 atmospheres did not reached the surface as originally thought. Instead, it was crushed at the height of 23 km. Ambiguousness was added into the data interpretation by the erroneous readings of the onboard radio altimeter. The matching of measurements with the altitude became possible to obtain by the combined analysis of the data from *Venera-4*, American *Mariner-5* spacecraft (having performed the almost simultaneous Venus flyby), and the radar measurements of the radius of planet. As a result, the real surface position was determined, and the measured data from 23 km where the spacecraft stopped functioning were extrapolated to the ground. This allowed us to determine that the temperature at the surface of Venus is 475°C, the pressure is 90 atmospheres and this extremely dense and hot atmosphere consists almost entirely of the carbon dioxide and is almost completely devoid of oxygen and water. Thus the closest planet to Earth turned out to be an incredibly hostile, unusual world completely dissimilar to our earthly one. If one recalls that the data on Venusian atmosphere were very limited before the flight of *Venera-4* (for instance, the estimate uncertainties of the surface pressure in various models were differing by more than a hundred times, from a fraction to several hundred atmospheres) and the main atmosphere constituent was thought to be nitrogen, the value of the obtained results was really hard to overestimate. Our next experiments on *Venera* spacecraft with the more advanced sets of scientific instruments having performed measurements at the planetary surface have fully confirmed these results, totally disproving the existing concepts of Venus as a twin of Earth.

The first flights of *Venera* stations were performed towards the night side of the planet, and though the model estimates showed that the difference of parameters on the night and day sides is insufficient under the conditions of high thermal capacity of Venusian atmosphere, it was tempting to perform landing on the day side of Venus. The goal was also to measure the illumination and 'see' the surface. M.V. Keldysh was insisting on the necessity of solving this complicated scientific and technical task, and I have discussed it several times with G.N. Babakin. I perfectly remember one of my visits to his DB in the autumn of 1969 where I've been almost every day those years. When entering the office of Georgy Nikolaevich I have witnessed him bending above the drawings surrounded by the colleagues. Having seen me, he suddenly stood up and said: '*Well, we got the day side for you!*' The solution of the problem which rested in providing the reliability of the permanent radiolink of the lander with Earth from the morning terminator region and nearly on the edge of planetary disc was non-trivial. It was found in the supplement of an additional (redundant to the primary) antenna with an almost horizontal omnidirectional diagram jettisoned from the spacecraft after its landing; we tenderly called it 'frying pan'. It was thanks to it that the large research program on *Venera-8* was completely performed in 1972.

Original design developments and technical solutions have provided for many years our undisputed leadership in Venus research, including those with the aid of new generation of spacecraft. This was mainly conditioned by that enormous attention which G.N. Babakin paid to the diligent ground testing of the hardware. On our initiative with V.S. Avduevsky and with the all-round support of G.N. Babakin at the S.A. Lavochkin Association facilities the special stand (autoclave) was built up that allowed us to fully simulate the scenario of spacecraft descent in the atmosphere of Venus and landing. Along with the complex of original solution on the thermal exchange and insulation proposed by us and utilized in the spacecraft design, it provided an outstanding technical achievement — operation of landers at the surface of Venus under the exceptionally harmful environmental conditions during one hour and a half. As a result, first the black-and-white and later on the colorful panoramic surface images were sent to Earth, the element composition and physical properties of the surface rocks, illumination and wind velocities were measured *in-situ*. Also the properties and composition of clouds were studied during the spacecraft descent with the aid of IAM-developed nephelometers used for the first time in the planetary exploration.

Unfortunately, our Martian program has become less successful than research of Venus. The accent was made on the complex studies of atmosphere with the remote (from the orbit) and direct measurements from the landers, as well as surface TV images. On behalf of M.V. Keldysh I was coordinating the preparation of program and carrying out the experiments on the Martian spacecraft with G.I. Petrov, including the real time exchange of measurement data from the Martian satellites *Mars-3*

and *Mariner-9* which operated simultaneously, within the framework of the Agreement between the Soviet Academy of Sciences and NASA on the cooperation in the research of space, Moon and Solar system planets signed in 1971 in Moscow by M.V. Keldysh and G. Low. As agreed by the sides, me and NASA Assistant Administrator Noel Hinners were named the co-chairs of the Working Group. One should say that the cooperation within this Working Group (although rather limited) continued successfully until the new US administration led by R. Reagan came to power in 1977. One should admit, of course, that the efforts and resources spent for the whole 'fleet' of *Mars-2-7* spacecraft were incommensurable with rather poor results, especially when compared to the data from experiments onboard American *Mariner-9* and especially *Viking-1* and *-2*. The large disappointment for us was the fact that in 1971 after the successful landing of *Mars-3* lander on the Martian surface under the conditions of enormous dust storm the communication was lost only in 20 s, this is why no measurements and panoramic imaging were performed. The attempt to repeat this experiment with *Mars-6* spacecraft in 1974 has also failed. On the other hand, this time me and colleagues obtained the unique data on the parameters of atmosphere of Mars measured during the spacecraft descent which allowed us to build the first model of Martian atmosphere based on the direct measurements.

Remembering now, in 50 years, the first two decades of the space age incredible in their intensity, the daring ideas, courage and enthusiasm, one might be surprised and excited how much has been done, what horizons of the unknown were opened, which technical solutions were put in the reality. During those years it seemed that everything is possible, there was a kind of euphoria, though the successes were accompanied by the tragical episodes. I knew well the members of two first cosmonaut corps and still have friendly relationships with them. I have experienced the feeling of worry incomparable with anything else during Yu.A. Gagarin's flight to space which was replaced by the wild delight after his landing. Then the time of bitter losses came started with the absurd death of Yura Gagarin. I have deeply sorrowed the loss of Volodya Komarov, whom I knew well, at the *Soyuz-1* tests, death of my friend Kolya Rukavishnikov with whom we once worked together at S.P. Korolev's DB. Have many times experienced the unrest and worry during the flights of our automated spacecraft to the Moon, Venus, Mars which were carrying, without exaggeration, a part of the soul. And the delight and happiness incomparable to anything else when the flights were successful. For example, for the whole life left in memory are the feelings of 1975 summer when we stood in the Flight Control Center in Eupatoria with A.S. Selivanov beside the graph plotter which was slowly giving out the panoramic view of Venusian surface transmitted by *Venera-9*. This was something nobody on Earth had yet seen before us!

Our space program of those years undoubtedly had luck since the real leaders were standing at its roots who were ultimately devoted to the interests of space endeavors, to the idea of space discoveries and did not spare themselves for the sake of this great goal. These were, first of all, S.P. Korolev and M.V. Keldysh who both not incidentally have passed very young, full of creative plans and ideas which were not realized during their time. S.P. Korolev, for example, was dreaming of the human flight to Mars and developing the explicit project of its realization as early as in 1970's. His sudden death in 1966 has with no doubts made the decisive impact on the failure of developing the heavy N-1 launcher and undertaking the flight of the Soviet man to the Moon within N-1-L3 project (probably before the Americans) that has not been performed and finally abandoned. Among the enthusiasts who were literally burning themselves for the idea G.N. Babakin should also be mentioned. It is amazing that in only six years of his leadership at the DB of S.A. Lavochkin Association a dozen of the first-class spacecraft were created. With the passing away of M.V. Keldysh we have lost not just a leader in the advancement of space programs but also a resistant fighter for the most challenging ideas and projects. The history, as it is known, doesn't admit the conditional mood, but I am sure that neither M.V. Keldysh nor S.P. Korolev would have permitted the falldown in space science and industry which occurred to us during the severe perestroika years and whose consequences can be hardly redeemed.

My contemporaries related to space from the very beginning of their careers had been undoubtedly fortunate of being 'born in time' and standing among the participants of this epoch-making achievement of the human civilization. Much more sophisticated spacecraft are being designed and launched nowadays, the avalanche of discoveries in different areas of space science, planetary exploration and astrophysics is continuing, cosmonauts crews are permanently working on the Earth's orbit, space has powerfully invaded our life due to the wide usage of communication, navigation and meteorological satellites, surveillance and remote sensing satellites which facilitated the control over the observance of treaties on the weapon cuts and global status of ecosystems. The following development of this field along with the wide spread of information and nano-technologies is breathtaking; it opens the really exciting prospects for the mankind. But that unique time and flavor of the first space decades will hardly come again which has no match in its novelty, creative stress and inspiration and will forever stay in memory of people who has experienced it as the happiest period of their lives.

S.P. Korolev and M.V. Keldysh inspect a cabin of a space ship in OKB-1 Design Bureau. Moscow Region, 1962

State Commission, that leaded works on development and launch of First and Second Artificial Earth Satellites. Baikonur, November 3, 1957

Arthur C. Clarke

UNITED KINGDOM, SRI LANKA

The achievements of the world's best known writer of science fiction, Sir Arthur C. Clarke, bridge the arts and sciences. His works and his authorship, ranging from scientific discovery to science fiction and from technical application to entertainment, have made a global impact on the lives of present and future generations. In a landmark paper *Extra-Terrestrial Relays* in 1945, he was the first to set out the principles of satellite communication. One of his short stories inspired the World Wide Web, while another was expanded to make the movie *2001: A Space Odyssey*, which he co-wrote with Stanley Kubrick.

Born in Somerset, England, in 1917, Sir Arthur's literary achievements were recognized by Queen Elizabeth II when she honoured him with a Knighthood in 1998. Sir Arthur has lived in Sri Lanka since 1956. He has both an asteroid and a dinosaur named after him.

FIFTY YEARS OF THE SPACE AGE: THE BEST IS YET TO COME!

One weekend in 1939, shortly before the outbreak of World War II, visitors to London's Science Museum might have come across a dozen young men peering through a contrivance of rotating mirrors at a spinning disc a few metres away. Hanging just above them was the Wright biplane — but the experimenters had set their sights on something far more ambitious than flight in the atmosphere. They believed that one day it would be possible to travel to other worlds.

I am now the only survivor of that little group of British Interplanetary Society (BIS) members: none of us could have guessed that the Space Age would dawn merely 18 years later, or that humans would land on the Moon in just three decades. But we were already concerned with the problems that might arise during such a voyage. One of these — well known even to Jules Verne, when he wrote *From the Earth to the Moon* in 1865 — was that for most of the time the occupants of a spaceship would be weightless.

Because this condition cannot be reproduced on Earth for more than a few seconds, no one knew how the human body would react to it. Some horrifying scenarios had been predicted: one medical 'expert' stated that the heart would race uncontrollably in zero gravity, so that any foolhardy astronauts could expect a swift but hopefully merciful death.

However, there appeared to be a simple solution: make the living quarters of the spaceship a slowly revolving drum, so that centrifugal force gave the occupants the sensation of weight, allowing them to walk on what was now a cylindrical 'wall'. Stanley Kubrick showed this, on a rather lavish scale, in *2001: A Space Odyssey*'s orbiting Hilton Hotel.

AHEAD OF TIME

So we premature 'space cadets' had designed a spinning spaceship — but how to observe the Moon and stars, if we were revolving several times a minute? Fortunately, astronomers had long ago solved this problem for the once-a-day turning Earth, with an instrument known as a coelostat. This employs mirrors moving in such a way that the reflected sky appears stationary.

To demonstrate the BIS's considerably higher-speed version, we used a spinning disk on which three letters had been painted. These were unreadable until one peered into the coelostat; then the motionless letters 'BIS' appeared. I am indeed happy to say that the Society is still very active, and is now the world's oldest organisation devoted to space research and advocacy.

And what a transformation we have seen in that time! As late as 1940's, eminent scientists continued to deride rocket pioneers and scoffed at any discussions on travelling to space. For example, in the January, 1941 *Philosophical Magazine*, Canadian Astronomer J.W. Campbell 'proved' mathematically that it would take a million tons of take-off weight to carry one pound of payload on the round trip. The *Saturn-V* managed to do several billion-fold better than this.

Perhaps the most famously reported criticism of space travel was that made by the Astronomer Royal, Richard Woolley (1906–1986). I had met him at Mount Stromlo Observatory in Canberra, Australia, only the year before. I still remember how he was galloping over the mountain, looking for a lost cow: as a farmer's boy myself, this instantly endeared him to me. However, when he arrived in England from Australia in 1956, exhausted after a 36-hour plane journey, he was reported as saying that space travel was '*utter bilge*'. He never able to live that down!

I later found out what his actual words had been: '*All this writing about space travel is utter bilge — to go to the Moon will cost as much as a major war*.' Note that he did not dismiss the idea — if he had said '*90 percent of the writing*', and a '*minor war*', he would not have been far wrong.

None of us then knew that the Space Age would dawn within a few months — on 4 October 1957, with the launch of *Sputnik-1*.

WEEK OF SPUTNIK

Although I had been writing and speaking about space travel for years, I still have vivid memories of exactly when I heard the news. I was in Barcelona for the 8th International Astronautical Congress. We had already retired to our hotel rooms after a busy day of presentations by the time the news broke. I was awakened by reporters seeking an authoritative comment on the Soviet achievement.

For the next few days, the Barcelona Congress became the scene of much animated discussion about what the United States could do to regain some of its scientific prestige. While manned spaceflight and Moon landings were widely speculated about, many still harboured doubts about an American lead in space. One delegate, noticing that there were 23 American and five Soviet papers at the Congress, remarked that while the Americans talked a lot about spaceflight, the Russians just went ahead and did it!

So much has happened since that momentous week, and many dreams of science fiction writers have come to pass — including a few of my own. We have been to the Moon, and created a permanent space station. A few hundred men and women from dozens of nations have been to Earth orbit. Unmanned space probes have either landed on, or flown past, all planets, returning a wealth of information and thousands of stunning images. Orbiting space telescopes are investigating the deepest reaches of our Universe, and their results are available for all of us to access on the World Wide Web (which, incidentally, was inspired by one of my short stories).

Closer home, the communications satellite I invented more than 60 years ago (through my paper in *Wireless World*, October 1945) has changed our world beyond recognition in just two generations. It has helped create an inter-connected and incessantly chatting global village, which is now evolving into the tele-family of humankind.

We are still taking stock of how space exploration has impacted our species and civilisation, and perhaps we should allow more time for the perspectives of history to set in. But it's important to document everything for the benefit of future historians. For example, it was only recently that I found out that Dr. Wernher von Braun had used my 1951 book *The Exploration of Space* to convince President Kennedy that it was possible to land men on the Moon. (Yet an early reviewer of the book had concluded: '*Mr Clarke is not a very imaginative man*'. I wonder we where might be now, if I'd been a bit more imaginative...)

The first half century of space travel has seen many triumphs and tragedies. No one expected the first chapter of lunar exploration to end after only a dozen men from a single nation had walked upon the Moon. Neither did we imagine, in those heady days of the Space Race in the 1960's, that the Solar system would be abandoned — at least for a while — in the paddy fields of Vietnam. Or that the nation that ushered humanity into Space would itself disintegrate within four decades.

But in the long term, these setbacks and distractions don't really matter. In the coming years and decades, we will consolidate our still tentative hold on space.

And let's mind ourselves that this is not the first time that our ambition had outrun our technology. In the Antarctic summer of 1911–1912, ten men reached the South Pole, and only five returned. They used only the most primitive of tools and energy sources — snowshoes, dog sleds and their own muscles. Once the pole had been attained, it was abandoned for nearly half a century. And then, in the International Geophysical Year (1957–1958), humans returned with all the resources of modern technology — and they stayed. For half a century now, summer and winter, a few thousand men and women have been living and working at the South Pole.

So it will be with the Moon. When we return in the near future, it will be in vehicles that make the *Saturn-V* rocket look like a clumsy, inefficient dinosaur of the early Space Age (which it was). And this time, we will stay — and slowly extend onward to the planets, beginning with Mars.

NEXT FIFTY YEARS

I believe that the Golden Age of space travel is ahead of us. We can see a good parallel with the development of commercial aviation. The first half century of air travel was dominated by governments, military and the rich who could afford it. The jet engine and long-haul, fuel efficient aircraft then enabled economies of scale, bringing it within reach of many ordinary people. A similar scenario is set to unfold in space travel.

During the first 50 years of space travel, less than one thousand people have gone to space, most of them highly trained and all at tremendous cost (excepting a few recent 'space tourists', all others have been financed by tax payers). Technological innovations and investments now being made will usher in a new era of 'citizen space traveller' in the next half century.

Before the current decade ends, fee-paying passengers will be experiencing sub-orbital flights aboard privately funded passenger vehicles, built by a new generation of engineer-entrepreneurs with an unstoppable passion for space. And over the next 50 years, tens of thousands will gain access to the orbital realm – and then, head onward to the Moon and beyond. It won't be too long when bright young men and women would set their eyes on careers in Earth orbit ('*I want to work 200 kilometres from home* — ***straight up!***').

Looking into the future, what may we expect in space during the century that has now dawned? Well, tourism may be one of the most important, and of course the first space tourist, Tito, has been up to the International Space Station. Another application would be space hospitals. Although zero gravity has some disadvantages, just think of all the things that could be done in a weightless condition — what a boon to burn patients, or people with muscular defects. In a rotating space hospital, one could have any value of artificial gravity, from zero to even more than Earth value. Some of these possibilities I described in a little squib called *NASA Sutra* which is included in my collection of essays, *Greetings, Carbon-based Bipeds!*

For all this to happen, we have need reliable, economical ways to reach orbit. The rocket got us into space, just as hot-air balloons got us started in aviation. And it too will be superseded — but by what?

At this very moment, hundreds of very bright people are trying to develop better propulsion systems that can take humans and payloads into space. My view is that there will soon be a variety of methods to travel to orbit, to suit diverse needs and budgets. Among them, I see at least one idea that can ultimately make space transport cheap and affordable to ordinary people: the Space Elevator.

ELEVATOR TO SPACE

It was first imagined in 1895 by Konstantin Tsiolkovsky, who was inspired by the Eiffel Tower in Paris to consider a tower that reached all the way into space. But concept was developed by the Russian engineer Yuri Artsutanov in the early 1960's.

Today's communications satellites demonstrate how an object can remain poised over a fixed spot on the equator by matching its speed to the turning earth, 22 300 miles (35 780 km) below. Now imagine a cable, linking the satellite to the ground. Payloads could be hoisted up it by purely mechanical means, reaching orbit without any use of rocket power. The cost of launching payloads into orbit could be reduced to a tiny fraction of today's costs.

The Space Elevator was the central theme in my 1978 science fiction novel *The Fountains of Paradise*. When I wrote it, I considered it little more than a fascinating

thought experiment. At that time, the only material from which it could be built — diamond — was not readily available in sufficient megaton quantities. This situation has now changed, with the discovery of the third form of carbon, C_{60}, and its relatives, the Buckminsterfullerenes. If these can be mass-produced, building a Space Elevator would be a completely viable engineering proposition.

