History of Rocketry and Astronautics

Proceedings of the Forty-Eighth History Symposium of the International Academy of Astronautics

Toronto, Canada, 2014

Marsha Freeman, Volume Editor

Rick W. Sturdevant, Series Editor

AAS History Series, Volume 46

A Supplement to Advances in the Astronautical Sciences

IAA History Symposia, Volume 34

Copyright 2016

by

AMERICAN ASTRONAUTICAL SOCIETY

AAS Publications Office
P.O. Box 28130
San Diego, California 92198

Affiliated with the American Association for the Advancement of Science
Member of the International Astronautical Federation

First Printing 2016

ISSN 0730-3564

ISBN 978-0-87703-627-2 (Hard Cover)
ISBN 978-0-87703-628-9 (Soft Cover)

Published for the American Astronautical Society
by Univelt, Incorporated, P.O. Box 28130, San Diego, California 92198
Web Site: http://www.univelt.com

Printed and Bound in the U.S.A.

Chapter 6

Ukrainian Scientific-Technical Schools in Rocket and Space Engineering*

Iryna Fedorenko, Oleksii Kulyk and Dmytro Faizullin†

Abstract

This chapter deals with the creation of scientific, scientific-technical, and scientific-design schools in Ukraine: of practical rocket science, rocket propulsion engineering, strength challenges, and missile flight theory. These domains of research were established by the "Yuzhnoye" Design Office in the middle of the 20th century. Its creation was one of the fundamental results of the activity of the rocket and space center in the city of Dnipropetrovsk.

I. Introduction

In 2014, the famous Yuzhnoye State Design Office is celebrating its 60th anniversary. An anniversary is always a reason for summing up and the analysis of work, and evaluating the prospects for development.

One of the fundamental results of the activity of the "Yuzhnoye" Design Office (DO) was the creation of scientific, scientific-technical, and scientific-design schools in Ukraine. These schools, formed by scientific and technical

* Presented at the Forty-Eighth History Symposium of the International Academy of Astronautics, 29 September – 3 October 2014, Toronto, Canada. Paper IAC-14-E4.1.1.x21833.

† National Aerospace Education Center of Youth named after A. M. Makarov, Ukraine.

communities with a common purpose and mission, are capable of keeping and developing scientific methodology and traditions. This is the key to their long-term existence and the effective work of scientific teams in these specific areas.

In this regard, that the rocket-and-space industry of Ukraine has been successfully functioning for more than 60 years is of great interest. This branch of industry dates back to early 1950s of the 20th century. Its creation was dictated by the necessity to strengthen the defense capacity of the Soviet Union. For that purpose, the rocket and space center was founded in Dnipropetrovsk in the 1950s. It was the origin of a number of scientific and technical schools: of practical rocket science (Academicians M. K. Yangel, V. S. Budnik, V. F. Utkin), rocket propulsion engineering (Academicians V. V. Pilipenko, V. F. Presnyakov, Doctor of Science I. I. Ivanov, Doctor of Science V. A. Makhin), strength problems (Academician V. I. Mossakovskyi, Corresponding Member of the Academy of Science of Ukrainian SSR P. I. Nikitin), missile flight theory (Corresponding Member of the Academy of Science of Ukrainian SSR N. F. Gerasyuta). The Dnipropetrovsk center gave a big boost to development of instrument engineering with the result that the rocket and space instrument-making scientific-technical school was created (B. M. Konoplyov, V. G. Sergeyev, Ya. E. Aizenberg). All those schools were formed owing to the hard, task-oriented work of huge teams and specialized subdivisions thereof. Activity of the above four teams resulted in four generations of strategic missiles (the "Satan" missile among them), four types of vehicles for launching space objects (including the so-far unsurpassed Zenith launch vehicle, which is the basis of the Sea Launch International Project), and dozens of types of space vehicles for military and commercial applications. From the standpoint of public utility, the results of the activities of members of the team of the Ukrainian rocket and space center should be briefly formulated as follows: they created the efficient nuclear-rocket shield of the country ensuring long-lasting peace on our planet [1]. Therefore, the fruitful work of Ukrainian rocket scientists is an object of research into the scientific-technical schools' formation and development.

