S N Vernov (left) with Academician G B Khristiansen.

S N Vernov (left) with Academician B M Pontecorvo.

S N Vernov's name belongs to the pantheon of scientists who symbolize the pride and glory of the physical science in this country and of the Russian Academy of Sciences and its Physical Sciences Division.

Studying the heritage of the research work of S N Vernov and his students is a good school for young generations of scientists who seek to leave their mark on modern science as it strives to achieve understanding of the fundamental laws of the Universe.

Included in this article are photographs taken by Yu A Tumanov, D V Bobkov, and A T Abrosimov, and also photographs received from the family archive of E S Vernova.

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S N Vernov as a Moscow University scientist

V A Sadovnichy

The date 11 July 2010 marks the 100th anniversary of the birth of Academician Sergei Nikolaevich Vernov — the scientist of world renown, Hero of Socialist Labor, recipient of the USSR Lenin and State Prizes, one of the founders of the Research Institute for Nuclear Physics (RINP) [now renamed as D V Skobeltsyn Institute of Nuclear Physics (SINP)] of Moscow State University and then its Director from 1960 till 1982, and Head of the Nuclear Physics Division at the Department of Physics of the M V Lomonosov Moscow State University. The name of S N Vernov marks grandiose achievements of this country in the implementation of the Soviet Atomic project, in space exploration, in gaining knowledge of the fundamental properties of matter.

In the second half of the 20th century, nuclear physics, space physics, and high-energy physics took a giant jump to an enormously higher qualitative level. This was reflected in the birth of many other scientific and technological fields. It was a renaissance of fundamental and applied research throughout the world, especially in this country. Sergei Nikolaevich Vernov proved to be just the person that the State and Moscow State University needed at that very moment. To quote a metaphoric comparison made by Georgii Borisovich Khristiansen, he acted for more than 25 years as an outstanding conductor of research on the structure of matter and space physics. It was to a large extent owing to S N Vernov that Moscow State University continues to show great achievements in these fields of science.

S N Vernov, in his capacity of RINP Deputy Director from 1946 till 1960, and RINP Director from 1960 till 1982, made a huge contribution, alongside D V Skobeltsyn, to the creation and further evolution of this Institute and of the Nuclear Physics Division at the MSU Department of Physics and to training the personnel for the Soviet Atomic project and for space research.

It was in the years of S N Vernov's work at Moscow State University that space research using artificial satellites (sputniks) and space rockets was born and then grew in volume and stature. Direct contacts between S N Vernov

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and S P Korolev, Chief Designer of Soviet missiles, were established already in 1947, and in 1956 MSU RINP was added to the list of research institutes invited to take part in scientific experiments on sputniks. S N Vernov became a scientific leader of the program of cosmic ray research on artificial Earth satellites.

The first meeting with the designers of the future satellite finalized the specification data for our instruments (gas-discharge counters were supposed to be used as radiation detectors): weight of the instrument — not more than 2.5 kg; energy consumption — 2 W and telemetry through a single 'dry' channel with a frequency 50 Hz.

Gas-discharge counters in the instruments were coupled to recording electronics, for which one of the following three options was available at the time: low-power electron tubes, thyratrons with unheated cathodes, or semiconductor elements. Electron tubes were rejected immediately because of their high power consumption. Huge effort was spent on developing thyratrons with unheated cathodes: even a prototype device with acceptable weight and power consumption was assembled, but it proved absolutely impractical because of the unstable operation of thyratrons. The only way out was to use semiconductor elements.

It should be noted that semiconductor technology, which at that time (1957) was only emerging, was almost unknown to experimentalists. This only intensified Sergei Nikolaevich's insistence that thyratrons be replaced with semiconductor diodes and triodes. His expectations were fully justified: the semiconductor circuits were stable and operated reliably in a wide range of temperatures and withstood vibrations excellently. The Fizpribor plant manufactured the instruments and they were ready to travel into space. The only operation to conduct now was to test them for the length of service life. Suffice it to mention that the radiation recording instrument designed in 1957 at RINP was then used on sputniks for more than 25 years and earned very high reputation. Even today, one can find the circuits assembled for that launch and discover that they are perfectly functional.