What makes the Space Elevator such an attractive idea is its cost-effectiveness. A ticket to orbit now costs tens of millions of dollars (as the millionaire space tourists have paid). But the actual energy required, if you purchased it from your friendly local utility, would only add about hundred dollars to your electricity bill. And a round-trip would cost only about one tenth of that, as most of the energy could be recovered on the way back!

Once it is built, the Space Elevator could be used to lift payloads, passengers, pre-fabricated components of spacecraft, as well as rocket fuel up to Earth orbit. In this way, more than 90 per cent of the energy needed for exploration of the Solar System could be provided by Earth-based energy sources.

Looking even further ahead, one could see the virtual elimination of the rocket except for minor orbit adjustments. By extending the elevator, it would act as a giant sling, and payloads could be shot off to anywhere in the Solar system by releasing them at the correct moment. Of course, rockets would still be responsible for the journey back to Earth — at least until elevator/slings were constructed on the other planets. If this ever happens, the most expensive component of travel around the Solar system would be for life support — and inflight movies.

As its most enthusiastic promoter, I am often asked when I think the first Space Elevator might be built. My answer has always been: *about 50 years after everyone has stopped laughing*.

Well, the laughing stopped a few years ago, and some serious investments are now being made in building a prototype. So I will now revise my timeframe to 25 years.

Nikolay ANFIMOV
RUSSIA

Director General of TsNIIMASH (the Central Research Institute for Machine Building). Doctor of Science. Academician of the Russian Academy of Sciences. Top scientist in aerogasdynamic, heat transport, ground testing of rockets and spacecraft, system designing of space transportation systems. Expert in boundary-layer theory, heat transport and heat protection of high-speed flight vehicles and thermal control at automated interplanetary stations.

Born in 1935 in Moscow.

Graduated from the Moscow Institute of Physics and Technology in 1958. Worked in the Research institute of thermal processes. Employed in TsNIIMASH since 1974, Director since 2000, Director General since 2002.

Awarded the Red Banner of Labour (1971), National Order of Russia (IV level, 1996), Legion of Honour (France, 2003), Professor Zhukovsky Award (1969), USSR and Russia State Awards (1980, 2002), Russian Governmental Award in Science and Technology (1996).

SYMBOL OF THE SPACE ERA TAKE-OFF POINT

...My life was not directly influenced by the *Sputnik* launch: I had got into space rocket systems four years before this event. But I have a distinct recollection of the day when the first artificial Earth satellite was launched. At that time, I was a sixth-year student of Moscow Institute of Physics and Technology, Aero-Mechanical Department — and spent all my time in the so called Nll-1 GKAT (Research Institute-1 of the State Committee for Aeronautical Engineering) — currently M.V. Keldysh Research Center. My research manager was Georgy I. Petrov, Corresponding Member of the Academy of Sciences, subsequently Academician, managing director and first director of the Space Research Institute of the Academy of Sciences. The famous TASS radio-announcement was communicated by Yury Levitan in the unique solemn way of our announcer №1. From Georgy Petrov I knew that a satellite launch was being prepared, but still it was kind of shock to hear that official announcement and it will remain engraved in my memory till the end of my life. There was another thing to remain in my memory forever — sense of involvement in the event; it was shared by all my colleagues in the small group of Nll-1 Laboratory №4, even though no one of them directly participated in the launch preparation.

It was mentioned in the TASS announcement that the *Sputnik* (satellite) could be observed through binoculars, and the list of cities/times was also given. I remembered when the *Sputnik* would be seen from Moscow, and that evening left home for Serpukhovskaya square with rather weak binoculars hoping to witness the *Sputnik* traveling across the sky. To my great disappointment, I failed, and for a long time since then, I used to take any bright dot moving across the sky for the *Sputnik*. This idea, however, used to be immediately rejected by my inner voice of reason (enriched with the physical and technology education I had got) saying that these were just flying jet lights.

EVENT HORIZON

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The first artificial Earth satellite's launch of October 4, 1957 became a milestone on the human way to space, the beginning of a new – space – era of our civilization development.

On the one hand, space flights can be regarded as a logical development of aviation whose motto has always been 'higher, faster, farther'. Aviation and rocket-and-space technology have a lot in common: theoretical basis, a number of similar onboard systems, some of the purposes. But, on the other hand, aviation alone would have never overcome the last trajectory section before entering the outer space, through low-density atmosphere, reaching the Earth orbital velocity. And of course, both the first satellite launch and human spaceflight by no means could have become possible without rocket technology development. As a carrier rocket for the first artificial satellite, P-7 the first intercontinental ballistic missile was used.

The *Sputnik* launch proved that human beings are capable to create artificial celestial bodies. At the same time, it showed to each Earth's inhabitant how small our planet is, if it only takes a man-made device one hour and a half to complete a revolution around it. And, finally, this event meant that the country shot ahead in the scientific and technological race, and even the Russian word 'Sputnik' was immediately assimilated by many foreign languages.

The first satellite was very simple in design. It's not for nothing that it was called PS-1 (simplest satellite-1). Nevertheless, it had the honor to be a 'forefather' of many generations of artificial Earth satellites developed and produced in the country — at first, at Dnepropetrovsk OKB-586 (Experimental Design Office-586, currently Yuzhnoe design Bureau of the Academy of Sciences of the Ukraine) and at other experimental design organizations.

The mind boggles at the incredible pace of new spacecraft implementation after the first *Sputnik* launch. Less than a month passed after October 4, when the second artificial Earth satellite with the first living creature (a dog named Laika) aboard was set into near-earth orbit. Another six months — and the third satellite, of 1327 kg, was flown generously equipped with hardware for outer space exploration.

The first three satellites were mainly designed to prove in practice viability of spacecraft for physical, medical and biological research work directly in the outer space. It could be visually presented by a 'tree' whose branches would stand for scientific disciplines derived from the 'main trunk' — the first artificial Earth satellite. They all are very well known. Of course, speaking of the first *Sputnik* role and significance, we mean the space missile system R-7 carrier rocket and the Simplest Satellite-1 in tandem.

Unfortunately, within the last 50 years our progress in launch means (carrier rockets, boosters, space tugs) development has not been fast enough: improvement of their performance characteristic is too slow, there is no qualitative leap in development of engines of promising technical potential, and, lastly, payload ascent cost is inadequately high which is a mighty limiting factor for further space activities. But at the same time we are witnessing huge progress in the development of spacecraft themselves – and this became a real revolution in all space disciplines.

We could mark out three basic scientific and technical directions whose realization became possible after the *Sputnik* launch and due to rocket-and-space technology.

- basic space research: Solar terrestrial system, cosmic rays, planets, small bodies of the Solar system, deep space, etc.;
- space technology use for the sake of socio-economic development (or 'people's economy', as we used to say some time ago);
- space technology use for military purposes.

Basic and applied space researches were the initial task accomplished by means of the first satellites. And indeed, before issuing the challenge of solving quite complicated basic and applied problems by means of satellites, we should have obtained more information on near-earth space itself, as well as on mechanism and system operation in the outer space. For this purpose, as early as on December 10, 1959, Government regulation titled *On Space Exploration Development* was issued. It mentioned — among other tasks — automated interplanetary station missions to Venus and Mars. Moreover, this regulation established Interdepartmental Scientific and Technology Committee for Space Exploration chaired by Academician Mstislav V. Keldysh. A lot of great large-scale tasks were accomplished: the first flights to the Moon, to Venus and Mars, launches of *Elektron* and *Proton* spacecraft for exploration of near-earth space, including the Earth radiation belts. And at last, on April 12 1961, the first manned space flight took place. It was Yury Gagarin, our compatriot, who laid foundation of one of the most important space exploration programs — the one of manned cosmonautics.

Wide possibilities of space technology use for the sake of the country's socio-economic development also became evident after the first *Sputnik* launch. Space communications, Earth observations from space, all transportation means and special technique navigation with the help of satellite navigational systems – this enumeration including both routine things and things still waiting in the wings could be infinite. And experience showed that space technology use for economical purposes is most efficient when it is commerce-based. Moreover, in the USA and a number of other western countries, characteristics of some commercial, 'household' technique (like electronic components, computer hardware, digital cameras, etc.) are considerably superior to the ones of similar devices developed as military production. There even arose a special term – 're-conversion' meaning military use of civilian economy sector developments.

Space technology military use was kept in mind at the very beginning — while decisions on first satellite launches were taken both in the USSR and the USA.* By now, it became evident that military spacecraft development was kind of revolution in the military activities — indeed, it's not for nothing that October 4 was declared Russian Space Forces Day! Informational support provided from space is a determinative factor that enables Armed Forces to accomplish strategic tasks using so called 'smart' weapons and giving up nuclear ammunition.

* *Baturin M.* Space Diplomacy and International Law, Yu. A. Gagarin RGNIITsPK, 140 pages, Star City, 2006.

The first artificial Earth satellite launch greatly influenced science development, technological advance and geopolitics. Satellite launch radically changed mankind views on state sovereign right to ambient space and environment. Before the *Sputnik*, it was taken for granted that a state sovereign right is valid within the state boundary for firm ground, body of water and air space. Satellite flight is subject to the laws of ballistics and mechanics; its velocity is many times as high as the one of any land, water or air transport, so the satellite frequently crosses state borders, and the notion of state sovereign right for outer space loses its meaning. It resulted in appearance of a special field of law — space law, and adopting a postulate of state boundary absence in the space and of all states' equal rights to the near-earth space.

It is obvious that the satellite launch had a great influence on engineering progress. To begin with, it owes to developing and creating technical means of orbital insertion; moreover, these means should have been as economically efficient as possible. In the next place, it is connected with possibility of launching spacecraft of various purposes, while development of these vehicles undoubtedly requires essential technical progress in various science and technology fields, since, as a general rule, technical requirements to target space hardware are much more sophisticated than to the ground one.

The first artificial satellite was launched via R-7 intercontinental ballistic missile designed shortly before that, and up to now it has been a routine practice to use ballistic missiles withdrawn from standby alert for spacecraft' launches, but later on design of special means for payload orbital insertion took its rise, like for example *Zenit* rocket, currently Russian-Ukrainian, using environmentally friendly propellant components, automated pre-launch setup, etc. More than that, airspace orbital insertion means came to be designed so that the space rocket is launched on a pretty high altitude from a plane which allows to avoid wasting the rocket propellant budget for initial acceleration and overcoming dense atmosphere resistance. We should also mention extensive research front and commencement of practical work on reusable space transportation systems — i.e. partially reusable (like American *Space Sh*uttle or Russian *Energia-Buran*) and, in prospect, fully reusable ones.

And, lastly, it is absolutely evident that the satellite launch opened quite new prospects for space science development, for refining our knowledge of the Earth, the Solar system and the Universe, since it meant the possibility to perform space research via contact methods as well as improved the remote research method: reduced the distance and released researchers from the Earth atmospheric interference. Besides, it became clear that human beings are able to perform in-space researches and different kinds of operations, as well as to see the Earth from outside which will dramatically change global phenomena investigation: large things are to be looked at from afar!

Space activity results are regularly reflected in all kinds of scientific and technical publications, discussed at annual congresses of the International Astronautical Federation and the Committee of Space Research and at other scientific forums. One can find detailed space activity analysis in the analytical report of the K.E. Tsiolkovsky Russian Academy of Cosmonautics*. But for discussion of 'most momentous results' a touch of subjectivity is inevitable. That is why I will just count here – not in order of their significance — those ten results of space activities that I consider to be the

* Team of authors. Analytical report of the Russian Academy of Cosmonautics 'Current state and prospects of space activities in Russia', 2004, РАКЦ.

most important: global space communications; global positioning system and global navigation satellite system (GPS, GLONASS, *Galileo* in future); global hydro-meteorological monitoring of the Earth; space monitoring of the Earth using high resolution capabilities and in various spectral ranges; international space system for tracking and rescue ships and aircrafts in distress (KOSPAS-SARSAT); long duration manned missions and in-space activities; man-on-the-Moon mission; space scientific laboratories — long duration orbital stations, 'flying telescopes', etc.; interplanetary transfers and exploration of the Moon, Venus, Mars and minor Solar system bodies via automatic interplanetary stations; first deep space photographic images showing objects that cannot be seen from the Earth — far side of the Moon, topography and surface structure of the Moon, Venus, Mars, fine texture of Saturnian rings...

Outer space exploration prospects are promising enough, but unfortunately I have to admit that their initial assessment proved to be too optimistic. By no means can space exploration keep up with the forecasts made by scientists at the very beginning of the space era. As an example I could mention forecasts for 2001 from proceedings of the American Aeronautical Society Memorial Symposium held in commemoration of Robert Goddard, rocketry pioneer, in Washington, DC in 1966, i.e. more than 40 years ago*. Their translation into Russian was published by *Mir* publishing house in 1970.

Reading reports contained in the proceedings, one can only be astonished at the optimism of cosmonautic development fast pace expectations shared at the dawn of space era even by experts. Here is, for example, one of the forecasts – made by an employee of *Martin* company, William Perdy:

- Manned flight with Venus fly-by — 1980–1985
- Manned Moon observatory — 1985–1990
- Manned flight with Mars fly-by — 1985–1990
- Manned flight to Mars — 1990–2000

No one of the counted events has ever taken place. And plenty of time will pass until we evidence them...

But let us consider a more authoritative and weighty opinion. Eugene Konecci, Head of the American Council for Aeronautics and Astronautics, in his opening speech at the above mentioned symposium said that by 2001 major advances could be expected in the following directions:

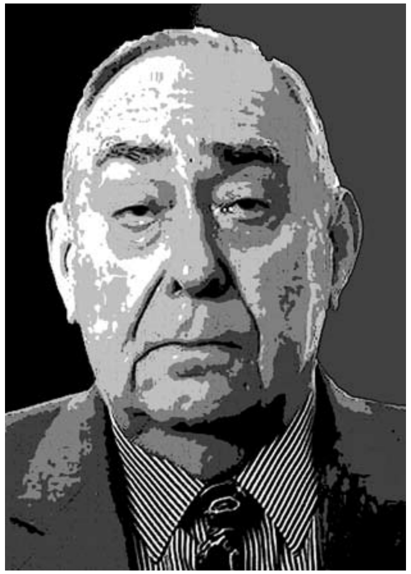
- *Flights of robot explorers with operation period of 5...10 years to all zones of the Solar system and its nearest neighborhood* — this forecast is realized.
- *Multiple use of spacecraft in manned space transportation systems with cost reduced down to 20 dollars per 1 kilo* — it was implemented by the *Space Shuttle* orbital spacecraft design, but the actual cost of inserting one kilo of cargo into a low orbit is higher by a factor of 10^3.
- *A low-consumption manned transportation system for flights to the nearest planets will be in operation or under construction. A nuclear pulse rocket, or electric propulsion with nuclear reactor, or nuclear engine with gas-phase core will be used as a propulsion device. And by most pessimistic estimate, nuclear jet with gas-phase core will be put into operation by 1990* — not realized and so far it's not clear when this forecast can be implemented.

* Space Age in Fiscal Year 2001. Proceedings of the Fourth AAS Goddard Memorial Symposium, 15–16 March 1966, Washington, D.C. An American Astronautical Society Publication.

EVENT HORIZON

- *In 2001 the long-expected success in the field of thermonuclear fusion will at last materialize. In this case active development of thermonuclear rockets may begin, while the issue of inter-stellar flights may become vital enough and subject to consideration and discussion* — success in the field of thermonuclear fusion has been long-expected up to now, as to inter-stellar flights, by no means can they be a matter of any serious discussion.

In conclusion, reflecting upon remote future of the process and results of penetration into outworld secrets and laws of the, I would like to express my belief: human beings will never perceive the Universe laws in full. But by no means is this belief pessimistic, on the contrary, it is definitely optimistic, because it implies that space research will keep calling forth new and new discoveries. Mankind has always needed them and will always need them, and the higher it is ascending the 'progress stairs' — the more.



Mikhail VINOGRADOV
RUSSIA

Lieutenant General of the Russian Air Defence Forces. Professor. Academic Secretary of the Committee of Scientists for International Security and Arms Control (the Russian Academy of Sciences), Chairman of the Russian Committee of Scholars for Global Security since 2003. Honorary member of the Russian Military Sciences Academy.

Born in 1924 in Moscow.

Graduated from the Ryazan Machine-gun Military college in 1943. Took part in the Second World War in Air force (May 1943–1945). Later served in the Moscow air defense district (divisions and headquarters). In 1961 graduated from the Air Force Military Academy (now the Zhukov Military Air and Spacecraft Defence Academy). Served as corps Director of Operations, military expert in the Air Defense and Air Forces headquarters in Cuba (1963–1964), then Chief of Staff of the Air Defense Forces corps and Director of Operations in the Air Defense district headquarters.

Served in the General Staff of Armed Forces of the USSR (in the Main Operations Division before 1985, in the Center of Strategic Research in 1985–1989). Total military experience equals 47 years.

Awarded 5 orders and a number of medals.

50TH ANNIVERSARY OF THE ARTIFICIAL EARTH SATELLITE

On October 4, 1957, I was in the street of a town, then named after Kalinin, now being the town of Tver, when I heard the news about the launch of an Artificial Earth Satellite, the first in the history of mankind. It was the first month of my studies at a military academy, now called Aerospace Defense Academy. I was still in high spirits because I had successfully passed my initiation period, while the message heard over the radio about our native AES added up the feeling of pride to my private joy. I was proud of my country, its science, its designers, engineers, and workers, who used their brains and hands to create it.

Despite the 50 years that have passed, I clearly remember how people in the streets were sincerely happy about the heard news and short beeping signals from the board of *Sputnik*. The way into the outer space had been paved! In three and a half years, on April 12, 1961, the flight of Yuri Alexeevich Gagarin initiated the direct penetration of people into space. And back in 1969, the US astronauts N. Armstrong, B. Aldrin and M. Collins performed the first expedition to the Moon. These were milestone events for successful advances in the outer space exploration. And, although I did not participate in the space epopee personally, I have been closely following the reversals of fortune in space during all these 50 years.

It is my understanding that, by virtue of its volumetric and physical parameters, the outer space plays an extremely important part in the life of the world community. After the appearance of space information systems, the contribution of space into the development of economy has become very large, in particular, for leading countries. Communication is impossible without space, in particular, after the transfer to digital technique. Earth remote sensing plays an important part. The GPS- and GLONASS-type navigation systems cannot operate without spacecraft. It is indicative that currently about a half of the objects deployed in space are commercial, including those belonging to civilian corporations.