School is the brightest manifestation of the collective forms of creative work, under the direct ideological and practical guidance of a teacher and scholar, who nourishes this group with scientific ideas and defines the methods and content of works to be performed at the school. It is a keeper of traditions, and scientific ideology. This is a concentrated experience of several generations, a kind of "relay" passing of knowledge and experience.

Specific features of scientific-technical school are as follows:

- Clear scientific and technical orientation of research activity of the school;
- Bringing the results obtained to the practical implementation thereof;

- Close cooperation of the workers of science, engineering, and production, aimed at solving specific tasks connected with the development of scientific and technical progress in these sectors;
- Pronounced economic effect and the cost-effectiveness of scientific-technical research and development activity.

As is obvious, scientific-technical school is aimed at creating a specific product and it is no longer an informal association since its constituent elements—basic studies, applied research, design development, and personnel training—should be integrated into a single system governed by well-known laws of system management [2].

They are detailed below:

1. Principle of consistency (integrity) "The system (object) possesses the properties which are not available in its parts or elements. This characteristic of the system is attributable to its structure, i.e., the interaction, connection of elements within the system. It allows the system to preserve its qualitative certainty."
2. Principle of decision making based on the selection and processing of information. Selection is an underlying concept of management; it can be made only by the processing of appropriate, that is, necessary and sufficient, amount of diverse information.
3. Principle of compulsory feedback. Feedback is an impact of results of functioning of any system (object) on the nature of this functioning.
4. Principle of dual-channel management.

Optimization of the method of obtaining, by the system, the information about the state of the media inevitably leads to using two specific channels of information. One channel transmits the relational data to the system, i.e., information from the past which is accumulated by the system.

To the greatest extent, the principle of dual-channel management should be observed in scientific-technical teams. Within their structure, functional units which provide for the stable part of the team's life, are storing and using information from the past, while issue-related units and their leaders, through which the medium requirement passes, are synthesizing information from the present time and ensuring the development of projects appropriate to the needs of the time as far as possible.

The principles formed allow drawing up the typical structure of scientific-technical school. It should include the following links:

- Production and research link which ensures creation of the methods of designing and actualizing the product design on the basis of applied research;
- Academic link which provides the first link with the basic studies on the definite technical design specifications;
- Educational link providing for personnel training for the two links above at the level of the latest achievements of science, and maintaining such a level due to the participation, in various forms, in the activity of these links;
- Coordinating body which is engaged in joint discussion of scientific problems and issues, with recommendations for practical implementation. The leaser (founder of the school) directly manages, as a rule, the production and research link, since he/she is ultimately responsible for the result.

Let's consider the Ukrainian scientific-technical schools of rocket and space engineering from the point of view of the formulated provisions.

II. School of Practical Rocket Science

The origin of the Ukrainian school of practical rocket science dates back to 1951, when it was decided to create rocket production on the basis of an automobile plant. V. S. Budnik, in parallel with design support of the serial production of R-1, R-2, R-5 rockets (developed by S. P. Korolev), initiated the development of his own rocket on hypergolic components of rocket propellant. The passionate energy and persistence of V. S. Budnik gave the impulse to form the group of enthusiasts (sub-activists) in the established designers' environment. Owing to their aspirations, the work on development of a new direction in rocket engineering was started, and the first design-and-engineering link of the future school of rocket scientists was formed. Invaluable contributions to its development were made by Academicians M. K. Yangel, V. S. Budnik, V. F. Utkin, and S. N. Konyukhov who, being at the head of the Design office, were forming the methodology and traditions of designers and engineers.