On 4 October 1957, the world learnt that the USSR had launched the first-ever artificial Earth satellite. As the date of the launch of the first sputnik was kept top secret, the launch-ready instruments designed and built under Vernov's supervision were not installed and stayed behind. Just imagine what Sergei Nikolaevich would have felt: the sputnik carried 50 kilos of batteries but was only capable of sending the 'I am alive' signal — 'beep-beep-beep' — while RINP had on the table a ready instrument weighing only 2.5 kg left unused on the ground!

The situation changed drastically after 4 October. Already the second sputnik launched on 3 November 1957 carried two gas-discharge counters with semiconductor electronics, built at MSU RINP and intended for recording cosmic radiation. Cosmic-ray intensity was measured for the first time at altitudes never reached before, and a significant increase in the intensity of the detected particles was observed at high latitudes (Fig. 1). On 15 May 1958, the third Soviet sputnik was launched, and it also had instruments built at MSU RINP. As a result, S N Vernov and his team finally established the existence of two Earth's radiation belts: the inner belt, discovered by American scientists in February–March 1958 utilizing the equipment installed on the Explorer satellite, and an outer belt discovered by MSU scientists in July 1958. In 1960, S N Vernov and A E Chudakov were awarded the Lenin Prize for the discovery of Earth's outer radiation belt.

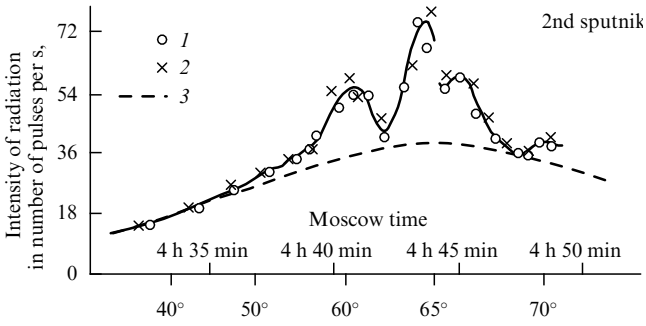

Figure 1. Data on cosmic radiation recorded on the 2nd sputnik during one of the passages over northern areas of the USSR: dashed curve — the mean values, circles — readings of instrument No. *1*, × — readings of instrument No. *2*.

The investigation of radiation belts was unfolding in an atmosphere of very intense competition against American scientists, and within a very short time interval — the interval between the launches of the second and third artificial Earth satellites was a mere six months! This made the recognition of the scientific merits of MSU RINP and S N Vernov for the discovery and interpretation of radiation belts all the more commendable. In summer 1959, an International Conference on Cosmic Ray Physics was convened at Moscow State University. The audience included many foreign scientists, among them a representative American delegation. The scientific achievements of Soviet scientists were reported to this conference by S N Vernov. The report that caused maximum interest was S N Vernov's talk on the mission of automatic space station Luna-1, which realized the world's first contact of a recording instrument (again built at RINP) with the lunar surface.

In 1957–1982, S N Vernov supervised at MSU RINP the design, manufacturing, and launching of instruments which were installed on 140 sputniks and space rockets. By now this number has risen to 400. As a result, S N Vernov and the staff of the Institute were able to make an important contribution to studying various phenomena in extraterrestrial space (radiation belts, magnetospheres of Earth and other planets, auroras, galactic and solar cosmic rays, anomalous component of cosmic rays, active processes on the Sun and in the heliosphere, etc.).

Diploma of the Lenin Prize Laureate delivered to S N Vernov.

S N Vernov (4th from the left) with participants in the International Conference on Cosmic Rays at Moscow State University (1959).