EVENT HORIZON

The outer space has become particularly important for ensuring universal international security, including the military sphere. Since I, as a military professional, was engaged not only in the anti-aircraft but also in the anti-missile and space defense, as well as in information systems in these fields, I had to go deeply into military-space problems. For me, the following statement has become the basic principle for using the outer space for military purposes: unlike land, sea and air, this sphere is still weapon-free, and we should prevent it from being turned into a seat of war for as long as possible and better never.

It should be acknowledged that, potentially, the outer space displays great options for carrying out such activities. Space-based weapons can hit targets in space, on the ground surface and in the air with the use of conventional ammunition, nuclear, laser, electromagnetic and other means. This weapon belongs to a strategic class because it will be capable of striking strategic global information networks. It is precisely because of the above that it is not permissible to launch weapons into the outer space.

There is nothing blameworthy about the fact that motives of using space for *military purposes* are always present in space programs. Protection of national interests by military means and desire to reliably ensure the country's safety remain a high-priory task in the policy pursued by any state. However, one should distinguish two approaches to the military use of the outer space. One thing is to deploy communication, reconnaissance, missile-attack warning, navigation, topography and land-surveying, Earth remote probing, meteorological and other systems in space, i.e. what is treated as a passive military use of space means. Another thing is to deploy weapons of different classes in space: 'space-to-space', 'space-to-ground', as well as to deploy weapon of the 'ground-, air-, and sea-to-space' class on the ground, in the air, and in the sea. Otherwise, it is called anti-missile weapon. In this connection, I have doubts about the appropriateness of such a frequently used slogan as 'Non-Militarization of Space', since militarization of space is a fact of our life. The passive use of space for military purposes is not only permissible but is also necessary to preserve national interests of states in the field of security. But it is not permissible to deploy weapons in space. It is not for nothing that a few years ago a slogan 'Non-Weaponization of Space' became publicly used in the USA.

Back in the 60's of the previous century, the first decisive step was taken along that road, following the damage created by nuclear tests performed by the USSR and USA outside the Earth atmosphere. As a result of explosions of nuclear ammunition, significant turbulences of the Earth magnetic fields were recorded, radio- and TV-communication was disrupted, operation of some important military satellites was violated and, once, that of an electric power supply grid on the Hawaii Islands. During the talks that took place at that time, both the sides had to admit that nuclear explosions in space could significantly hinder normal use of near-earth orbits during the flights of the AES, disrupt operation of important communication systems, interfere into the space reconnaissance and the missile-attack warning systems, while the radiation emission would close the prospects for flights of manned spacecraft.

Therefore, taking into account the essential national interests, the USA, the USSR and the Great Britain carried negotiations and in August 1963 signed in Moscow *Treaty Banning Nuclear Weapon Tests in the Atmosphere, in Outer Space and*

Under Water. This allowed a certain 'safety zone' to be created in space for achieving scientific, commercial and passive military goals. At the end of 1963, the UN General Assembly endorsed a Declaration which called upon the nations — UN participants to refrain from deployment of mass-destruction weapons on any orbits and not to lay national claims on celestial bodies.

Further on, these efforts were confirmed by signing a number of international agreements on the legal aspects of the use of space for military purposes. Out of the above, the Treaty signed in 1967 *On Principles Governing Activities of States in Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies* should be singled out. The main thing about it is the prohibition on launching of weapons of mass destruction into space. In the same year, the UN adopted a Convention on exploration and use of the near-earth space, allowing its use for peace purposes only. At the same time, the USA and the USSR, who voted for adopting it, had been secretly conducting activities on development of space weapons, beginning as early as in the 50's. Apparently, to justify these steps, it was stated that at the beginning it was ground-based weapon.

Beginning from 1957, the *Bold Orion* aviation-based anti-missile weapon was being developed in the USA without significant advances towards the desired goal.

Other activities were conducted on the basis of ground missiles: on the Quajelain atoll, following the *505* Program, on the basis of the *Nike Zeus* complex, and on the Johnston atoll, following the *437* program, on the basis of the *Thor* ballistic missiles. In the final analysis, the Americans turned these programs down.

In the USSR, this problem was tackled since the beginning of the 60's. From 1963 to 1982, during the tests of the *Satellite Fighter* (SF) complex, 40 vehicles were launched into space to verify this system: 20 targets and 20 interceptors. In 1968, the SF complex destroyed the satellite target for the first time in the world. And from July 1, 1979, the weapon was added to the country's armory and placed on a combat duty after a pilot operation period.

At the end of the 1970's, the USSR and the USA began negotiations about prohibition of anti-satellite weapons but they proceeded without success. In 1983, the USA walked out of the negotiations and continued to active development in this field. In 1985, the US side performed the first tests of a new aviation anti-satellite system ASAT, which had been initiated back in 1977, with the use of missiles with conventional ammunition. A two-stage missile *SRAM-Altair* was launched from the F-15 fighter, which hit the *Solwind* AES at the altitude of almost 450 km (according to other sources, at the altitude of about 1000 km). In 1997, a ground-based laser facility MIRACL hitting the MSTI-3 AES was demonstrated. The experiment result was classified but it is known that the satellite was not destroyed. The development of the KE-ASAT anti-satellite vehicle was continued.

In the USSR the last test launch of the upgraded SF anti-satellite vehicle took place on June 18, 1982. And on August 1983, mass-media published Yu. Andropov's Declaration about a unilateral cancellation of the anti-satellite weapon testing program in the USSR. In April, 1993, a decision was made about decommissioning of the Soviet SF system.

But in January, 2007, China alerted the whole world when a ballistic missile was launched at night of January 12 from the Sichan test pad in the province of Sichuan. It destructed the old Chinese weather satellite *Fengyun-1C*, launched to the orbit

back in 1999, at the altitude of 865 km in space. According to US sources, three previous attempts were aborted, while the fourth was successful. China that has always opted for non-weaponization of space together with other countries, can now openly announce its space ambitions.

On the whole, the situation with reaching the international agreement on prohibition of development, testing and operation of anti-missile weapons of any type of deployment, including the outer space, has come to a dead end, which, apparently, is of no interest for the UN.

There is one more loss in the field of rendering the outer space free of weapons. When in December, 2001, the USA stepped out from the *Treaty on Limitation of Anti-Ballisitc Missile Systems*, signed in 1972, the ban on launching any anti-missile defense weapons to space was actually removed, including the weapons with conventional ammunition, which is used by the Americans in their work on the development of the national system of anti-missile defense.

Among other international legal documents, one should note the 1976 *Convention on Registration of Objects Launched into Space*; the 1977 *Convention on Banning Military or Any Other Harmful Means Acting on the Environment* (space included); the 1979 *Agreement on the Activity of States on the Moon and other Celestial Bodies*, containing a ban on the use of any types of weapons on celestial bodies (but not in the outer space). Unfortunately, together with stating the importance of the above-mentioned documents, one should note their significant drawback: they do not contain a ban on launching conventional weapons or their components to space, as well as weapons based on new physical principles.

It is not coincidental that already at the beginning of the 80's, practical attempts were undertaken by the USA at space deployment of weapons. R. Reagan's *Strategic Defense Initiative* Program was the first in this field but after its failure, the paved road was indirectly followed by President Bush Sr. and President Clinton. However, the maximum activity was achieved during the era of President Bush Jr. The Directive *National Space Policy*, signed by him in October, 2006, became the apotheosis. It excludes the possibility of signing new treaties, limiting the USA activity in space. As stated in the Directive: '*Proposed arms control agreements or restrictions must not impair the rights of the United States to conduct research, development, testing, and operations or other activities in space for U.S. national interests*'. The Directive allows the USA to '*deny, if necessary, adversaries the use of space capabilities hostile to U.S. national interests*'. It is for the USA to decide independently, which countries can be included in this list. It is stated in the document that the USA '*preserve its rights, capabilities, and freedom of action in space*'. But, currently, as estimated by experts, it is already 15 countries that can independently perform space launches and of the order of 40 states, even such countries as Nigeria, that have their own satellites. It is noted in the document that to protect their national interests, the USA would '*take those actions necessary to protect its space capabilities; respond to interference; and deny, if necessary, adversaries the use of space capabilities hostile to U.S. national interests*'. Therefore, the US Defense Minister was directed to '*develop capabilities, plans, and options to ensure freedom of action in space*'. In the opinion of Theresa Hitchens, Director of the Center for Defense Information, the document, signed by Bush, opens the door to the war strategy in space.

Russia still advocates 'space without weapons'. The Ministry of Foreign Affairs of the RF prepared a document, published in the Internet site on September 20, 2006: *On the* *position of Russia at the 61st Session of the UN General Assembly*. It is stated in the document that: '*Prevention of deployment of weapons in space is one of the top priority tendencies of the Russian foreign policy in the field of strengthening strategic stability and international security*. The Russian leaders believe that '*it is not justified that the key issues of the disarmament topic have practically dropped out of the global agenda, while it is premature to speak about the end of the arms race*'.

On February 10, 2007, President of the Russian Federation V.V. Putin, taking the floor at the Munich Conference on security policy issues, declared: '*...more than once we have put forward the initiative directed at non-admission of weapons in space... We have prepared a draft of a Treaty on prevention of deployment of weapons in space. In the nearest future it will be submitted as our formal proposal to the partners. Let us work on it together*'.

I fully support the position of the Russian leaders on this issue and share the opinion of those people who are convinced that attempts of establishing military superiority in space would bring about a response, which might unleash a new arms race. In its turn, such a position would increase the vulnerability of the important space infrastructure, used in the spheres of business, telecommunications, passive use of military space, etc., thus creating conditions for undermining the strategic stability and international security. It is not permissible to let it happen.

Susan EISENHOWER
USA

Chairman Emeritus and former President of the Eisenhower Institute.

Ms. Eisenhower has spent more than 20 years working in the foreign affairs. Best known for her work in Russia and the former Soviet Union. Currently serving the 4th term in the National Academy of Sciences' standing Committee on International Security and Arms Control (CISAC).

In 2001, after serving 2 terms on the NASA Advisory Council she was appointed to the International Space Station Management and Cost Evaluation Task Force. She has also served as an Academic Fellow of the International Peace and Security program of Carnegie Corporation of New York, and is a director of the Carnegie Endowment for International Peace and the Nuclear Threat Initiative.

President of the *Eisenhower Group*. Senior Director of *Stonebridge International*.

In the 1970's she worked as a stringer for *The Saturday Evening Post*, later wrote a column for *Wolfe Newspapers*. The author of 2 regional bestsellers: *Breaking Free* and *Mrs. Ike*. She has also edited four collected volumes on regional security issues – the most recent, *Partners in Space* (2004).

INTERNATIONAL RESOURCE AVAILABLE TO ALL NATIONS

This time 50 years ago Soviet launch of *Sputnik* changed the world and called into question the strategic vision of space in a most fundamental way. Nowhere else does international cooperation come together with the notion of international security as it does in Space, the only global commons that borders every community, simultaneously affects every country and provides an unprecedented potential nexus of social, economic, and military power. Today space is being utilized in ways never before considered possible. It allows us to track of banking records, to communicate globally, to monitor weather systems, to predict and warn against catastrophic environmental dangers, to trade with others, and to travel safely across the globe. Space has rapidly become an integral, fundamental part of every nation's infrastructure, including and perhaps most critically, the military ones.*

Alas, at the same time these most valuable space assets, whose movements are governed by the laws of orbital mechanics and follow a predetermined and predictable course through space, are vulnerable to even the most primitive of attacks. This vulnerability has prompted policy-makers throughout the world to consider how we can most effectively balance today's civil, commercial uses against our growing requirements to use space for the conduct of military operations. However, real multilateral debate, involving all major space-faring nations, on such most crucial strategic questions is all but absent. This is why it would not be a stretch to argue that the recent Chinese anti-satellite missile test came as a result of our own failure to even

* Based on Speech to National Defense University's (NDU) *Spacepower Symposium*, April 25, 2007.

talk about the security of space with other space powers. (I wonder sometimes if it is a coincidence that this Chinese test took place this year — 2007).

The launch of *Sputnik*, we know, was particularly alarming to the United States and its military leaders. Some who were around at that time will remember that the creation of a CIVILIAN space agency rather than a military one was NOT a foregone conclusion. Eisenhower faced pressure from the military services and the aerospace community to make the space program a predominantly military organization. He was worried about two things: the reaction of the international community if our military establishment were given responsibility for activities related to peaceful, cooperative ventures in space. Not only would the program be hampered by the necessity to classify certain advancements, it would be regarded with suspicion internationally. The very establishment of NASA and the statement of national space policy in 1958 underscored the desire for international cooperation and charged the new agency with the duty of '*maintaining the US position as the LEADING ADVOCATE of the use of outer space for peaceful purposes*.' The US was also prepared to '*join with other nations, including the USSR, in cooperative activities with respect to outer space*.'

In the early 1990's, the US and Russia were at last open to cooperate in a big way. The decision to establish the *Shuttle-Mir* program and then bring the Russians into the International Space Station program heralded an entirely new age in space cooperation.

As space-faring nations were deeply engaged in building the Space Station, however, changes were also underway in the military sphere. The most public and controversial event in this area was new policy direction in 2002, US withdrawal from the *Anti-Ballistic Missile Treaty*. The ABM Treaty had been in force for three decades. The move was the first time in modern history that America had backed out of a major international arms agreement. In addition to these political moves, the US increasingly articulated a vision for space that appeared as aggressive to many in the international community. The *United States Air Force Doctrine Document on Counter Space Operations* stated in 2004 that the US would achieve and maintain space superiority, and the '*freedom to attack... as well as the freedom from attack*'*. This was published at the same time, that the United States had consistently refused to enter into international dialogue on 'rules of the road' for Space. Is it the best way to protect our space assets at a time when a single relatively primitive but properly guided missile can hold our entire commercial, scientific, and military infrastructure hostage, as China's recent test so profoundly emphasized?

For the last three years, the Eisenhower Institute has been engaged in a project seeking to address these questions. Its approach has been based on a vision that integrates the interests of all space stakeholders — military and civilian, domestic and international — within a new security framework that underscores the principle of space as an international resource, available to all nations. In pursuit of this goal, we have established and convened the International Space Expert Panel, consisting of some of the world's foremost experts on space.

It is a pragmatic approach for achieving a consensus among space-faring nations to maintain and 'lock in' American advances, but, at the same time, thus preventing the full weaponization of space. It is not an attempt to scale back ground-based temporary and reversible systems already in existence. Nor is it an effort to curtail the militarization of space. We envision it to be a voluntary association like the MTCR, not a new and cumbersome international treaty. The Framework is an attempt to define a politically plausible 'middle way' for policy-makers of all countries.

* *United States Air Force Doctrine Document 2-2.1: Counter Space Operations*. August, 2004.

Our strategy, applicable to both established and emerging space powers, would reward responsible countries that choose to join the regime voluntarily and isolate those choosing not to join or abide by the regime's principles. At the same time the plan would not prohibit complementary measures undertaken by the signatories in order to make their space assets more secure and redundant. Key to this proposal is the establishment of a multilateral regime based on an international agreement banning on-orbit offensive weapons and the testing of any destructive anti-satellite weapon based on land, sea, air, or space.

The creation of this framework would be a critical first step toward ensuring that space remains a secure environment for the assets of all space-faring nations. The group would then be in a strong position to engage new emerging space powers and to address other important space security issues such as minimizing space debris.

There is little question that space security has become a fundamental component of international stability. As the current predominant space power, the United States has the most to lose in space, and therefore, has the greatest incentive to protect its space assets, but they are not the only ones with something to lose. All of the world's nations have a stake in making sure the current tenuous stability in space does not degenerate into a weapons race or outright military confrontation.

When we look back at the late 1950's, we sometimes forget that the ensuing 'Space Race' could have just as easily turned into a 'space ARMS Race'. Yuri Gagarin and Neil Armstrong could just have easily been substituted for anti-satellite systems, military space stations, or possibly even nuclear weapons in orbits. Eisenhower shrewdly fought off the ambitions of many who competed vigorously for the ownership of the space projects that would eventually emerge from the *Sputnik* launch. Eisenhower's policy of advancing cooperation could stand again as a model in today's world. In his *Atoms for Peace* speech — another effort by the President to craft a new way of looking at the terrible potential of another disaster, the use nuclear weapons — Eisenhower outlined the leadership role the United States could play in finding constructive ways to address one of the greatest threats to mankind. He said: 'Occasional pages of history do record the faces of the 'great destroyers', but the whole book of history reveals mankind's never-ending quest for peace and mankind's God-given capacity to build. It is with the book of history, and not with isolated pages, that the United States will ever wish to be identified. My country wants to be constructive, not destructive. It wants agreements, not wars, among nations... In this quest, I know that we must not lack patience. I know that in a world divided, such as ours today, salvation cannot be attained by one dramatic act. I know that many steps will have to be taken over many months before the world can look at itself one day and truly realize that a new climate of mutually peaceful confidence is abroad in the world. But I know, above all else, that we must start to take these steps — now.'

50 years after *Sputnik* we too have the opportunity to take such steps, at a time far less complicated. The 'cold war' is history; the number of space powers is few and nearly all of the space powers today are imbedded in cooperative projects. Everyone will gain from a stabilizing framework; for no one will win in a space confrontation. Finding a viable consensus among space-faring nations is strategically important. It is doable. But above all: it has never been timelier.

Tobias C. OWEN
USA
Professor at the University of Hawaii (Institute for Astronomy).

He has conducted studies on the origin and composition of planetary atmospheres and comets, including discoveries of HDO (from Earth) and noble gases (from the *Viking* spacecraft) on Mars. He led teams that discovered the rings of Jupiter.

American Chair of the NASA-ESA team that developed and initiated the *Cassini-Huygens* Mission to the Saturn system. Extensive experience in planetary missions: *Viking* Mission to Mars (1969–1978) with responsibility for atmospheric analysis, *Voyager Imaging Team* (1972–1990); *Galileo* Mission (1977 to 2000), Interdisciplinary Scientist and member of different experiments for *Cassini-Huygens* Mission, Associate Investigator on the ESA *Rosetta* Mission, Interdisciplinary Scientist on the Russian *Phobos* Mission.

Honorary Doctorate at the University of Paris. Fellow of the American Association for the Advancement of Science. Fellow of the American Geophysical Union.