At the same time, V. S. Budnik initiated the close relationship of the Design Office with the newly formed Physical and Technical Faculty of the Dnipropetrovsk State University so that the training of professionals was in line with new developments. For that purpose, he together with Dr. N. F. Gerasyuta, Head of Design Department, began the teaching activity at the University. As a result, after a few years, the Physical and Technical Faculty became the source of manpower for rocket construction and the second link of the school, i.e., training. Professors I. K. Kosko, V. I. Mossakovskyi, V. I. Onishchenko, etc., were at the head of this link at different times. Due to their efforts, modern equipment was

added to the training base, and the teaching staff was filled with talented scientists.

New developments demanded serious scientific support. Therefore, V. S. Budnik and in particular, M. K. Yangel, who became the head of "Yuzhnoye" DO in 1954, started to establish strong creative relationships with the Institutes of the Academy of Science of Ukraine. The Institute of Mechanics, [ITM] Institute of Materials Science, and the Paton Institute of Electric Welding, Institute of Cybernetics, became long-term partners. But the growing problems of a scientific nature required the direct involvement of scientists in the developments, and M. K. Yangel initiated the creation of a special scientific organization of a rocket and space profile in Dnipropetrovsk. This organization, after a number of organizational transformations, (special sector at the Presidium of the Academy of Science, Institute of Technical Mechanics of the Academy of Science) became the third link of the Dnipropetrovsk rocket science school. Its development was to a large extent promoted by Academicians M. K. Yangel, V. S. Budnik, V. A. Lazaryan, V. V. Pilipenko, Corresponding Member of the Academy of Science of Ukrainian SSR, N. F. Gerasyuta, I. I. Ivanov, S. M. Kovtunenko, and V. I. Mossakovskyi. As it was mentioned earlier, production is the decisive link of any scientific-technical school. Managers of the Design Office focused on strengthening the relationship with production, instilling in the DO and plant teams the understanding of the indissoluble connection between them. This work ultimately led to the revolutionary decision, to transfer pilot production from "Yuzhnoye" DO to the structure of the Yuzhny Machine-Building Plant with the functions of making prototype models assigned to the Plant [1]. It turned the Plant into the main link of the school, i.e., the production link.

Therefore, a classical scientific-technical school in rocket and space machine-building was formed in Dnipropetrovsk over many years. It now comprises four links—design-and-engineering link ("Yuzhnoye" DO), production link (YuMZ Production Association), scientific link (Institute of Technical Mechanics [ITM] of Academy of Sciences [AS] of Ukraine), and HR link (Dnipropetrovsk National University, [DNU] Physical Technical Faculty [PTF]). These links are closely related by common topics and scientific-organizational guidance. The peculiar feature of this school is the principle declared by its founder M. K. Yangel: development of the Dnipropetrovsk school should be not just good, but the best in the world. This orientation of creative activity promoted the creation of four generations of military rockets, eight types of launchers of various classes (SL-7, SL-8, SL-11, SL-14, SL-16, Zenit 3SL, Zenit SLB, Dnepr, Cyclone-4, Vega, first stage of Antares, and 71 space vehicles of different applications. Specimens created in 1980–1990s are unsurpassed so far in world rocket and

space machine-building (in the relevant class). These are military rocket SS-18-3 "Satan," Zenit launch vehicle. On the basis of the latter "Sea Launch," the Project of the Century, has been implemented [3].

Traditions set up by the founders of the school allow it to hold the leading position in the world rocket-and-space machine-building until the present time. The traditions and methodology of the school are continuously developed under the leadership of A. V. Degtyarev, General Designer of "Yuzhnoye" DO. On his initiative, during years 2012–2013, various activities on strengthening cooperation with the Academy of Science of Ukraine, higher educational institutions of Ukraine, research and training organizations of the Ministry of Defense of Ukraine were carried out. This is the key to the success of the school at the present time, and in the years to come.