A man of boundless energy, enthusiastic about all science, faithful to science without limits, S N Vernov possessed a keen sense of the new in science, having the rare ability of never letting the goal drift out of his sight. His talent and his assertive, determined character helped to launch projects on many fronts, not directly connected with research on the artificial Earth satellites: stratospheric research; the study of extensive air showers (EAS); dosimetric measurements in space which founded a new branch of science — space radiometry, and work on space materials and high-energy physics research. We wish to highlight his efforts to expand high-energy physics research at MSU RINP: a new building for the Institute, the creation of a unique photographic-plate-viewing center in it, the promotion of scientific links with the largest research centers abroad possessing high-energy accelerators and providing viewing material to MSU RINP. As a result, Moscow State University has obtained important scientific results in high-energy physics, including the recent discovery of the top quark. These results are recognized by the world's scientific community and define the key positions occupied by the University in the study of the fundamental properties of matter on prestigious international projects carried out in such scientific centers as CERN (Geneva, Switzerland), KEK (Tsukuba, Japan), Fermi National Accelerator Laboratory (FNAL) (Chicago, USA), Thomas Jefferson National Accelerator Facility (TJNAF) (Newport News, USA), as well as research centers in Germany, namely DESY (Hamburg) and FAIR (Darmstadt), at the National Institute of Nuclear Physics (INFN) (Genoa, Italy), Joint Institute for Nuclear Research (JINR) (Dubna, Russia), Institute of High Energy Physics (Protvino, Russia), and other very large research centers (Fig. 2). In 2009, the Large Hadron Collider (LHC) started operating at CERN. This is the grandest integrated research facility in the world. MSU — one of the leading universities in the world — is participating in this unique scientific project of the 21st century in three key experiments: CMS (Compact Muon Solenoid), ATLAS (A Toroidal LHC ApparatuS), and LHCb (Large Hadron Collider beauty experiment).

Sergei Nikolaevich was an exceptionally bright person: this was obvious in everything he undertook. He was a master of conjuring a creative atmosphere around himself, and of mobilizing large teams of researchers for addressing the most important tasks. We, his colleagues, were always in awe of his ability to concentrate spiritual and physical efforts on the most important task. This approach never failed to bear fruit. Many programs that he initiated and supervised would result in discoveries of new phenomena and new physical laws.

One of Sergei Nikolaevich's main characteristics was his insistent wish to closely link the solution of fundamental problems of science and urgent practical tasks. Priority discoveries made by S N Vernov and his students allowed MSU RINP to obtain most important methodological and technological results. Many of these results are now employed as domestic and international standards for describing the space environment and its effects on space vehicles. This is very important for developing criteria for radiation safety of space flights.

Instruments for monitoring radiation in Earth's neighborhood which were designed and then mass-produced at RINP were installed on the International Space Station, many satellites of the GLONASS (Global Navigation Satellite System), and on special-purpose satellites.

The laboratories of MSU RINP designed and manufactured flight kits of scientific instruments for the Russian–Indian University sputnik YouthSat, for the experimental programs TUS (Treck Facility), RELEK, and NUKLON included in the Russian Federal Space Program and aimed at studying the precipitation of magnetospheric electrons, and ultrahigh-energy cosmic rays.

S N Vernov's students and followers built unique world-class ground-based facilities to study the highest-energy cosmic rays (Tunka-133, MSU EAS). They created a new field of research: space materials science. Fundamental knowledge was obtained about the behavior of materials under space conditions, methods of their protection against

Figure 2. International relations of MSU RINP in high-energy physics research.

Sergei Nikolaevich Vernov at the International Conference on Cosmic Rays (Dhampur, India, 1963).

adverse effects of the space environment, and technologies for developing advanced materials for space applications, including nanomaterials.

These days MSU is accomplishing a breakthrough to the future by implementing the development program undertaken on the instructions of the President and the Government of the Russian Federation for 2010–2020. One of the most important breakthrough directions of this program is the integrated research named as the 'Investigation of the structure of matter and space, and application of space technologies.'

Now, nearly fifty years after our first steps into space, the first Universitetskii-Tatiyana sputnik was built at RINP with the assistance of the MSU Department of Mechanics and Mathematics. Its launch on 21 January 2005 marked the 250th anniversary of the founding of Moscow State University. Unique information on the physics of transient airglow in Earth's upper atmosphere (Fig. 3) has been collected over the two years of the satellite's time in orbit in the course of observation of solar activity. The next satellite, Universitetskii-Tatiyana-2, was launched on 17 September 2009. The separation of the third stage of the booster rocket was for the first time observable in real time by the robot telescope of the MASTER system (Mobile Automated System of TElescope Robots) developed by scientists of the MSU P K Shternberg State Astronomical Institute and the Moscow association Optika; the unique characteristics of MASTER robots exceed those of western analogs (Fig. 4).