List of his awards include Grand Prix Marcel Dassault (with J.P. Lebreton and D, Gautier) Academie des Sciences 2006; Regents' Award for Excellence in Research, University of Hawaii, 2006; NASA medal for exceptional scientific achievement, analysis of Martian atmosphere, 1977

THE WORLD SINCE SPUTNIK

The successful launch of the first artificial satellite by the Soviet Union in 1957 was a watershed event in the history of the world. Mankind had made a moon! In one giant step, we suddenly entered the 'Space Age' and life on Earth would never be quite the same.

The political consequences in the United States were immediate and painful. Americans had gotten accustomed to the idea of being first, of being the world's technology innovators. Here was a clear demonstration for all the world to see that this was no longer the case. Such embarrassment! Panic sent in! Courses in Russian language suddenly sprang up at colleges and universities. Editorials in newspapers decried the poor state of American education and clamoured for more emphasis on mathematics, physics and engineering, 'the way these things are taught in the Soviet Union!'

The dawn of the space age was soon followed by another dramatic achievement: in 1959, the USSR obtained the first images of the far side of the Moon!

Exploration has always been a deeply seated drive in human beings. The ancient Greeks explored the Mediterranean Sea, Marco Polo found China for the Europeans, Columbus brought Europe to the Americas, the Polynesians discovered Tahiti and Hawaii, etc. But the far side of the Moon! Only science fiction writers like Jules Verne or visionaries like K. Tsiolkovsky had considered an adventure like that. Suddenly exploration had been lifted into a new dimension. The sky was no longer the limit.

It is impossible to trace the detailed effects of this new awareness, but experience with past discoveries of 'new worlds' suggests a strong stimulus to the collective imagination. Those science fiction stories no longer seemed so far-fetched. Serious scientists

and engineers could begin planning ever more ambitious trips into space. What was hidden under the perpetual cloud cover of Venus? How did the Earth get such a large Moon? Is there life on Mars? What kinds of primitive chemistry are still taking place today in the outer Solar system? These questions and many more were no longer simply the subjects of speculation — we could build spacecraft that would venture forth to find the answers.

The effects of *Sputnik* on humanity at large have been more subtle but even more significant. A satellite that circles the globe reduces the planet to a single entity. The Earth was no longer one country here, one continent there, but an entire world, whole and complete. It would be some time before this reality would become part of people's consciousness, but *Sputnik* set the stage for this profound change in the perspective of Earth's inhabitants.

Now we can take our place as one planet among the others in our system. As we celebrate this anniversary, every other planet has been visited by our spacecraft, changing forever from moving points of light in our night skies to worlds in their own right.

This heightened awareness of our place in a planetary system has led to an ever-intensifying search for other such systems. We now know over 200 stars that have one or more giant planets in orbit around them. At the same time, these explorations of the Solar system and the Galaxy have failed to find evidence of any life other than the life we know on Earth.

Thus in the 50 years since *Sputnik*, our sense of what constitutes our habitat has enlarged dramatically. School children now grow up with colorful pictures of our planets and a perspective on our place in the cosmos that was completely hidden from their grandparents at the same age. To gain a vivid picture of this change, it is only necessary to look into a college textbook written in 1936 by a distinguished professor of astronomy, Forest Ray Moulton:

'*There is no hope for the fanciful idea of reaching the moon*,' Moulton boldly declared, '*because of insurmountable barriers to escaping the Earth's gravity*.'

Fortunately, the Soviet team that launched *Sputnik* was not impressed by such declarations! Professor Moulton's sense of certainty was based on good physics but a very poor sense of technological progress. He teaches us to be humble about our abilities to predict what the future holds in store.

Having broken the bonds of Earth and explored our planetary neighbours, what has this new perspective done for humanity? The record is mixed, but we seem to be on the threshold of some dramatic developments whose origin can be traced back to those first '*beeps*' from the little *Sputnik*, saying '*hello!*' from space. On the one hand, we can deplore the fact that with all these extraordinary technological accomplishments, we are still trying to solve our largest social problems in the same manner as our cave-dwelling ancestors — by force. Hydrogen bombs are nothing more than the best clubs we have learned to make so far. It is truly appalling that the irrefutable awareness of the Earth as a planet, which holds an extraordinary potential for uniting all the world's inhabitants, is constantly being torn to shreds by the ravages of wars. This has got to stop!

And there are glimmerings of hope that one day it will. We are presently enjoying the longest period of peace among the perpetually warring tribes of Europe in the history of the world. With some dedicated effort, this harmony can be extended to include other nations as well.

Similarly, after centuries of exploiting the treasures of the Earth for our own selfish purposes, we are witnessing a growing concern about the mess we are making of our environment. Our beautiful blue and white planet, perhaps unique in the Universe for its possession of intelligent inhabitants, deserves better treatment. The steadily growing realization that we live on a single, vulnerable world that is a mere dust mote in a great uncaring cosmos, is among the greatest gifts that the space age initiated by *Sputnik* has given us. This awareness is slowly, but ineluctably engendering a greater sense of our responsibility for our environment. We can now see clearly that we ourselves constitute one of the greatest threats to life on our precious planet. The most recent manifestation of this growing planetary perspective is the major effort getting underway to avoid the catastrophic change in global climate we humans are causing. This is a threat that is not limited to one country or one continent; it is a global problem that requires a global response.

The next enormous step we must take is to stop, or even better, reverse the rampant growth of the human population. People have been multiplying at an ever-increasing rate, such that the doubling time for the world population is now less than a human lifetime. To put this in more graphic terms, consider that it has taken over a million years to produce the present population of the world. We are poised to achieve the same number of people in just 45 years! At the time *Sputnik* was launched, there were 2.9 billion people on the planet. Today (6/4/2007) there are 6.6 billion. To build the balanced world without wars we desire, all of these people should be able to have the same standard of living as the citizens of highly developed countries. For this to happen, the pressure on the environment will be enormous.

Think of the Earth as it was even 200 years ago — a beautiful, life-giving world, circling the Sun at just the right distance to provide the proper range of temperature needed by the immense variety of its living inhabitants. The nature of life itself remains mysterious to us, but it is easy to see that the survival of this phenomenon at its present level of richness requires a delicate, yet sturdy equilibrium both among the different species and with the environment.

The problem we confront is that this benign range of temperatures is also controlled by the composition of the atmosphere and we humans have been irresponsibly altering this during the last few decades. Think what has happened in 200 years: One of the forms of life that makes the Earth so very special has totally upset the delicate balance that keeps all life in harmony increasing in number without any apparent limit, consuming everything it can find. In the process, it has changed the composition of the very air we breathe. We, humans, are behaving like a metastasizing cancer, its cells proliferating until they destroy its host. In our case the host is the Earth, and while we are in no danger of destroying the planet, we are steadily reducing it to a much less livable place. In the case of a cancer, when the host dies, the cancer dies as well. In our case, we are at risk of providing serious hardship for large segments of the world's population.

This must stop! There is nowhere else to go. And that knowledge is another of the important gifts from *Sputnik* and its descendants. We can certainly dream of covering Mars with the same shopping malls, apartment blocks and arrays of highways and hotels with which we are decorating the Earth, but sending humans to Mars will not solve our problems. We have to do that on Earth, and the sooner the better!

All this may seem a far cry from the brave little *Sputnik*, circling the Earth and broadcasting its presence for the entire world to hear. But these signals from space provide

another perspective: we have an existential imperative to take care of our planet and each other, because beyond *Sputnik*, beyond orbiting space stations or outposts on the Moon and Mars, there is only the dark, unspeakably cold and unforgiving vacuum of space.

It is time to turn again to the dreamers, the kind of men and women who did not accept the dogma of so-called experts, and gave us *Sputnik*. We need a comparable achievement to refresh our thinking and show us once again that people with wings can do remarkable things for the planet on which they live. Perhaps this is the most important message of *Sputnik*: What seems impossible to some just takes a little longer for others. After 50 years, this first bright, cosmic adventurer, circling the planet high above our familiar sky, can still inspire us.

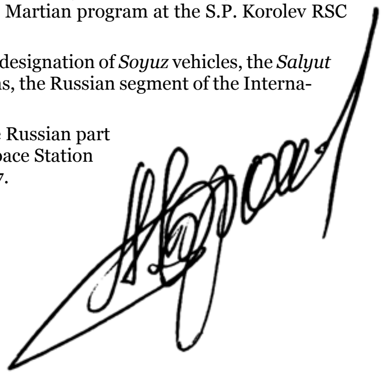
Leonid GORSHKOV
RUSSIA

Chief Research Officer at the S.P. Korolev RSC *Energia*, Doctor of Science, Professor.

Full member of the Tsiolkovsky Russian Academy of Cosmonautics. One of the chief of the Martian program at the S.P. Korolev RSC *Energia*.

Research fellow in the designation of *Soyuz* vehicles, the *Salyut* and *Mir* orbital stations, the Russian segment of the International Space Station.

Deputy Director in the Russian part of the International Space Station Program in 1994–1997.



SPUTNIK-1 EXTENDED THE WORLD BOUNDARIES

– How did the launch of the Sputnik affect the worldview, the science and culture and the technological progress?

The orbital insertion of the *Sputnik-1* was just another milestone of the rocket technology in the Soviet Union. However, this milestone made a revolution in people's minds. Of course, everyone realized people will sooner or later fly in space. But understanding is one thing, being a witness at the time when it is done — is totally another.

The ancient vision of visiting extraterrestrial worlds was turning into reality. Even the dream of finding intelligent beings did not seem to be unrealistic anymore.

After the first *Sputnik* was launched to orbit, using space opportunities for everyday life became a routine. Communication and TV, monitoring of the Earth surface from space, scientific research in space became a part of our life. Today, space technologies are among most crucial elements of the scientific and technological potential in developed countries. However, most importantly, this opened a new area of human activity and created a new vector in civilization progress.

'— *Was Sputnik-1 really a new thing in space technology?*

The satellite was pretty unsophisticated in terms of design and systems. It was even amply named PS, meaning simplest satellite. The launch of the first satellite was above all the triumph of the rocket technology. The booster R-7, famous '*semyorka*', was the first in the world to support the launch of the artificial satellite to Earth orbit. However simple, this satellite demonstrated the first steps in creating 'space' sys-

tems — thermal control, power and others. More complex spacecraft were the milestones of the space exploration. But this does not diminish the huge importance of the first artificial Earth satellite: it was the *First*!

'— *It is often said that the launch of Sputnik-1 was a politically motivated event in the Soviet Union. Is this true?*

It makes no sense to look at the events of this magnitude through the eyes of the politicians. They see politics in everything. Many people in our country say that the *Apollo* program to reach the Moon in the US was pure politics. Certainly, this project was political for President Kennedy and his team. It was of an utmost importance to him to show the whole world how powerful the Unites States was. Whereas NASA engineers saw the first human flight to the Moon as an exciting challenge. *Apollo* program was a great technological breakthrough for American industry. The first human landing on the Moon surface was a milestone for the whole civilization, which will stay in the history forever. The same refers to the *Sputnik-1*. We should not only see politics in this.

'— *We take pride in the fact that our country was the first in space exploration. The first satellite was Soviet, the first cosmonaut was Soviet, first orbital station was Soviet – we were the first at many stages of the space exploration. Do you think this happened by chance?*

I think this was very logical. Of course, government support was critical. However, I would say the main success factors were technological and intellectual potential of our country.

'— *Yes, but everything altered later on, when the first man on the Moon was American, the first Space Shuttle was also American. It seemed we have lost to our competitors beyond any hope. Is this true?*

Not quite. We wanted ardently the first man on the Moon to be Soviet. But we did not manage that due to a few reasons. We set the course in 1969 for construction of orbital stations. Certainly, we wanted to build the first orbital station ahead of the Americans. And we succeeded. The purpose of the orbital stations was a wide range research program in various areas of the science and technology. Years of research resulted in vast amount of scientific data which, as we hope, would support many scientific and technological contributions.

One of the critical activities onboard the orbital stations was the preparation for future interplanetary missions. The systems supporting the extended human flights, which are the main issues for interplanetary missions, can only be created and mastered onboard the orbital stations. No other country on Earth has gained this experience as we did. Many elements of the future interplanetary systems were developed while supporting operation of the orbital stations. In terms of Mars manned flight, Russia is technologically ahead of many other countries, which among other factors, has been contributed by activities at the space stations as well. So, I believe, saying we are hopelessly behind would be a major underestimation.

'— *What do you think of competition in space exploration? Would not it be better to cooperate and integrate? You mentioned Mars manned space flight: would it not be logical to make this an international effort?*

Certainly, we are developing international cooperation in space exploration, and will continue doing so. However, we are bound to have national space programs as long as we have different countries. Each individual country is committed to developing its own cutting edge technologies based on internal experience and projects. It is specifically true if the technology is in demand on the world market. For this reason the space exploration is shared by international and national programs. The competition is a great incentive in technology development and it will certainly stay in space flights.

Mars exploration is a long term process, and virtually every country possessing appropriate technology will take part in it at certain stages. Mars flights program will require various vehicles, bases, and research and construction tools. National programs of individual countries meet individual challenges in Mars exploration. Every country will take share of the path to the long expected final destination.

The US has recently declared that the flight to Mars to be the national program. Basically, Americans can engage other countries at the participant countries' expense. However, one should spend his money with maximum efficiency. It's quite possible Russia will find it more effective and promising to develop its own key technologies for manned flight to Mars, which will open an opportunity for extending the national programs into the future.

'— *There is a popular view now that the space exploration is not a priority in the commercial activity in the world. Would it be more prudent to address the most critical issues for the world population?*

Yes, there are many problems in the world that need investment. Even feeding the Earth population is a far more critical issue than, say, manned flight to Mars. But, fortunately, the humanity never went by this seemingly apparent principle, in spite of the fact that the life for world population has never been trouble-free. However, this is precisely the reason why we do not have to sit at the fire clad in animal hides anymore. The humanity did not 'waste' the opportunities it had in front of it. The exploration of the surroundings near our own 'house' — from the world ocean to the outer space — is a part of developing our civilization. This is not the only purpose of the space exploration, there are other very practical purposes, and space exploration helps tackle many global issues.

'— *What are these global issues, and what is the potential of the space exploration? How will it affect the humanity?*

Some of them can not really be handled without the tools provided by the space science. Here is an example. As you know, environmental resource of the planet Earth has it's limits. The increased flow of the energy, however clean, into the Earth environment, can not be indefinite. On the other hand, one can hardly curb the ever growing appetites of the humanity. Moreover, if we do not act appropriately, we could end up at the point of no return, when humanity will have depleted the environmental resource of the Earth, and the situation would be irreversible.

There is a lot of discussion about the search of 'clean' energy sources, fighting the greenhouse effect etc. This should be done, but these activities can only postpone the point of no return. Sooner or later people will have to start removing power consuming and environmentally unfriendly industries from the Earth surface.

That is why we can not avoid building structures and setting up production in space in the future. Orbital station missions, building spacecraft, deployment of huge transforming structures, development of life supporting systems, missions to planets in the Solar system and explorations of other planets – these are all steps on this path.

Speaking of the potential, the humanity is doomed to continuous expansion and extension of our 'ecumene'. This process is indefinite.

'— *You have mentioned global problems. Does Russia have to spend large assets on space exploration? These assets are very limited.*

First of all, Russia's poverty is absolutely not true. The country, as well as the government, has considerable assets. These assets should be invested in the country's economy.

Despite the positive economical growth, Russia's vulnerability is in orientation on natural resources (output and export of the hydrocarbons, metallurgy etc), which the President of the Russian Federation highlighted numerous times. We have not been able to restore the economy after the crisis in 1990's yet. Which industries should be restored as a priority? I believe those industries that use cutting edge technology sought for on the world market. Space industry is one of them. Our country has been and still is at the cutting edge in many space technologies.

The cause of restoring the industry has a social aspect as well. The number of organisations participating, say, in building orbital stations *Salyut*, *Mir*, Russian Segment of the International Space Station was nearing tens of hundreds. These organizations are distributed throughout various regions and cities of the country. Building space equipment requires more than just 'space' industries alone. It requires various instruments and accessories, materials etc. This brings jobs for specialists and employs latest technology, which is always crucial for any country.

We have become used to the term 'brain drain'. Many scientists are leaving Russia, but, at first it does not seem to be a problem. In reality, it only seems that way. The process, when high skilled workers leave the country and are substituted by unskilled migrants, is highly hazardous for the country and poses threat to its very existence. The scientists are leaving Russia not because they are better paid abroad, but primarily because our country does not have a program where young scientists can apply their skills. Russia needs significant science programs as breath of life. In particular, manned spaceflight to Mars will require participation of various kinds of scientists — biologists, doctors, material scientists, physicists, programmers, chemists and many others.

You can view such a concept as the 'country prestige' in different ways. But the prestige of a state is a concept that has economical aspect to it. Remember, how soared prestige of the US after the *Apollo* program.

'— *Nevertheless, a common person is more concerned about his own well-being. Do you think Russian people will support development of the space industry?*

It all depends on who you call a 'common person'. If this is a person who is only concerned about his own well-being and who does not care about his children and grand-children, then, these people would probably not support the development of the space technology. I saw at times that people imagine a 'common person' as an abstract being with motivation level close to insects. This idea is wrong. In any case, government policy should not use this approach.

In 2002, the President of the Public Opinion Foundation A.A. Oslon published public poll results about the public support of designing a manned spaceflight to Mars in Russia. This was not the happiest year for Russia. However, it turned out that majority of Russians supported this flight. I quite realize that we should be cautious about the polls: a lot depends on the context and the wording of the question. But it still is a curious fact.

By the way, the emotional response of millions of 'common people' in the world to the launch of the first satellite, Gagarin's flight, American landing on the Moon is also very significant. *I am sure*, that majority of people in our country support the space science. This is despite the fact that the idea of 'insect-like' behavior is widespread.

'— *Did the launch of the Sputnik-1 influence your life?*

Absolutely. In a very direct way. All my life is related to space science. And I think I have been very fortunate.

William Vernon JONES
USA

Senior Scientist for Suborbital Research in the NASA Headquarters. Senior Science Program Executive/Suborbital; Chief Scientist, Space Physics Division; Chief Scientist in Cosmic and Heliospheric Physics in the NASA Headquarters. Visiting Senior Scientist since 1985.

Earned his B.C. in Engineering Physics from the University of Tulsa in 1963; Ph.D, in Physics from the Louisiana State University in 1967. In 1967–1968 was an Alexander von Humboldt Fellow in the Max-Planck Institute for Extraterrestrial Physics, Garching, Germany. Worked in the Louisiana State University in 1969–1988 (Professor; Associate Professor; Assistant Professor; Research Associate).

Visiting Research Scientist in the Laboratory for High Energy Astrophysics, Goddard Space Flight Center, 1975–1976. Visiting Research Scientist in the Institute for Cosmic Ray Research, University of Tokyo: JSPS, 1981.