III. School of Flight Theory

The formation of scientific-technical school of practical rocket science gave an impulse to the establishment of topical schools. One of principal schools is the school of flight theory. The initiator of its creation (super-activist) was Dr. N. F. Gerasyuta, Head of the ballistics sector in the newly formed department of the Chief Designer of the young rocket plant. He managed to bring together, in the short term, talented people, and to form the team which was already at the stage of mastering R-1 and R-2 rockets, and made important proposals towards increased firing range and accuracy. The team was rapidly reaching its creative potential and by the middle of 1960s solved the most complex tasks in the domain of flight theory.

Within the team, there were the leaders on certain directions: Dr. A. A. Krasovskyi (ballistic), Dr. I. M. Igdalov (flight dynamics), Dr. N. I. Uriev (anti-rocket defense penetration). Each of them trained the "pleiades" of talented scientists: V. V. Briker, L. M. Kozak, A. D. Sheptun, Yu. P. Pankratov, V. T. Gilenko, E. P. Kompaniyets, N. V. Zykov etc. The Division at "Yuzhnoye" DO became the first link of the school (computation and analysis link). In order to support the scientific development and training of specialists in flight theory, N. F. Gerasyuta succeeded in establishing the special chair at PTF of DSU (Automatics Chair) and took up this office on a part-time basis. The large group of scientists-theoreticians has been trained at this Chair which became the second link of the N. F. Gerasyuta school. In order to promote the fundamental developments in rocket science, N. F. Gerasyuta, by order of M. K. Yangel, created in Dnipropetrovsk the above mentioned sector of technical mechanics problems, and became its director on a voluntary basis. Within the structure of the sector,

the dynamics department was organized to be involved in basic studies on this topic and soon it gained the deserved authority and weight in the scientific community of Ukraine. Among the members of the team of dynamics department there were distinguished scientists, such as G. L. Madatov, A. P. Alpatov, etc. The department became the third link of the scientific-technical school of N. F. Gerasyuta.

With the understanding that the implementation of both scientific and design-engineering developments is not possible without computer engineering, N. F. Gerasyuta made a great effort to create the modern computer center. It was headed by Dr. V. T. Gilenko. This was the fourth (production) link of the N. F. Gerasyuta school.

The scientific potential of the school, allowing it to provide "Yuzhnoye" DO with developments in modern scientific achievement for many years, is evidenced by the fact that it raised about 100 top-level scientists, several dozens of skilled teachers, and specialists of the highest qualification.

IV. School of Rocket Propulsion Engineering

This school dates back to 1958, when within the structure of the "Yuzhnoye" DO, the specialized design bureau on liquid propellant systems was created (КБ-4). It was headed by I. I. Ivanov, the trainee of the Russian school of propulsion experts led by V. P. Glushko. By that time, the young team of КБ-4 already had the experience of working with propulsion systems, supporting the serial production of V. P. Glushko's developments at the new Dnipropetrovsk rocket plant. The propulsion systems of V. P. Glushko for the first rockets were not yet optimized. As the Plant's Director A. M. Makarov stated, they were "pulled through" by the specialists of КБ-4 under the guidance of I. I. Ivanov. "Pulling through" means bringing the production technology to the required level of reliability. КБ-4 is the first and the most important link of the Dnipropetrovsk school of propulsion experts. It materialized due to the energy of its leader and his ability to engage others in problem solving. The number of problems was growing in proportion to the scope of the work.

The second link became the Chair No. 2 of propulsion engineering at the PTF of DSU, where I. I. Ivanov gave lectures in special courses. The third link of the school became the department of Liquid Propulsion Systems (LPS) at the Institute of Technical Mechanics (ITM). The triad of links created a single informal creative team, which solved a number of the most complicated scientific problems over the years. In the limited scope of this paper it is sufficient to mention solving the problem of high-frequency oscillations in the main rocket en-

gines, a unique engine with afterburning of the regenerative special fuel, and the "Moon" engine with multiple ignitions in the conditions of weightlessness. This informal team was characterized by extraordinary diligence, enthusiasm, commitment, responsibility, persistence, creativity, engineering courage, great insight, mutual trust, and goodwill. This style of work of the school ensured success in its activity.