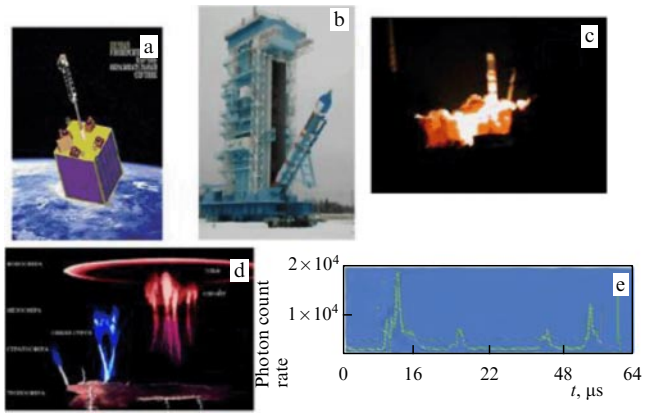

Figure 3. The first Moscow State University sputnik, Universitetskii-Tatiyana, launched on 21 January 2005 from the Plesetsk launch pad: (a) general view, (b) booster rocket being prepared for the start, (c) launch, (d) possible transient emission in the stratosphere of Earth, and (e) flashes of radiation recorded by the satellite's instruments.

The next to fly will be the satellite Mikhailo Lomonosov, on the date marking the 300th anniversary of the birthday of the famous Russian scientist, the founder of Moscow State University. In fact, these two launches are precursors of a whole fleet of Moscow State University sputniks. These achievements are an additional indicator of the high-quality foundation of space research built by S N Vernov and his disciples.

Sergei Nikolaevich was not only an outstanding and highly talented scholar, but also a teacher in the highest and noblest sense of the word. S N Vernov organized within the framework of the Nuclear Physics Division a training program at the MSU Department of Physics for space explorers and assembled a large scientific school which continues to work fruitfully and produce results. Hundreds of specialists feel completely justified in regarding themselves as his students: they learned their profession through his lectures, in joint work, and at seminars, to which he always paid maximum attention. The notion of 'Vernov's school' is considerably wider than the circle of his students at MSU. Nevertheless, even this smaller circle counts among its members some illustrious scientists — true space explorers.

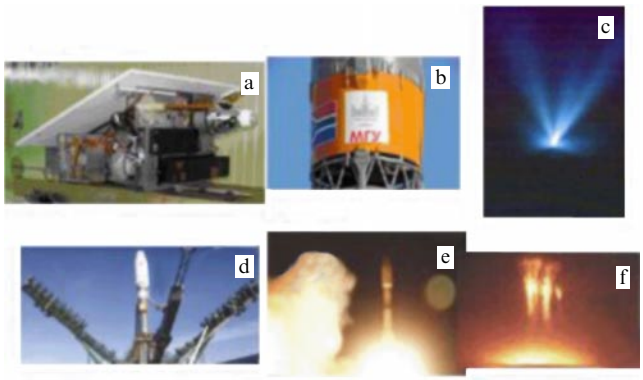

Figure 4. The Moscow State University sputnik Universitetskii-Tatiyana-2, launched on 17 September 2009 from the Baikonur Cosmodrom launching pad: (a) general view, (b) booster rocket with MSU logotype, (c) several hours before the launch, (d) launch, (e) separation of booster stages (robot telescope MASTER), and (f) transient flashes registered by instruments aboard the sputnik Universitetskii-Tatiyana-2.

Among them we find three Academicians (G T Zatsepin, G B Khristiansen, A E Chudakov), and 45 DSc and 225 PhD scientists.

S N Vernov successfully combined productive research with science administration in his capacities of Deputy Academician-Secretary of the Nuclear Physics Division of the USSR Academy of Sciences, Chair of the Scientific Council on the Cosmic Rays integrated program, Chair of the Nuclear Physics Section of the Scientific and Technical Council of the USSR Ministry of Higher and Medium Special Education, member of the editorial boards of the journals *Nuclear Physics*, *Proceedings of the Academy of Sciences*: *Physics Series*, *Geomagnetism and Aeronomy*, *Vestnik of Moscow State University* (Physics Series), and member of a number of learned and scientific councils.