FROM THE SPACE RACE TO THE VISION FOR SPACE EXPLORATION

I consider myself privileged to have lived during one of the most exciting times in history that I can imagine, the beginning of the space era. The launch of *Sputnik-1* by the USSR on October 4, 1957 and the events that followed over the next few years will be forever ingrained in my memory. I began taking classes at the University of Tulsa, Oklahoma a few weeks before the launch of *Sputnik-1*, which was followed one month later by the launch of *Sputnik-2* on November 3. After the success of the *Sputnik* launches and the embarrassing failure of the first American attempt to launch a satellite in December, 1957, *Explorer-1* became America's first satellite, a couple of weeks after the start of my second semester. The first major scientific discovery of the space age was based on data returned from *Explorer-1* and *Explorer-3*, launched in January and March, 1958, respectively. The intense bands of radiation detected by these spacecraft are known as the Van Allen radiation belts, in honor Professor James A. Van Allen who led the University of Iowa team that discovered them. Many years later I was privileged to meet Professor Konstantin I. Gringauz, who told me that particle sensors on the *Sputnik* satellites had also detected those radiation belts.

The US National Aeronautics and Space Administration (NASA) was created as a Government Agency in 1958, in a climate perceived by many Americans to be almost a national emergency. NASA launched its first satellite, *Pioneer-3*, on December 6, 1958. *Pioneers-3* and *-4* were equipped with Geiger counters intended for measuring the space radiation between the Earth and the Moon. *Pioneer-3*, launched on December 6, 1958, did not reach the Moon due to a slight error in the satellite's velocity and direction after burnout. However, it discovered a second radiation belt around the Earth before it reentered Earth's atmosphere a day after launch. *Pioneer-4*, launched

March 3, 1959, successfully flew by the Moon within a distance of 60 000 kilometers the following day, to become the first US spacecraft in solar orbit.

On October 7, 1958, NASA announced Project *Mercury* and its major objectives to place a spacecraft with a human onboard into orbital flight around Earth, to observe human performance under such conditions, and to recover the human and spacecraft safely. At that point it was questionable whether a human could function as a pilot-engineer-experimenter in the harsh conditions of weightless flight. However, it was expected that space flight conditions would be similar to those experienced by military test pilots. In January, 1959, the service records of hundreds of talented test pilots were assembled. Through a variety of interviews and written tests, this group was pared down to 32 candidates, who endured even more stringent physical, psychological, and mental examinations. On April 9, 1959 NASA introduced the *Mercury* Seven astronauts: Scott Carpenter, L. Gordon Cooper, Jr., John H. Glenn, Jr., Virgil I. 'Gus' Grissom, Walter M. Schirra, Jr., Alan B. Shepard, Jr., and Donald K. 'Deke' Slayton. They were immediately adopted as heroes. By then the US and the USSR were obviously in a 'space race.' If there was any doubt about who was ahead, it disappeared with the news on April 12, 1961 that Russian Yuri Gagarin had become the first man in space.

I recall listening to my car radio throughout Alan Shepard's 15 min suborbital flight on May 5, 1961. It was incredible to me, an undergraduate student, that less than three weeks later on 25 May 1961 in a speech before Congress, President John F. Kennedy challenged Americans to land a man on the Moon and return him safely to Earth before the decade was out! How could anyone believe that it would be possible to go from one manned 15-minute suborbital flight to sending an astronaut to the Moon and returning him safely to Earth in less than 9 years? The suborbital flight piloted by Gus Grissom on July 21, 1961 was another step in achieving the first manned orbital flight of John Glenn on February 20, 1962. The President had said, '*It will not be one man going to the Moon, it will be an entire nation. For all of us must work to put him there.*' Among other things, this implied to me that everyone would participate in that virtual trip by contributing to the budget for a greatly accelerated program. Of course, the dream of exploring near space came true on July 20, 1969, when *Apollo-11* landed astronauts Neil Armstrong and Buzz Aldrin on the Moon's surface.

The US had finally scored a first in the space race! But, it came at a price. On January 27, 1967 tragedy struck the *Apollo* program when a flash fire occurred in the command module during a launch pad test of the *Apollo/Saturn* space vehicle being prepared for the first piloted flight, called the AS-204 mission. Three astronauts died in that tragic accident: Gus Grissom was a veteran of *Mercury* and *Gemini* missions; Ed White had performed the first US extravehicular activity during the *Gemini* program; and Roger Chaffee was preparing for his first space flight. The investigation report made specific recommendations that led to major design and engineering modifications, in addition to revisions of test planning, test discipline, manufacturing processes and procedures, and quality control. The AS-204 mission was re-designated *Apollo-I* in honor of the crew. My Ph.D. graduation ceremony occurred on the same day as that tragic fire.

I recall the *Apollo-Soyuz* Test Project in July, 1975 being marketed as a demonstration of the ability to rescue astronauts/cosmonauts potentially stranded in space. But, it became a symbol of the détente policy beginning about that time. The *Soyuz* and *Apollo* flights docked on July 17, after having been launched within hours of each other on July 15. While docked, the two crews spent time in each other's craft and conducted joint scientific experiments. The mission was considered a great success from both a technical and public relations perspective. By easing the tension of the space race, it signaled the possibility of a move from competition to cooperation between the two superpowers. The original *Soyuz* Module and a mock-up of the *Apollo* Command Module are on display in the National Air and Space Museum in Washington, DC. The *Apollo* Command Module is on display at the California Science Center in Los Angeles, California. This *Apollo-Soyuz* mission was the last *Apollo* flight, as well as the last manned space launch for the US until the first *Space Shuttle* flight in April, 1981. The Soviet Union flew its next manned space flight the following year in June, 1976.

EVENT HORIZON

The greatly improved US-Soviet relations based on historic meetings of President Ronald W. Reagan and General Secretary Mikhail S. Gorbachev in Geneva, Reykjavik, Washington and Moscow opened up new opportunities for cooperation in many areas of interest to both countries, and indeed to mankind. The 1987 US-USSR *Cooperative Agreement in the Exploration and Use of Outer Space for Peaceful Purposes* recognized the long-standing commitment of both countries to space and exploration. The two leaders agreed to a new initiative to expand civil space cooperation by exchanging flight opportunities for scientific instruments to fly on each other's spacecraft. They also agreed to exchange results of independent national studies of future unmanned Solar system exploration missions as a means of assessing prospects for further US-Soviet cooperation on such missions. Scientific missions to the Moon and Mars were noted as potential areas of bilateral and international cooperation. It was further agreed to enhance the scientific benefit that could be derived from the two countries' space research missions by expanding exchanges of scientists and space science data.

It was now cooperation in space activities rather than competition between the two superpowers! By this time, I had phased back my academic career as Professor of Physics at Louisiana State University (in Baton Rouge) to become Chief Scientist, Cosmic and Heliospheric Physics at NASA Headquarters in Washington, DC. This put me in the enviable position of being a US delegate on one of the original US-Soviet (later US-Russian) Joint Working Groups for scientific cooperation in space. Mikhail Panasyuk of the Moscow State University Institute of Nuclear Physics and I Co-Chaired the Cosmic Ray Implementation Team, which reported to the Working Group on Solar-Terrestrial Physics. The results from this Team of scientists provide a good example, as well as validation, of the broad goals of the 1987 US-USSR *Cooperative Agreement*.

One of this Team's subgroups of scientists answered a two-decade old question about the charge state of 'anomalous' cosmic rays that neither side working alone could have addressed. Simultaneously, it discovered a new radiation belt that is formed when some anomalous cosmic-ray ions are trapped in the Earth's magnetic field. This project used the Earth's magnetic field as a particle analyzer to compare measurements from the US IMP-8 satellite outside the magnetosphere with track detectors flown on Soviet Cosmos Satellites inside Earth's magnetosphere. Another subgroup studying ultra-heavy cosmic rays with track-etch detectors provided TREK, the first U.S.-designed instrument to fly on a Soviet spacecraft following the 1987 Agreement. TREK was launched by Russia to the *Mir* space station in August, 1991. It was returned in part by a dedicated re-entry capsule in 1994 and the rest by the Space Shuttle *Atlantis* in November 1995.

American president George H.W. Bush and Russian president Boris Yeltsin signed the *Agreement between the United States of America and the Russian Federation Concerning Cooperation in the Exploration and Use of Outer Space for Peaceful*

Purposes in June, 1992. This agreement established a joint space program, during which one US astronaut would board the Russian space station *Mir* and two Russian cosmonauts would board a Space Shuttle. This short program was amended in September, 1993 when American Vice-president Al Gore and Russian Prime Minister Viktor Chernomyrdin signed an agreement for major cooperation in building what became known as the *International Space Station* (*ISS*). They also agreed that America would be involved in the *Mir* program under the code name 'Phase One' (the construction of the *ISS* being 'Phase Two'). During the course of the program, eleven Space Shuttle missions flew to the station, carrying out crew exchanges and conducting a myriad of scientific experiments. These missions allowed NASA and the Russian Space Agency to learn how to work with international partners in space, and how to minimize the risks associated with assembling the large ISS in orbit.

The US space policy announced on January 14, 2004 by President George W. Bush was intended as a response to the Space Shuttle *Columbia* disaster, the state of human spaceflight at NASA, and a way to regain public enthusiasm for space exploration. This *Vision for Space Exploration* calls for completion of the ISS and retirement of the Space Shuttle by 2010, with development of the *Orion* spacecraft (originally known as the *Crew Exploration Vehicle*) by 2008 and its first human spaceflight mission by 2014. It also calls for development of Shuttle-derived launch vehicles, exploration of the Moon with robotic spacecraft missions by 2008, and with crewed missions by 2020. The *Vision* was met with some controversy, and throughout much of 2004 it was unclear whether the US Congress would be willing to approve it. However, in November 2004 Congress passed an omnibus-spending bill that gave NASA the budget that the President had requested to kick-start the *Vision*. According to then-NASA Administrator Sean O'Keefe, that spending bill was as strong an endorsement of the *Vision* as anyone could have imagined. The NASA Authorization Act of 2005 explicitly endorsed the *Vision*. The current NASA Administrator, Michael Griffin, who took office in April 2005, is committed to the *Vision* and wants to reduce the four-year gap between the retirement of the Space Shuttle and the first manned mission of *Orion*.

The *Vision* has put NASA and the nation on a bold path to return to the Moon and eventually put humans on Mars. This long-term endeavor is, however, subject to the constraints imposed by annual funding approvals from Congress. Furthermore, there is concern that NASA may not have the workforce needed to achieve that multi-decade vision. Per NASA's request, the National Academy of Sciences Committee on Meeting the Workforce Needs for the National *Vision for Space Exploration* has explored the science and technology workforce needs. It concluded that NASA does not currently possess the requisite in-house personnel with the experience in human spaceflight systems development needed to implement the *Vision*. However, the Committee acknowledged that NASA is cognizant of this fact and has taken steps to correct it, primarily by seeking to recruit highly skilled personnel from outside NASA, e.g., industry and retirees. On the other hand, the Committee questioned whether NASA is attracting and developing the talent it will need over the long term. NASA last had substantial in-house involvement in human spaceflight systems engineering in the 1970's, during the design phase of the Space Shuttle program, so people skilled in human spaceflight are now likely to exist only in industry. NASA needs to leverage its robotic spacecraft workforce skills to meet some of the human spaceflight skill needs.

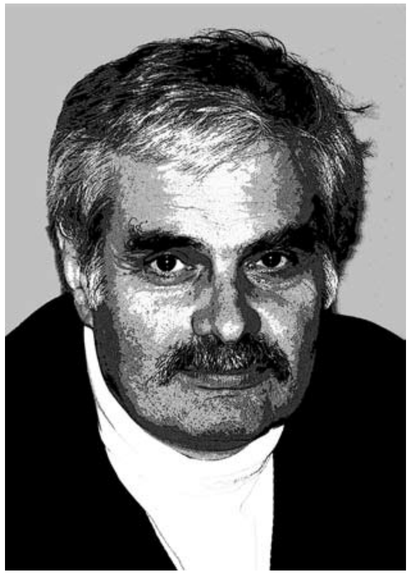
Among other things, the Committee recommended that NASA increase its investment in proven programs such as sounding rocket launches, aircraft-based research, and high altitude balloon campaigns, which provide ample opportunities for hands-on flight development experience at a relatively low cost of failure. Further, it recommends that NASA should also recognize the ability of these programs to provide hands-on experience for its younger workers, and consider that as an equal factor in the criteria for their selection. It is indeed true that these programs provided training for many of the leaders in space research. Most of the principal investigators on NASA missions were trained in either sounding rocket or balloon missions. Notable examples from the balloon program include astronaut and former NASA Chief Scientist John Grunsfeld, California Institute of Technology Professor and former Jet Propulsion Laboratory Chief Scientist Tom Prince, as well as 2006 Nobel Laureates John Mather (NASA Goddard Space Flight Center and George Smoot), (University of California, Berkeley). My own graduate, post-doctoral, and university faculty research relied heavily on balloon-borne investigations of high-energy cosmic rays.

EVENT HORIZON

An explosion of motivated people wanting an advanced degree in science or engineering so they could be part of the space program followed the launch of *Sputnik*. For example, I attended school in a rural area of the Ozark Mountains in Arkansas before the *Sputnik* launch. There, I was a member of the Arkansas State Champion Dairy Cattle Judging Team and President of the local Future Farmers of America chapter. I had planned to become a veterinarian, but my major became engineering physics when *Sputnik* was launched just as I started college. I went to graduate school on a National Defense Education Act Fellowship. An Alexander von Humboldt Fellowship allowed me to do post-doctoral research at the Max-Planck Institute for Extraterrestrial Physics in Germany. After being a University professor for 17 years, I started my NASA career in 1985 to lead development of a large cosmic-ray research facility for the Space Station. That project was terminated when the Space Station was restructured, but I stayed more than busy serving as NASA Program Scientist for numerous heliospheric missions, including *Pioneers-10* and *-11*, *Voyagers-1* and *-2*, *Ulysses*, SAMPEX, ACE and others.

In five decades, we have made unprecedented progress in exploring space. Yet, that beginning is just a small, albeit critical, step in the long journey to our becoming a space-faring civilization. Referring to what became the *Apollo* project to land a man on the Moon and return him safely to Earth, President Kennedy said, '*No single space project… will be more exciting, or more impressive… or more important… and none will be so difficult or expensive*.' That endeavor was successful to a large extent because Congress provided the funding necessary to achieve its goal, although the funding rapidly declined after the goal had been achieved: other pressing issues needed to be addressed. President Kennedy's words might also apply to President Bush's *Vision for Space Exploration*, which would undoubtedly be exciting, impressive, important, difficult, and expensive. Likewise, I could paraphrase President Kennedy's words and say '*The Vision for Space Exploration will not be one nation going to the Moon, Mars, and beyond, it will be an entire world. For all of us must work to send Earthlings there*.'

We have seen several decades of cooperation in space since the competition of the *Sputnik-Apollo* era. American, Russian, and international crews have lived and worked together onboard the ISS. Russian launch vehicles have kept the ISS supplied during the hiatus of Space Shuttle launches following the *Columbia* disaster. The Japanese and Europeans have developed Transfer Vehicles to supply their ISS modules. This era of cooperation has seen many examples of successful collaborations. It seems to me that now may be the time for international cooperation and/or collaboration to pursue mankind's goals for exploring space, as well as the Earth. Furthermore, even in an era of tight budgets, collaborations in suborbital programs could facilitate another boom in the science and technology education necessary to realize the *Vision for Space Exploration*.



Karoly SZEGO
HUNGARY

Head of Department of Natural Sciences in the Office of the Hungarian Academy of Sciences. Science adviser in the KFKI (Central Research Institute for Physics) Research Institute for Particle and Nuclear Physics. Professor at the Roland Eötvös University since 1998.

Born in 1943. Diploma in Physics, the Roland Eötvös University, Budapest, Hungary, 1966. Ph.D in 1972, D.Sc. in 1987.

Research Fellow in CERN (1972–1973). Member of the Committee on Space Research (COSPAR) Bureau in 1990–1998 and National representative in COSPAR (1990–2002). Former chairman of the Committee on Astronomy and Space Sciences of the Hungarian Academy of Sciences.

Scientific contribution includes obtaining first images of a cometary nucleus (Halley).

Awarded by Diploma for International Cooperation (NASA, 1982); State Prize of Hungary (1986); Token of Esteem (USSR, 1986); Gagarin Medal, (1987). Group achievement awards from NASA for *Cassini* mission (1998); *Cluster* mission (2004). Group achievement award from ESA for *Rosetta* mission (2004). Also awarded by Zoltan Bay award, 2007.

SPACE, 21ST CENTURY: CHOICE OF PRIORITIES

In October 4, 1957, when *Sputnik-1* was launched, I was 13 years old. I, like everybody else around me was much excited, but I doubt that the significance of the event was immediately grasped. I was radio-amateur at that time, and I would have liked to receive the signals directly. That was certainly out of question for me at that moment, and I learned many, many years later from Prof. Konstantin Gringauz that he himself published a paper in the Russian journal for radio-amateurs (not under his real name) how the signals could have been received (Prof. Gringauz was a member of the team who designed the radio system of *Sputnik-1*). Certainly there was no indication in that paper he showed me where the radio signals would have come from, how they were emitted; but in the paper there was a complete description how such a receiver could have been built using electronic components available in the next shop. Hence, whereas on one hand the secrecy around the launch was high, on the other hand efforts were made that Soviet radio amateurs could participate in the event by receiving directly the famous '*beep-beep*' signals. Actually, I still wonder how many persons really participated in that interesting ground activity.

To me the significance and importance of the first successful launch unfolded slowly. Not that I was not aware of the technical achievements. As a student interested in engineering and physics I have understood well the difficulty of rocket techniques. As I recall, I have understood its military significance as well simply by following the worldwide reflections. What I understood poorly that it really means the beginning of a new era, the beginning of the use of the outer space for the benefit of the whole mankind.

The launch of *Sputnik-2* and *-3* made it clear that the October 4 event was not a singular one; it was really the beginning of something astonishingly new. And the race for the outer space between the superpowers was also switched into high gear. I followed with high interest each bits and pieces of the news about the new missions, and I was excited to learn the available details. Alas, the details were sparse. And in a strange way my heart and mind both were split about space research. Does it belong more to the arms race than to science, or just the otherwise? Despite all that worries, me — and probably the whole world — became more and more interested about the new horizon opened up before our eyes, we were thinking about life on other planets, how people will travel in outer space, how aliens from distant stars could visit the Earth. And interest grew to hear all stories about unidentified flying objects, to find possible signs of aliens visiting Earth eons ago, etc. The sci-fi literature had become very popular, and many of the excellent authors introduced interesting questions how space exploration could affect our minds, our thinking, and our life. The significance of the October 4 launch slowly started to change human minds over the world.

I became a physicist, and I started to work in the field of particle physics. Researchers detecting and analysing cosmic rays were next door, but somehow space research was out of our focus. We discussed space as an interesting part of the news, as a part of the modern world, as an exciting field of technology, but not as an emerging field of science to which we should jump in. Very likely the secrecy surrounding space research had an impact there; but as a matter of fact, it seemed to be impossible to participate in space exploration. This situation has changed suddenly when the Soviet Union decided to involve other countries in space research in the framework of the INTERCOSMOS cooperation. A rich window of opportunities opened up, and the Hungarian engineers and scientists have learned a lot from the rich experience made available for them. Hungary has started to build space instrumentation (the very first one was a micrometeorite detector). This has provided the solid foundation of our current space activities based on broad international cooperation; and very likely Hungary soon will be a member of the European Space Agency.

It is not easy to tell when I started to realise that space activity was changing not only the future but the everyday life, and it was not something that would impact the distant future only. There were many different factors that pointed into this same direction.

One component was the spin-offs of space technology that reached the civil world. It is a general effect that science results have a high impact on technology, but maybe space had a higher impact on microelectronics. Our ability to put humans into space was the next component that stirred up new horizons. The appearance of space observatories has had a very high science impact. But to me, telecommunication and meteorology were those two elements that have made 'space' really part of the everyday life. When we talked about the other components, it was always evident that we were doing something in space. Opposite to that, telecommunication and meteorology are used as everyday commodities, without knowing that we are using actually space technology. The space around us has become entangled with ground activities, forever. In the same way as we do not know in which power station the electric current we use was generated, in the same way we do not know what elements of communication go through space. Space has become an important component of our security. It is easy to put together a long list how space activity makes our everyday life easier, e.g. finding the way from one location to another, decreasing the risk of maritime traffic, etc. This is the most important development to my mind when ground and space is not distinguished, when the area of our normal activity is broadly expanded, when space is part of our conscious/unconscious everyday life. To monitor and predict the global change of our environment is impossible without its space segment. Our 'vertical region of interest' is continuously expanding.

It would be a mistake to pretend that space technology did not bring about unfounded hopes. UN conferences were organized how to share the benefits of space exploration between developed and less developed states. In many cases, however, the expected benefits were unreal; especially in the field of remote sensing the economic return very likely was somewhat overestimated. Nevertheless, these and similar meeting might have convinced politicians that space is an important matter, and many new countries joined to this club.

Have we used the space opportunities in the right way? My answer is that we have used it in the same manner as we are using our other opportunities; neither better nor worse. The pioneer years were different from the current consolidated era. The pioneer years of space exploration was part of the race between superpowers, and my hunch is that the race was an important reason why space was funded. In the consolidated phase funding and manpower defines the contours of space activity. We could do more in space, similar to many other activities. But dreams and realities differ.

The future of space activities is strongly correlated with the future of all other activities. As space is entangled with everything else, its future cannot be disentangled. This is the point where our vision about our future comes into the play in a very strong way. What are the requirements of a sustainable development? Is environment more important than diseases? Should social inequalities takes precedence over technical options? Do we compete or cooperate? The answers we give to these questions will decide the future of space activities as well.

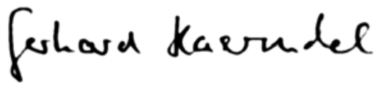
Gerhard HAERENDEL
GERMANY

Chairman of ACHME, the advisory committee of ESA's Human Spaceflight, Microgravity and Exploration Directorate.

Born in 1935, he received his Ph.D. in Physics from the University of Munich in 1963. Fellow of the Max-Planck Institute for Physics and Astrophysics in 1969, Director at the Max-Planck Institute for Extraterrestrial Physics, MPE in 1972–2000. Honour professor at the Technical University of Braunschweig in 1987, Vice President of the International Academy of Astronautics in 1987, President of the Committee on Space Research (COSPAR) in 1994–2002.

Vice President and founding Dean of the School of Engineering and Science of the International University Bremen, now Jacobs University, in 2000–2005. From 2003 up to 2007, Chairman of the European Space Science Committee (ESSC) of the European Science Foundation.

He has more than 40 years of experience in space research, including the function of Principal Investigator of several international rocket and satellite projects.



FIFTY YEARS AFTER SPUTNIK — A VIEW OF A PLASMA PHYSICIST

I was never a space romantic. I do not enjoy science fiction. My entry into space science was entirely coincidental, perhaps not entirely. What did I feel when I learnt about the *Sputnik-1* launch? I simply do not remember. I was a third-year student in Tübingen, focusing on math and physics, singing and philosophy. Probably I just took notice of what had happened on October 4, 1957, not particularly surprised, since progress was so rapid in those years. Space was far away from my interests. However, that was soon to change.

In the year following this event it became clear to me that I wanted to apply physics to astrophysical issues. In 1959 I went to Munich, where a year before Heisenberg and Biermann established the Max-Planck Institut für Physik und Astrophysik (Max-Planck Institute for Physics and Astrophysics). Courageously I approached Biermann, and he accepted me as diploma student. In the seminar that Ludwig Biermann and Arnulf Schlüter held together, I got the assignment to report about the discovery of the Van Allen Belt. And when by the end of 1959, for formal academic reasons, Biermann had to transfer me to Schlüter, the German pioneer in plasma physics and full professor at the University of Munich, the latter asked me to elaborate on the physics of the radiation belt. So I did and became one of the first German students writing their doctoral thesis on a space theme.

In this situation, it was no surprise that Reimar Lüst, who had been charged by Werner Heisenberg and Ludwig Biermann to build up a space research group, hired me as the 'in-house' plasma theorist. Already in late 1962, the small group of Reimar Lüst set out to develop a new tool of studying the Earth's environment, barium plasma clouds. These were heroic years of finding technical solutions, testing them on sounding rockets in the Sahara desert, in Sardinia, Kiruna and Ft. Churchill, and leaving to me the task to extract the physics out of the data.

Now I was deeply engaged in space. Soon enabled to plan and carry out my own rocket campaigns, I quickly got used to two essentials of work in space, international collaboration and global thinking. More and more satellites encircled the Earth irrespective of national borders. The notion of a common Earth, now visible from a distant vantage point, penetrated deep into the imagination of many. Space researchers felt that they were members of one community and, when composing missions and payloads, quickly learnt to take advantage of the talents of their colleagues, wherever located, in order to best satisfy the scientific needs. A great space brotherhood had grown, nowhere better manifested than at the COSPAR meetings, where even the 'iron curtain' lost some of its separating powers.

Space plasma cannot be characterized by a few parameters like a dense gas. Understanding our active plasma experiments and their effects on the local environment required the measurement of a host of particle and field parameters. Thus quite naturally, my sounding rocket payloads became international space laboratories assisted by a widespread optical observations network on the ground, sometimes complemented by aircraft. The most elaborate project was Project *Porcupine*. Besides scientific participation from France, Austria, USA, ESA we also had a *Xenon* ion gun from Moscow on board. It was the first German-Soviet collaboration in space, casually initiated upon a lecture of Academician Roald Sagdeev at the Bavarian Academy of Sciences. It was the beginning of long-lasting friendships with our Russian colleagues.

What changes in our views of the world did I experience in the course of my life? I like to classify them in three realms, the practical side, the cultural side, and the adventurous side. The benefits for our daily life by the communication, the weather, the Earth observation, and navigation satellites, in spite of their enormous impact, are being accepted by the public more and more as something ordinary, that ought to be so. But not long ago the sailors on the ocean had to inspect the sky at the horizon in search for the first sign of an approaching storm. Now weather satellites deliver many times daily cloud images, also for the night sector, and many other weather data, and nobody wonders any more how this is being achieved. One can say the same about the widened view of our near-earth environment as well as of the distant universe, brought about by space means. The explosively expanded knowledge has sunk into our culture, few ask the question how and by what means. The beautiful images from the *Hubble Space Telescope* provide perhaps the best reminder to the public of the marvelous advances of space technology standing behind. The deepest awareness of space, however, seems to be conveyed by the frequent appearances, on the television screen, of astronauts and cosmonauts working in their space ships or marching towards the elevator that will carry them to their capsule. And wherever they appear in public, these men and women attract much attention. After so many years of human space flight, they are still being perceived as the heroes of our times. On the other hand, the views from the space ships down on Earth, on the quietly progressing deserts, mountains and oceans underneath, awaken another sensation, that of the beauty of the planet we happen to live on and may raise in many people, particularly the young, the desire to have this experience one day on their own.

When I think what changes I experienced in my discipline, I already have a hard time to remind myself, how recently the space between Sun and Earth has been filled with material, structure, and action. When I attended my first space symposium in Paris in 1962, it was the time of COPERS, the preparatory organization for ESRO and ESA,

there was still a lively debate about solar wind or solar breeze, the only matter known beyond the visible corona being the zodiacal light. And then, in rapid succession, we learnt about the magnetopause, the tail, the solar wind, the bow shock. We were taught how the solar wind becomes supersonic. I remember well when the first close images from Mars and Mercury were shown, how deeply impressed we were by the sudden unveiling of the true nature of these heavenly bodies, which had been playing godlike roles in the development of our civilization. Meanwhile we have, thanks to the numerous deep space probes, vivid imaginations of the surface or atmosphere of all the planets, of their satellites and planetary rings, of asteroids, and even of comets. We have watched recently with excitement the penetration of the *Huygens* probe into the opaque atmosphere of Titan. Our Solar system has received a visible face, is more and more being sensed as our home in the Universe. And the space between these bodies is now full of structures with shock waves and plasma clouds, cosmic rays modulated by the solar wind, generated on the Sun or inside the heliosphere, dust grains from interstellar space. One space probe has already come near to its boundary, the heliopause. And in the center of all this, resides the Sun whose violent exterior is continuously under surveillance with UV- and X-ray telescopes, slowly revealing the secrets of the powerful flares and coronal mass ejections and enabling predictions of the space weather. Equally impressive is the progressive unraveling of the solar interior by means of the helioseismology. We are beginning to understand the Sun's mysterious dynamo. Space telescopes in concert with the ever growing ground-based telescopes have expanded our knowledge of the Universe with a breath-taking pace. Perhaps most exciting is the information about its origin and gross composition thanks to the mapping of the cosmic background radiation and the improved determination of its expansion rate. An understanding of the formation of stars and galaxies, of the role of Dark Matter in this process is emerging. X-ray, UV-, optical, and IR- space telescopes have filled this Universe with exotic objects of all kinds, black holes, accreting neutron stars, supernova remnants and cosmic gamma bursts. We live, thanks to space research in a fantastically enriched Universe. What can science fiction add?

The plasma physicist, however, must add how much we have progressed in discovering and understanding processes that are crucial for the dynamics of the matter between the stars and in their environments. Collisionless shocks could be studied *in-situ* in the solar wind advancing our understanding of their role as accelerators of cosmic radiation. The intriguing magnetic reconnection process, on whose existence many colleagues had, for a long time, severe doubts, has now become common lore helping to understand not only magnetic storms in the Earth's environment, but also the dramatic eruptions of energy in the solar atmosphere. A fantastic zoo of plasma waves has been found with satellite antennas telling us how energetic particle communicate without colliding with each other. The fascinating auroral plasma physics, in particular the acceleration process itself, has been unraveled by hundreds of sounding rocket flights at high latitudes and launches of some well instrumented low-orbiting satellites. I remember being immersed in the debate in the 1960's and 70's about the existence or non-existence of parallel electric fields, which are now generally accepted. It is a continuing joy for me to work in this community and share the quest for a fuller understanding of the host of intriguing phenomena, some of which exhibit their beauty to the eye, like the aurora borealis or, aided by x-ray imaging, the complex coronal loop structure.

Where will we go from here? Space in service of mankind, as tool to probe the distant Universe, will be with us for long. Space tourism may become a serious business.

On the science front, it will not be too long until gravitational waves will be identified, and gravitational astronomy will widen our information about the most dramatic events in the universe. Nulling IR-interferometry may identify earthlike planets and signatures of their habitability. Robots will land on satellites of the giant planets and drill through the ice of Europa. Human beings will step on other bodies than the Moon, foremost on Mars, searching for traces of life elsewhere. They will be the great explorers of the future. I believe that all of this will develop into a joint endeavor of mankind, rather than continuing as competitive actions of individual nations. With the realization that mankind is bound for ever to physically stay within the Solar system, traveling to destinations within the accessible space will become a common goal of humanity.

EVENT HORIZON

Eric GALIMOV
RUSSIA

Director of the Vernadsky Institute of Geochemistry and Analytical Chemistry of the Russian Academy of Sciences. A member of the Presidium of RAS.

Academician of the Russian Academy of Sciences. Doctor of Science in Geology and Mineralogy. Specialist in carbon and isotope geochemistry, biosphere evolution and planetology, geochemistry of the Moon and chemical evolution of the Earth.

Born in 1936 in Vladivostok. Graduated from the Gubkin State University of Oil and Gas. Chief of carbon geochemistry laboratory in the Vernadsky Institute of Geochemistry and Analytical Chemistry (1973–1992), Director of the Institute since 1992.

Editor-in-Chief of the *Geochemistry* magazine. President Emeritus of the International Association of Geochemistry and Cosmochemistry. Chairman of the RAS Meteorites Committee. RAS Space Council Bureau Member.

Awarded the Vernadsky medal of RAS (1984), Prize from the International Lunar Exploration Working Group (2004), the Sign of Honour (1986, 1999), and Treibs Medal (2004).

THE MOST IMPORTANT INDUSTRIAL CHALLENGE OF THE 21ST CENTURY

There are periods and days when the mankind does not simply make a considerable step forward, but alters the whole trajectory of its development. A linear straight-ahead forecast turns then out to be much poorer than the reality to come. Such a date was that of October 4, 1957, the day of launch of Earth's first artificial satellite. It was received with rejoicing, seen as an evidence of our might and technical possibilities; represented a step in the struggle for global leadership. However, few could foresee at the moment that exploration of space would change our very way of living. Nowadays, every man in the street who does not have to bother about knowing finer technicalities, enjoys everyday, 'matter-of-fact' use of mobile telephones, the Global Positioning System, satellite television, etc.

I believe that right now, we fail to fully grasp the opportunities exploration of the Moon will offer us; that is why we approach this enterprise so hesitatingly, gingerly, and lingeringly. Moon studies are vital for fundamental geology. I have on many occasions emphasized in my publications that reconstruction of earlier history of Earth, that of appearance of atmosphere, oceans and life, is impossible without studying the Moon. That is true if for no other reason that all traces of the first 500 or 600 million years of Earth's history have been completely erased from its geological annals; now in the Moon, such traces have been preserved. Another reason is that the Moon and the Earth constitute a genetically united system.

Moreover, the Moon may be of enormous practical value. Linear imagination seeks to expand the scope of conventional possibilities. It is however possible that the future does not hide where we expect it to. That is why it is today, in the year of the anniversary of the first launch artificial Earth satellite, that I would like to draw attention to another unique prospect, gigantic in its scale and possible influence on the fate of mankind; the prospect that became visible along with the exploration of space.

When considering exploration of the Moon and its resources, one should bear in mind that no mineral products, no materials at all, are economically worthwhile to be transported from the Moon back to the Earth. There is only one exception to this rule. This exception is helium-3.

We know that controllable thermonuclear synthesis has not yet been implemented industrially, although the development in this field already starts to acquire practical aspect. Construction of the International Thermonuclear Experimental Reactor (ITER) starts in France; the reactor will be able to provide thermonuclear synthesis power. It uses the deuterium-tritium reaction: $D + T = n + {}^4He$ (+17.59 MeV).

The deuterium-helium-3 reaction, $D + {}^3He = p + {}^4He$ (+18.35 MeV), requires three times as high a temperature for plasma ignition as the deuterium-tritium reaction. Besides, deuterium reserves at the Earth are limitless, while helium-3 is practically unavailable. That is why the reaction involving helium-3 appeared to be of no practical interest.

However, the helium-3 reaction possesses one unique property that distinguishes it from most nuclear reaction and, in particular, from the deuterium-tritium reaction: it involves emission of protons (p) rather than neutrons (n). Now neutrons penetrate deep into surrounding structural materials, make them radioactive, and destroy them. That is why related structures have to be replaced once every few years, and radioactive waste buried. Protons do not penetrate deep inside structures, nor do they induce radioactivity. Basically it is a flow of hydrogen. Therefore, structural materials can be used for decades. The problem of radioactive waste burial does not arise. It is rather surprising that a nuclear reaction can involve virtually no radioactivity. There is a low-level radioactivity related to the secondary deuterium- deuterium reaction. However, on the whole, the reaction with helium-3 is 50 times less radioactive that the deuterium-tritium reaction.

During the last few decades, it became evident that we are at the verge of a major fuel and energy crisis. Reserves of raw hydrocarbons are drawing to an end and will probably be exhausted in several decades. The so-called alternative power sources: wind power, photoelectric cells, etc., — can only provide partial solutions. According to existing calculations, they will not be able to replace the hydrocarbon fuel in the Earth's energy balance. Besides, we have coal. It is believed that, at the present rate of mining operations, the available resources will last for about 200 or 300 years. The share of coal in the modern energy balance is about 20 %. If it rises up to 70 % with coal replacing the hydrocarbon materials, the resources of coal will also prove to last for a shorter time. Besides, it is a very environmentally unfriendly source of energy. The only other option is then nuclear power engineering based on uranium fission. According to our experience, however, it involves a terrible scourge: nuclear waste. Currently, nuclear power production amounts to 7 % of the energy balance but, if the entire power demand, which is moreover constantly growing, were to be shifted to nuclear power engineering, the mankind would sink in the nuclear waste.

Development of thermonuclear synthesis based on the helium-3 reaction, environmentally clean and efficient in many other respects, would provide a perfect solution. However, raw materials for this process are only available at the Moon.

Lunar reserves of helium-3 are enormous: they amount to about one million metric tons. That will be sufficient for more than a thousand years. Energy value of helium-3 is also immense: 1 ton of helium-3 replaces 20 million tons of oil, i.e. yields about 10 GW of power. Providing for power demand of the entire humanity will take 200 metric tons of helium-3 a year; current power consumption of Russia would take some 20...30 tons a year.