The characterization of S N Vernov would be incomplete if we failed to mention his massive activities in popularizing science as such, and the achievements of scientists of Moscow State University in particular. His lectures and popular science articles appeared in many central newspapers and popular science magazines.

Sergei Nikolaevich Vernov was a cheerful and charming man. His innate kindness and responsiveness and his desire to help in times of difficulties earned him general respect and love. As luck would have it, I lived near him for several years in the main MSU building: his apartment was on the fifth floor, mine was on the fourth. Great friendship bound me to his first deputy at RINP, Professor I B Teplov, with whom we often discussed the problems of the Institute, and Sergei Nikolaevich's opinion was always offered on any subject in these discussions. On the other hand, Sergei Nikolaevich would never make a decision on an important issue without first working out a version taking into account I B Teplov's point of view.

Sergei Nikolaevich Vernov died on 26 September 1982 and was buried in Novodevichy Cemetery.

To perpetuate the memory of S N Vernov, a plaque has been mounted at the entrance to the RINP building at Vorobievy Gory, where he worked from 1953 to 1982, the auditorium 5–18 of the Department of Physics became the S N Vernov auditorium, outstanding students of the MSU Department of Physics are awarded the Vernov scholarship, and the S N Vernov contest for best research paper by a young scientist is regularly conducted at MSU RINP. One of the streets in Dubna in the Moscow region and a street in the town of Sestroretsk in the Leningrad region, where S N Vernov was born, bear his name.

Moscow State University is a leading research center in the country, contributing in important ways to progress in fundamental science and to strengthening of most needed scientific university education. Sergei Nikolaevich Vernov belongs to the constellation of scientists who are the pride of MSU. His path through science and life offers a brilliant example for the new generations of young researchers ready to do good for their Fatherland.

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S N Vernov centenary talk

V I Trukhin

The date 11 July 2010 marks the 100th anniversary of the birth of Academician Sergei Nikolaevich Vernov, the scientist of world renown, one of the founders of the Research Institute for Nuclear Physics (RINP) [now renamed as D V Skobeltsyn Institute of Nuclear Physics (SINP)] of MSU and of the Nuclear Physics Division (NPD) of the MSU Department of Physics.

Let us look at the brief history of the creation of the Research Institute of Nuclear Physics (RINP) and NPD. In 1940, a chair, Atomic Nucleus and Radioactivity, was set up in the Department of Physics of MSU on the initiative of Academician S I Vavilov and Corresponding Member D V Skobeltsyn. It was headed by D V Skobeltsyn, while S N Vernov and I M Frank became chair professors. In 1943, S N Vernov change his principal position to professorship in the Department of Physics of MSU, namely D V Skobeltsyn's chair, so that Vernov's pedagogical activities and his research were connected with Moscow State University until the last days of his life.

In 1940 and in 1943–1945, S N Vernov gave lecture courses on cosmic ray physics for students of the Atomic Nucleus and Radioactivity chair, and since 1944 he headed the chair's laboratory of the atomic nucleus — the first laboratory of nuclear physics at MSU. It was in this laboratory that S N Vernov launched his study of cosmic rays in the stratosphere, while Professor L V Groshev and Assistant Professor V S Shpinel were the first in the USSR to begin work on the study of the structure of atomic nuclei by β- and γ-spectroscopy. Students of the chair began to take active part in this research work.

In 1946, a Special Resolution of the USSR Council of People's Commissars created at MSU, on the basis of the chair and the chair laboratory, a Scientific and Research Center for training specialists for the Soviet Atomic project — the Institute of the Atomic Nucleus — mentioned in declassified documents as MSU NIFI-2; in 1956, this was changed to the current title MSU RINP (SINP). For two years, from 1946 till 1948, all the main organizational work of the institute and the chair (renamed Structure of Matter) became the responsibility of S N Vernov as deputy Director of the institute because Director of the Institute D V Skobeltsyn was sent to the USA as the USSR representative in the UN.

In this period, D V Skobeltsyn and S N Vernov tackled the task of creating an institute operating as large-scale university type nuclear physics center for conducting fundamental nuclear physics research and training of young researchers.

Work for the Soviet Atomic project demanded a sharp increase in the number of graduates specializing in nuclear physics. In December 1948, the USSR Council of Ministers

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