However, the helium-3 content in lunar soil (in the *regolith*) is very low, about 10 milligrams per metric ton. That means that some 20 billion tons of regolith will have to be penetrated each year, which is equivalent to an area of 30 by 100 km at a regolith layer thickness of 3 m.

Of course, processing billions of tons of lunar soil seems a fantastic enterprise. As of today, we consider delivering a few hundred kilograms to lunar orbit or to the surface of the Moon to be a great achievement.

What is needed, however, is to transfer almost all of the Earth's mining industry – its part that concerns raw fuel and energy materials – to the Moon. This process is bound to take several decades, but it has to be started now.

Presence of helium-3 at the Moon is a gift from the Nature. Let me draw the following comparison, which, I think, is rather graphic. It has been noted above that 1 metric ton of helium-3 yields as much energy release as 20 million tons of oil. The same statement can be expressed in a different way: 10 mg of helium-3 contained in one metric ton of lunar regolith roughly correspond to power output of 1 ton of oil. This is to say that the energy output of 1 ton of regolith matches that of the same amount of oil. That means that the regolith-covered surface of the Moon might as well be covered with an oil ocean. But this oil would be practically impossible to use. We cannot bring hundreds of millions of tons of cargo back from the Moon. Let us however imagine a genial engineer who says: I know how to transform 20 million tons of oil into one ton of matter, bring it back from the Moon (which does not constitute any problem), and then, down at the Earth, get the energy equivalent to 20 million tons of oil out of this single ton of matter. I believe that, should such an opportunity present itself, development of the project would already be well under way. But this is exactly the opportunity that presents itself in helium-3! The above precisely describe the concept of helium-3 production out of millions of tons of regolith, delivering a few tons of helium-3 back to the Earth, and producing energy, which is equivalent to the present-day resources of primary hydrocarbon materials at the Earth.

One may well ask whether the infrastructure of nuclear power engineering is now ready to consume and use helium-3. The answer is negative: as of today, such infrastructure is lacking implementation of controllable thermonuclear synthesis in its simplest version of deuterium-tritium reaction took over 50 years. The deuterium-helium-3 reaction requires much stricter conditions. On the other hand, one should not forget that, in these 50 years, we have learned how to control higher temperatures, starting from a few thousand degrees in the middle of the last century, up to hundreds of millions of degrees today. We have yet to make another, much shorter, step: to attain a controllable temperature three times higher. Note that modern technologies are quite beyond compare with what we had 50 years ago. A vast amount of experience in dealing with high-temperature plasma has been accumulated. Taking all this into account, can one hope for obtaining a controllable deuterium-helium-3 reaction within the nearest 20 or 30 years.

Actually, delivery of helium-3 from the Moon will not be necessary until 20 or 30 years later. But all required prospecting, exploration, testing, and other preparatory activities must be undertaken. At the initial stage, they might even be inscribed into the framework of general research work in the Moon. Suggested research projects include several high-priority tasks and, respectively, various methods for accomplishing them using spacecraft means. First of all, this concerns acquiring information on internal structure of the Moon as planned in *Luna-Glob* project. It involves using chemical and mineralogical interpretation of seismic data to acquire information on chemical structure of the lower mantle of the Moon, as well as to determine the size of the lunar core. The next top-priority task is to collect and bring back the lunar soil from the polar region.

Controlled collection of samples using lunokhods (lunar rovers) and delivering the accumulated collection back to the Earth may, in my opinion, eventually make a strategic basis of the unmanned form of Moon exploration. Automated lunar vehicles can also be used to develop a measurement network. Of course, the problem of internal structure of the Moon will not be completely covered by a single-time project using penetrators. The lunar vehicles positioning sensors along their routes will allow creating a long-term renewable seismic network that will in due time provide means for detailed in-depth seismic tomography of the Moon. The Moon's thermal flow and local magnetization levels also have to be studied.

Simultaneously, large surface areas have to be mapped with respect to their content in helium-3. A direct analysis of helium-3 concentration in lunar soil is difficult. There exist however indirect methods that allow estimating helium-3 availability to a sufficiently high precision.

The Moon has no atmosphere or magnetic field. That is why the lunar surface is continuously irradiated with a powerful flow of solar wind and micrometeorites. The solar wind is a flux of ions emitted by the Sun. These ions represented by nuclei of hydrogen, carbon, nitrogen, helium, etc. intrude into the minerals of the lunar soil. The longer regolith is exposed, i.e. the more mature the regolith is, the higher is the content of implanted elements, including helium-3. Solar wind is considerably rich in helium-3 isotope. The isotope composition of solar helium is $^3He/^4He \sim 3\times10^{-4}$, whereas for terrestrial helium, typical $^3He/^4He$ values range from 10^{-8} to 10^{-6}.

A characteristic feature of lunar soil lies in the presence of agglutinates. These are small-sized particles bound together with hardened melt (glass). Their formation results from fallout of micrometeorites. A high-velocity incoming micro-particle causes disintegration of regolith minerals and, simultaneously, impact melting. The melt captures micro-particles of the regolith and solidifies in the form of agglutinates. Concentration of agglutinates is a measure of maturity of the regolith. The longer the regolith is exposed, the more agglutinates it accumulates. Agglutinates contain the single-domain finely dispersed iron phase (Fe^0), which generates a ferromagnetic resonance signal. This, in its turn, can be used to estimate the content of elements implanted by solar wind into the regolith.

Size of regolith grains is of essence. Too large particles have a comparatively small surface area, while too small ones cannot retain helium. The optimum size is about 20...50 µm. Mineral composition of the grains is important, too. Helium is best accumulated in *ilmenite*, the mineral that contains titanium ($FeTiO_3$). There exists a distinct correlation between the content of iron and titanium and the helium-3 concentration in regolith.

All of these properties of regolith that allow estimating the value of soil with respect to helium-3 content can be determined using corresponding sensors and measuring devices installed aboard automated lunar vehicles. Iron and titanium content levels integrated over large surface areas can also be determined from measurements taken on orbital probes. In order to be able to calibrate orbit-based measurements, it is also essential to possess direct measurement data on these elements in the lunar soil, as provided by lunar vehicles.

Helium-3 prospecting is to be followed by experimental research on feasible technologies of helium-3 mining, isolation, and enrichment in lunar conditions, as well as by tests of lunar mining machines. This stage will probably require building lunar bases and direct involvement of men. Transition to this stage should be approximately planned for the year 2020. By this time, a reliable and efficient system ensuring transportation of personnel and cargo on the Earth-Moon route is to be developed.

However, the lunar helium will not be required before 2020 or 2030. It should be expected that by this date, the problem of industrial-scale controllable thermonuclear synthesis using helium-3 will be solved. No transportation of lunar helium will be necessary for experiments, not even for creating a sufficiently powerful experimental thermonuclear reactor. Some reserves of helium-3 isotope have been accumulated as a result of radioactive transformation of tritium used in thermonuclear weapons. That is why nations that possess thermonuclear weapons (Russia and the USA) have several hundreds of kilograms of helium-3 at their disposal.

It should be emphasized that development of lunar helium-3 will inevitably involve creating a number of other industries. Suffice it to say that the thermal processing of regolith (at 600...800 °C) involves, in addition to extraction of helium, separation of other elements, including hydrogen and carbon. These can be used to synthesize rocket fuel. It would not be difficult to develop oxygen production out of silicates and, therefore, to produce oxidant. The Moon is rich in titanium and native iron. That means that it possesses abundant primary materials for local metal manufacturing industry. In particular, metal structures and hulls of rocket ships can be manufactured directly at the Moon. Only some hi-tech elements will have to be delivered from the Earth. Water that is necessary for vital functions of the humans and for many technological processes will also be available to get at the Moon. Water resources might be contained in the polar areas. This issue is to be solved during the next few missions to the Moon. In particular, this is planned in *Luna-Glob* project.

The Moon constitutes the most cost-effective launching site for spacecraft. Developing production of fuel, oxidant, and structural parts for carrier rocket at the Moon will allow for large-scale exploration of the Solar system.

The Moon is the place where we can and must deploy for asteroid alert control systems, as well as those for monitoring and early prevention of catastrophic events at the Earth. Deep space monitoring systems are to be installed at the far side of the Moon, where they will be screened from radio interference coming from the Earth. No doubt, many other opportunities also exist that are just hard to imagine at present.

Traditional way of thinking, which considers the Moon as a remote astronomical object, has to be changed. The Moon is to be included in the economical cycle of the Earth. This is not a dream; this is a vital and unavoidable economical task that must be solved before the end of this century.

Space science and space industry are to be ready to this development of events.

Louis FRIEDMAN
USA

Co-founder and Executive Director of the Planetary Society (1980).

He received M.C. in Engineering Mechanics at the Cornell University in 1963, and a Ph.D. from the Aeronautics and Astronautics Department at the Massachusetts Institute of Technology in 1971.

Dr. Friedman worked at the AVCO Space Systems Division in 1963–1968. From 1970 to 1980 he worked on deep space missions at the Jet Propulsion Laboratory (JPL) in Pasadena, California. In 1979–1980 he originated and led the *International Halley Watch*. In 1978–1979, he was the AIAA Congressional Fellow on the staff of the Senate Committee on Commerce, Science and Transportation.

He is a member of the American Astronautical Society, the Division for Planetary Sciences of the American Astronomical Society, Sigma Xi and Fellow of the American Association for the Advancement of Science, the British Interplanetary Society and the American Institute of Aeronautics and Astronautics. He is a National Fellow member of the Explorers Club. He has written *Starsailing: Solar Sails and Interstellar Travel.*

REFLECTIONS ON THE 50TH ANNIVERSARY OF SPUTNIK

The legacy of *Sputnik* lies above all in its social and cultural impact. Sure, it began the space age, was a technological triumph, and launched the entire new field of space science — but that was already foreseen in the early and mid-1950's. And, sure, it demonstrated that the Soviet Union was a powerful nation, but nuclear weapons and intercontinental ballistic missiles had done that already. It was *Sputnik's* sudden and startling impact on the American psyche and on global politics that came as a complete surprise and created its true legacy.

Sputnik and the space missions that followed it are striking anomalies in the political landscape. They have little economic returns (at least on any practical time scale), no military value, and are minor part of national budgets and political discussion. And yet, the accomplishments of space missions are major world events, whose impact often dwarfs the other political events of the time. This was certainly the case with *Sputnik*, just as it was with the *Apollo* missions a decade later.

The cultural and political impact of space missions has been demonstrated many times since *Sputnik*: Yuri Gagarin's first human flight, the first spacecraft to the Moon, the first spacecraft to the planets, man walking on the Moon, the *Viking* landing on Mars, *Voyager's* journey to the end of the Solar system, the missions to Halley's comet, the *Hubble Space Telescope* and *Mir* and the International Space Station. All of these resonated around the world, captured the imagination of millions of people, and raised the international prestige of the countries who launched them.

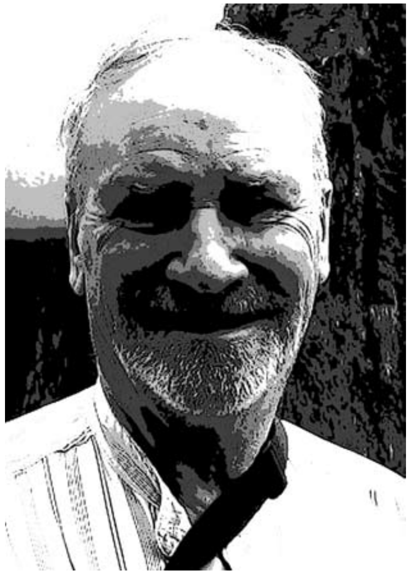
Sputnik and the missions that followed were, of course, the product of 'cold war' rivalry and nationalistic ambitions. Remarkably, however, they transcended these

roots to stand as symbols of human greatness, bringing out the best in us and offering hope for the future. The legacy of *Sputnik* is not Soviet might; it is a new era of human evolution beyond Earth. The legacy of *Apollo* is not its rockets; it is '*we came in peace for all mankind*'.

In the US *Sputnik* launched an education revolution, from which I personally benefited. President Eisenhower, while publicly downplaying the significance of *Sputnik*, initiated the National Defense Education Act to close the presumed dangerous education gap between American students and their Russian counterparts. This piece of legislation paid for much of my university education. In 1957 I enrolled at the University of Wisconsin, and a month later *Sputnik* was launched. The University immediately created its first space science course, taught by Werner Suomi. It may have been the first such course anywhere, and I was hooked. Space was the new frontier.

The link between space achievements and education continues to this day. It is an integral part of both the politics of space exploration and the scientific content of the missions themselves. Today, India and China are following in the footsteps of the Soviet Union and the United States by joining the ranks of spacefaring nations engaging in a new Moon race. The only reason they are doing this is that space exploration is a source of inspiration, a stimulus for education, and a spur for economic and technological growth.

The most amazing aspect of *Sputnik* is that it launched a great battle of the long and frightening 'cold war' — and that that battle was a peaceful one. The space race was a rivalry that gave the nations involved confidence, and provided inspiration for their young people to pursue excellence and high achievement. The 'cold war' has since come to an end, and the world is now a very different place. And yet — the vision of the space age that humankind can use its technology for peace and a better future remains. It reminds us that we can go to Mars, we can stop the environmental destruction, and we can use technology to improve life, not to destroy it. Confidence and inspiration are the legacies of *Sputnik*.



Gordon G. SHEPHERD
CANADA

Distinguished Research Professor at the York University, Toronto, Canada and Director of its Centre for Research in Earth and Space Science.

Member of the Committee on Space Research (COSPAR) Bureau.

He earned his B.Sc. and M.Sc. Degrees from the University of Saskatchewan and his Ph.D. from the University of Toronto.

As faculty member at the University of Saskatchewan (1957–1969) he developed rocket and ground-based methods of interferometric spectroscopy applied to the aurora and airglow. At the York University (from 1969) his satellite measurements began with the Canadian ISIS-II, from which he mapped the distribution of atomic oxygen red line emission at 630 nm. In 1991 NASA's UARS satellite was launched, carrying a WIND Imaging Interferometer (WINDII) for which Shepherd was the Principal Investigator.

In 2002 published *Spectral Imaging of the Atmosphere.*

REFLECTIONS ON THE 50 YEARS OF SPACE ERA

In 1957 I was appointed Assistant Professor at the University of Saskatchewan in Saskatoon, in the Western prairies of Canada. I had barely began teaching in September when *Sputnik-1* was launched. Fortunately we had some people with radio skills in the institute and soon we were all listening to the 'Sounds of Sputnik'. Because none of us were experienced in visualizing satellite orbits the head of our machine shop added an arm to a globe of the Earth, carrying a satellite, driven by a motor. We tried to get it synchronized to the actual motion of *Sputnik*. It was clear that my career and the space age were beginning together, although I couldn't see as yet how that would be accomplished. The following summer, after the larger *Sputniks* were launched, I assigned my first summer student (John Nilson) the job of photographing the tracks. He installed a rotating chopper in from of a fast camera to cut the track into one-second segments, every fifth one longer than the others. The chopper operated a clicker and he synchronized the clicks to the clicks of WWV radio station so that accurate times could be identified on the photograph. We received predictions of observations from Moscow by telegram and sent our observations back the same way. These were my first satellite measurements.

Our world view has become much more global since then. Although we still live in countries, their activities are much more closely coordinated, through agreements, collaborations, and common problems such as global warming. At the same time the space age has made technical demands that have reaped dividends in many other areas, some quite remote from space. In return, our science has benefited enormously from data that could have been achieved in no other way. To accomplish satellite missions, it is often necessary to have international collaborations, certainly for Canada, which does not have launch capability. Thus I was able in 1971 to launch a Red Line

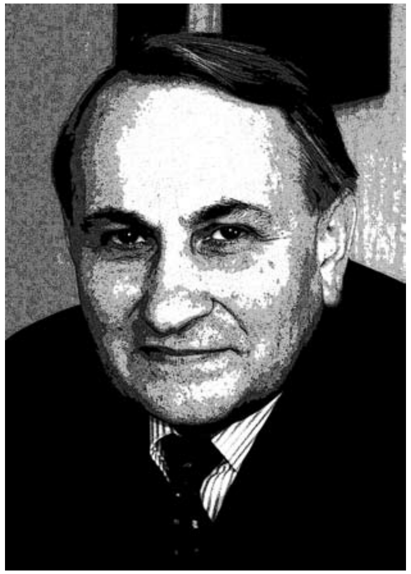
EVENT HORIZON

Photometer into space on the ISIS-II (International Satellites for Ionospheric Studies) to observe the atomic oxygen red line aurora and airglow only because there was an international collaboration. As to conditions of life, we are all concerned that life on Earth may become more difficult as our climate changes, especially in the Canadian Arctic. We absolutely need satellite capability in order to monitor the Earth and deal with this problem. In this sense, spacecraft will influence our life on Earth. While I work in the scientific world, I often meet those outside it who are 'space people'. Space is important in their thinking and has become part of their culture.

What have we gained and lost from space research? All new knowledge is a gain, as is new technology. GNSS satellites, communication satellites, images of my house from space on the Internet, information at my fingertips, all of this is a tremendous gain. However, there are some dark shadows. Unfortunately a great deal of impetus for the space age came from the race to build intercontinental ballistic missiles. Happily that period has passed, and space scientists perhaps helped with that. Many of those vehicles are being put to better use, for science. But there is another cloud on the horizon, and that is the placement of weapons in space. Let us hope that this period passes without ever being implemented.

Generally speaking, space remains an expensive activity. Most countries have many more scientists and other users available to make use of space than there is capacity to launch their space concepts and instruments. Collaboration is traditionally a way to share the data among more people and to make better use of it. My second space experiment came with the Wind Imaging Interferometer (WINDII) on NASA's *Upper Atmosphere Research Satellite*, launched in 1991, 20 years after my first experiment. This was an expensive experiment, but it produced wonderful data. We obtained an airglow emission rate and wind profile every minute, and over the experiment lifetime about one million profiles. Each one was the equivalent of what could be obtained with a rocket measurement, which are also fairly expensive, say one million dollars per flight. So the satellite produced a million million dollars worth of data, at much less cost than that. However, our technology now offers the possibility of smaller and less expensive ways to make measurements in space. This will make space measurements available to more and more people.

While space scientists are all users of space data, they are not the only users. The global population, even anyone connected to the Internet is a user. This can be a telephone user, a television watcher, someone using a GNSS receiver to find their location, or using satellite images to view a location for a holiday, or some other reason. It can simply be a person taking advantage of a weather forecast. The trend will be for more and more people to use more and more space information, in various forms. But everyday people relate to space in many other ways – we mentioned the space culture above. Humankind follows with great interest the exploration of space as well as its everyday use. Space endeavours will continue to bring humankind together in this way. All of this we owe to the remarkable achievement of *Sputnik-1*.



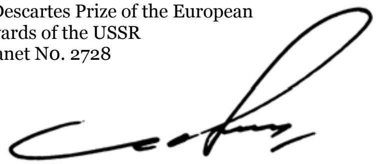
Yaroslav YATSKIV
UKRAINE

Director of the Chief Astronomical Observatory (the National Academy of Sciences of Ukraine) since 1975. Doctor of Science. Academician of the National Academy of Sciences of Ukraine. Specialist in astronomy, geodynamics and space research.

Fellow researcher of several space missions in the USSR (*Vega*, *Mars*) and in Ukraine (*Coronas*). One of the originators of the Ukrainian National Space Agency, Deputy Chairman of the Space Research Commission (the National Academy of Sciences of Ukraine). Vice-President of the European Astronomy Society. Member of the National Academy of Sciences of Poland. Member of the International Academy of Astronautics.

Born in 1940. Graduated from the Lviv University of Technology in 1960. Was elected vice-president of the International Astronomical Union (1982–1988), president of the IAU Commission No. 19 'Earth Rotation' (1982–1985).

Awarded by the Rene Descartes Prize of the European Union (2003), state awards of the USSR and Ukraine. Minor planet No. 2728 is named Yatskiv.



FIRST STEPS OF THE INTERNATIONAL COLLABORATION IN THE PEACEFUL RESEARCH AND EXPLORATION OF SPACE (1957–1987)

On the October 4, 1957, the whole world was stunned by the signals from the first artificial Earth satellite.* The new age of our planet's life has started, with space being the essential part of this life. From this day on, our understanding of the *world* as an environment of human civilization and *peace*** as a form of co-existence of different states, nations and peoples has drastically changed.

In the years that followed the problems of space research and exploration have widely developed, covering literally all the aspects of human activity. Depending on the goals, space experiments can be divided into three following groups: scientific, commercial and military ones. In their turn, each group covers a large number of areas, among those Earth studies, exploration of the Solar system and other astronomical objects by space techniques and facilities have, in our opinion, written the brightest pages to the space chronicle of the last decades.

* Based on the article by *Yatskiv. Ya.S.*, *West R.* Milestones of Space Age // Essays on History of Natural science and Technology. Kiev, 1987. V. 33. P. 30–42 (in Russian).

** Untranslatable: both 'world' and 'peace' in Russian are pronounced and written as 'Mir'.

The profits of the scientific and technical collaboration which has no national or interdisciplinary borders become more and more obvious. Many space projects have become so high-priced that individual states are now facing the difficulties in accommodating the related expense items with their budget. Mankind looks with understanding at the positive experience of collaboration which was and still is taking place among the scientists of many countries in different areas of science, for instance, in Antarctic research.

International collaboration in the area of space research appeared simultaneously with the beginning of human activity in this field. Though it was developing at varying pace in different periods of time, today one can witness unprecedented shift towards the more close cooperation. This tendency, without doubts, must prevail in future. We will try to illustrate this using examples from the history of research during the first three decades of the space age.

We belong to the generation which witnessed the epoch of the drastic changes in the evolution of mankind. Our childhood was passing during the most cruel war which came to end only after taking away tens of millions lives and destroying countless valuables. This catastrophe gave an impulse to the attempts of achieving the global international understanding which has been reflected in the historical documents of post-war years such as Charter of the United Nations.

Due to these and other reasons our generation has also had luck of living in the period of relative 'warming' of international climate. A very important role in that has been played by the international communication, and to even more extent, consciousness of common fate in this world of diminishing distances and limited resources. During this time living conditions of the people in all parts of world have improved, but at the same time we have fallen into dependence of various nonhuman technical inventions of mankind never seen before. Whether we like it or not, we cannot get rid of them yet.

It is too easy to forget the fact that many technological advances have arisen from the military research of the World War-II. Atomic facilities and PC, long-range rockets are the flesh of flesh of those terrible years. Of course, small rockets were known since a long time ago. However the crucial knowledge of how to launch heavy rockets to the distances of hundred kilometers has been only gained by the end of war. Similar to many inventions of mankind, rockets may have both positive and negative applications. One can splash the sky with the wonderful lights of fireworks on holidays, but one can open fire on peaceful cities. One can arrange the service for searching the ships in distress, but one can also break the walls of fortified structures. One can launch communication satellites and research spacecraft and deliver the nuclear warheads to other continent within a few minutes.

When the International Geophysical Year (IGY) under the auspices of the International Council of Scientific Unions (ICSU) has started in the middle of 1957, a flight to space was still merely a theoretical possibility. But just three months later the entire world was literally waken up by the signals of *Sputnik*, the first artificial Earth satellite. Like many millions of people, we were carefully watching the bright dot moving in the night sky which was soon followed by the others.

From the memories of the author:

Being the students of astronomy-geodetic specialty, my course mates and I didn't at once realized what a powerful tool of global Earth studies was being born before our very eyes. We were more concerned by the problems of zero gravity, supersonic velocities and other prerogatives of space flight. It was only in the end of 1950's that I understood what unprecedented perspectives we are given by looking at the Earth from above, covering with one glance the spaces which seemed huge before.

And what next? Other planets and worlds... Curious!

Probably this 'curiosity' was reflecting that constant striving to knowledge which inspires a human to get interested in the origin of the world around us and how it has evolved to the state we see it now. What are the constituent parts of Universe and what will happen to them in future? These are fundamental problems of the modern natural science, and the space research is making a strong contribution to solving them.

BASIC MILESTONES OF THE SPACE AGE

1957–1960

Since the very first days of the space age more than 200 stations of optical observations of artificial Earth satellites (AES) in 20 countries started their hard but exciting work. The main goal of these observations was not to lose the first messengers of Earth in the endless space.

Unlike the usual celestial bodies which are available for observing either in the day (the Sun) or in the night (stars, planets), satellites can only be seen during the short evening or morning hours when the surface of Earth has fallen in darkness while the satellite itself, being at a large height, is still sunlit. These observations performed in the different places of the globe allow to calculate the ephemeris of satellite, i.e. its position at any given moment of time*.

It turned out that the study of satellites motion and their orbit evolution allows to solve a number of important tasks in geodesy and geophysics on setting up the systems of coordinates, studying the Earth gravity field and so on. The visual and photographic satellite observations have been replaced with time by high-precision laser range measurements of satellites as well as their radiointerferometric observations.

Reflecting the global nature of the problem, the international collaboration in the framework of International Astronomical Union (IAU), International Association of Geodesy (IAG) and International Committee on Space Research (COSPAR) was developing more or less successfully during all these years.

The special attention has been paid to the research of the Moon and data exchange between the USSR and the USA on lunar projects.

On the other hand the 'space race' has started in late 1960's, and based on national prestige and military interests there was no sufficient collaboration of two great spacefaring nations, at least in the field of delivering the payload to orbit. However, the results of many measurements in space became widely known soon, in particular due to the regular contacts via COSPAR founded in 1958, International Astronautical Federation (IAF) and other scientific unions. It has to be noted however that there was indirect collaboration. The implied competition in space was inducing the inflow of man power and technical resources to the national space programs of the USSR

* In order to coordinate this work, the unique *Satellite Service* was created in 1956 according to the IGY program.

and the USA. This is why even the West European countries felt the need in the development of their own independent space projects.

1961–1984

And then the voice belonging to the first cosmonaut of the USSR Yu.A. Gagarin which we have heard on radio on April 12, 1961 has announced the start of the manned space exploration.

He has flown over the globe in less than 2 hours and safely landed on the territory of his native country.

From the memories of the author:

I have never seen such an overall jubilation in my life. The charming Gagarin's smile, his words 'Poyekhali!*' at the start, his thoughts of the Earth being so incredibly beautiful and tiny and that we should take care of it, became the symbols of our country in the 1960's.

The immediate result of the first manned flight in 1961 was the decision of the USA to start one of the most ambitious scientific-technical programs ever undertaken. The American president has declared that '*we will fly to the Moon in this decade*' and mobilized huge national resources comparable only to the expenses on the Manhattan project. The improved space 'capsules' were built; one-man *Mercury* spacecraft were followed by *Gemini* and *Apollo* S/C intended for two and three astronauts respectively. The flight control methods were developed.

During these years in the USSR the new records of flight duration were set and the first extravehicular activity of cosmonaut A.A. Leonov was performed.

And here came the morning of July 21, 1969 (in Europe) when the voice of the first man to step on the other celestial body — the Moon, arrived to Earth after traveling almost 400 thousand kilometers . This voice belonged to the USA citizen, astronaut Neil Armstrong. That was the new giant leap in the space exploration.

From the memories of the author:

This news – fantastic in its content, was just like a sobering cold shower. It became clear that the USSR has lost the space race to the Moon.

As a result of *Apollo* S/C flights a number of laboratories in the whole world have received the rich material and the possibility to study the samples of lunar rocks directly. And a little later, when the USSR has accomplished the landing of three automated stations on our natural satellite and delivered to Earth another set of smaller specimens, the exchange of lunar samples was made which allowed to perform a detailed comparative analysis of rocks from the vast territory.

In the same time an intensive operation of cosmonauts and astronauts on the Earth orbital routes continued. And, finally, in July, 1975 the American and Soviet crews have met on orbit in the joint *Soyuz-Apollo* flight. Besides collecting scientific information, the flight has shown the compatibility of the space rescue facilities. This activity became the practical realization of the UN Agreement on astronauts search and return of people and space objects which came into effect on 1968. This important Agreement was a consecutive realization of UN *Outer Space Treaty* of 1967**, the first basic international document regulating the use of space.

* It may be translated as 'Let's go!'

** Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies.

Meanwhile the research of Solar system by the unmanned spacecraft has reached the impressive results. The next target after the Moon was Venus which is often referred to as 'Russian' in the West meaning the fact that the USSR has sent 18 automated stations (including two *Vegas* S/C) to study of the Morning star planet.

Wide range studies of Solar system bodies were performed by the American spacecraft of *Mariner* series. Full range study of Mars took place in 1976 when American orbital stations *Viking-1* and *-2* have studied the whole surface and the landing stages have made detailed investigation of the soil.

The giant planets were fully studied by *Voyager* S/C in 1979–1981. Stations of *Pioneer* and *Voyager* type were the first artificial objects leaving the Solar system, this is why they are bringing aboard the plates with the coded information about our Earth civilization.

A wide scientific information obtained during these experiments allowed to set up a principally new level of research of Solar system origin and evolution and has resulted in the birth of new field of science — comparative planetology. This information, thanks to the international cooperation of scientists, was the issue of the mutual exchange and discussing at many forums.

1985–1986

What so special has happened in these years which allowed us to highlight them on the background of decades of diligent work in space research? These were the years when the calls for peaceful space have sounded from the heads of governments, workers of science and culture and all sober-minded people as never before. The unique collaboration on the study of the famous comet Halley has put these calls into life, and the idea of peaceful space research was undoubtedly prevailing over the various finesses of the 'star wars' kind.

On the basis of precise measurements it was predicted that comet Halley will return again to Earth and the Sun in 1985–1986. It is interesting that there were already attempts to coordinate all observations of the comet in 1910 (the year of the previous return of the comet to the Sun). But they did not have a success since many astronomical observatories were then unable to agree on the issues of rights on the data obtained and there were no relevant councils and unions. In order to avoid similar misconceptions for this time, the debates has started yet in late 1970's on establishing the international body which would coordinate observations of the new comet Halley apparition. As a result the *International Halley Watch* (IHW) organization was created approved by the International Astronomical Union (IAU) in August, 1982. It was based on two directing centers — in Pasadena (USA) and Bamberg (BRD). The Soviet program of ground-based comet Halley observations (SOPROG) was the regional part of IHW. More than 1000 professional and amateur astronomers from 54 countries participated in IHW. The comet was recovered with the 5-m Palomar telescope on October 16, 1982, far beyond the orbit of Saturn. By this time the comet was very faint having 24.5 magnitude which is 25 million times fainter than the object visible by the naked eye.

In 1983–1986 comet was already regularly observed from Earth, except for the period of time when it was hidden from us by the Sun. As it was approaching the Sun and brightening, more and more telescopes and other facilities were joining the program. No other comet was studied so thoroughly before.

With arrival of the space age and after the first successful flights to other planets the ideas of 1960's about the future flights to comets have turned into something a matter of course. It was clear since the very beginning that it would be good to coordinate space research in a way similar to what IHW has done with the ground based observers and that close cooperation is needed between these two ways of research of the celestial body. Four agencies having planned the spacecraft flights decided to create the Inter-Agency Consultative Group (IACG) consisting of administrative and scientific members. Thus in 1981 the direct cooperation was established between the European Space Agency (ESA), *Intercosmos*, Japanese Institute of Space and Astronautical Science (ISAS) and NASA for the first time. The first meeting of IACG was held in Padua (Italy).

The first spacecraft to reach the comet was *International Comet Explorer* (ICE, NASA) which flew through the tail of periodic comet Giacobini-Zinner on September 11, 1985. This spacecraft was used before to monitor the plasma conditions in the Earth atmosphere and later sent to the rendezvous with comet Halley. A series of witty manoeuvres was performed which included fly-by within only a few kilometers from lunar surface. After sending the data of cometary plasma and magnetic field measurements to Earth, ICE spacecraft has continued its journey to space and passed within 28 mln km from comet Halley on March 25, 1986. Japanese spacecraft *Suisei* ('comet') and *Sakigake* ('pioneer') flew by comet Halley on March 8th and 11th respectively and measured its interaction with the solar wind. Due to the strict mass limits they were not equipped by the protective shields from the destructive impact of the space dust as *Vega* and *Giotto* had and were studying the comet from the large distance.

The most complicated of five space projects was *Venera-Galley* mission, or VEGA for short with the participation of the USSR along with a number of socialistic and Western European countries. R. Sagdeev was the Head of the project.

According to this project, two spacecraft one after another headed first towards Venus, left balloons in its atmosphere and landers on its surface, and after making a journey about one billion kilometers long have encountered with comet Halley. According to flight plan this encounter should have taken place at the distance of 150 mln km from Earth and about 10 thousand kilometers from the comet nucleus at the relative flyby velocity of about 80 km/s. Performing this task required to join the efforts of many world observatories on determination of comet Halley's coordinates and calculating its ephemeris. More than 30 observation stations in the USSR participated in this program headed by the Chief Astronomical Observatory of Ukrainian Academy of Sciences in the framework of SOPROG. The task was completed: *Vega-1* and *Vega-2* flew by the nucleus of comet at the distances of about 9 and 8 thousand kilometers respectively. The information on the position of comet obtained with *Vega* spacecraft (precision about ±50 km) together with the measurements of positions of spacecraft themselves received from the Deep Space Network (USA) with a record-breaking accuracy of ±40 km have served as the base for yet another unique project *Pathfinder*. The theoretical justification of the project was given in the frames of IACG, and it was realized at ESA while controlling *Giotto* spacecraft.

As a result of the close interaction during the days when both *Vegas* were nearby the comet, ESA specialists got a chance to aim *Giotto* with unprecedented accuracy ±50 km, i.e. 10 times better than if using only ground-based observations for navigation. Indeed, *Giotto* has passed only within ±15 km from the calculated point, i.e. at the distance of only about 600 km from the cometary nucleus. This wonderful feat would have been impossible without cooperation between NASA, *Intercosmos* and ESA within Pathfinder project.

Eyewitness report:

I had a luck to witness the thrilling minutes of *Vega-1* encounter with comet Halley. During these historical days the Space Research Institute of the USSR Academy of Sciences has hosted well-known scientists from many foreign countries. Among them were such remarkable astronomers as F. Whipple – the biggest cometologist, author of the icy model of cometary nucleus, planetary researchers C. Sagan, V.I. Moroz, M.Ya. Marov, IHW managers Jürgen Rahe, J. Brandt and others.

The live broadcasts from space started on March 4 when *Vega-1* was at the distance of 14 mln km from the nucleus of comet – the images of coma with the brightness distribution in pseudocolors have arrived, data of the interplanetary medium and solar wind conditions were received. On March 5 the broadcast was performed already from 7 mln km. But the nucleus was still rather far to be able to distinguish its contours. One could only see that the central part of coma where the cometary nucleus resides was the brightest. These broadcasts have shown the operability of the whole equipment and allowed to select its optimal mode of operation.

But here came the decisive moment when the pioneering spacecraft entered the head of comet Halley and its instruments came into direct contact with the cometary matter, and the main camera of 120 cm focal length started to take pictures of the inner parts of comet's head residing inside the very gas-and-dust atmosphere of comet.

'*We've got the nucleus of comet Halley*,' — comments the deputy head of VEGA project professor A.A. Galeev.

A year after the comet rendezvous when it was quickly receding to the far space everybody was agreeing that the international cooperation had a huge success. Close contacts at the meetings and specially developed communication channels allowed the quick information exchange with the mutual profit. There appeared a possibility to increase the scientific return of several experiments due to knowledge obtained by other researchers. International cooperation has helped the scientists and specialists to know each other better and, which is of no less importance, collaborating sides had to smooth down 'sharp edges' to reach the effective result.

PERSPECTIVES OF THE INTERNATIONAL COLLABORATION IS THE AREA OF SPACE RESEARCH

A huge number of satellites and spacecraft were performing different tasks during the first decades of space age. Communication satellites were providing operation for thousands of telephone and television channels; meteosatellites were transmitting an endless flow of detailed images permitting weather forecasts better than before. Other satellites studied oceans and continents, meanwhile providing a terrific amount of the necessary information ranging from geological resources maps to agricultural maps, from the maps of growing towns to maps of oceanic streams and ice clustering in the seas. Some satellites served for navigation purposes and allowed to locate objects with an accuracy of a few meters, in any point on the Earth surface.

As more and more countries got involved into space research and developed their own programs, the experience in space technology is not a privilege of a few nations

anymore. Several countries in addition to two first spacefaring nations have now developed their space programs.

All this is influencing the forecasts of the future peaceful cooperation in space which will enter its higher level, supposing of course there will be no global catastrophes. From this point of view the political atmosphere on the planet and people's will to avoid arms race in space are getting the high importance.

Space research is an important and very impressive part of science including the natural development of Earth studies started by the previous generations of people. As the experience with comet Halley has shown, a few other fields of science are having such a direct impact on everybody's imagination. And if you are witnessing the fruitful, really international cooperation up there in space, don't you feel inside the desire to find the common language here, on Earth?!

SPACE: THE FIRST STEP

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