Among the achievements of Ivanov school are control engines for the first and second generation rockets; the engine for the 8K69 orbital head module for the rocket; the third stage engine of 11K68 rocket; engines for upper stages of 15A15, 15A16, 15A11, 15A18, 15A18M rockets; second stage engine for 8K99 rocket; engine for the "Moon block" of S. P. Korolev's H-1 project with provision for landing and take-off from the Moon's surface for the subsequent mating to the orbital manned spacecraft; and numerous onboard power sources for solid engines. Most of those developments in rocket science were first in the world.

The high scientific and technical level of the school of the Corresponding Member of the Academy of Science of the Ukrainian SSR is evidenced by the work there of Academician V. V. Pilipenko, Doctors of Science A. V. Klimov and I. G. Pisarev ("Yuzhnoye" DO), N. S. Kovalenko and V. A. Zadontsev (ITM), Professors V. A. Makhin and L. V. Pron, the large group of candidates of science, inventors and highly-skilled professionals. The school of Dnipropetrovsk propulsion experts is the heritage of the Chief Designer I. I. Ivanov. This school created by him and successfully working until now, confidently stepped into the 21st century holding the leading positions in the world of propulsion engineering.

V. School of Rocket and Space Instrument Making

The creation of the Ukrainian school of instrument makers dates back to the middle of the 1950s. Its center became the city of Kharkov with its well-developed network of higher education institutions and research institutes of various profiles [5]. By the time of the creation of the central link of this school, special design office No. 692 ("Khartron") in Kharkov the experience had already been accumulated in rocket engineering. For the first time, the Post Office Box 201 plant ("Communar") was involved in the creation of instruments for rocket control systems. In order to organize the serial production of the instruments of the first domestic rockets, a Special Design Office (SDO) was established at the plant with A. M. Ginzburg at the head. His associates were M. A. Kharchenko, I. A. Rubanov, V. I. Kamenskyi. A. M. Ginzburg, one of coworkers of S. P. Korolev, studied the [World War II] "trophy" rocketry in Germany and had excellent theoretical knowledge. The SDO of A. M. Ginzburg be-

came the basis of the powerful instrument-making company, "Khartron." In 1956, the development of the first domestic intercontinental missile R-16 using hypergolic propellant started. The Chief Designer of this missile, M. K. Yangel, realized that it was necessary to create Ukrainian instrument-making cooperation, with the main objectives being the development of "Yuzhnoye" DO. The most important link of such cooperation would be an organization capable of the independent development of the control systems. Therefore, this organization should attract specialists of high class, and provide the base for their training, continuous improvement, and replenishment in the following domains:

- General theory of motion of aircraft, aerodynamics, ballistics, theoretical mechanics, free flight in the Earth's gravitational field;
- Automatic control theory, steady motion theory, methods of investigation of dynamic systems, methods of their mathematical description;
- Electrical engineering, electronics and radio engineering, computer engineering and technology;
- Integrated design of complex systems, their optimization and testing;
- Gyroscopic and optical equipment;
- Design, engineering and manufacturing of control instruments.

The leading organization started to develop following the above strategic directions. Its scientific potential was growing due to close cooperation with the Kharkov Aviation Institute and Kharkov State University where the leading specialists of "Khartron" carried out extensive scientific and pedagogical activity.

The growth of scientific and technological potential provided the level of development corresponding to the highest standards of national rocket and space engineering. in the world. The "Khartron" branch, with Ya. E. Aizenberg at the head, became the real research center in the field of aircraft and space object control. In its ranks there were many scientists and experts who defended their doctor's and master's theses. The publication of articles in scientific journals of the highest rating, and obtaining numerous author certificates, prove the recognition of the organization as the leader in this industry.

Accordingly, the level of instrument developments has grown. Divisions of onboard and ground instruments employed computer systems as the basis of their development and created the perfect multi-computer automated complexes.

All the above contributed to the fact that the principal instrument-making company was created on M. K. Yangel's initiative for "servicing" of developments of "Yuzhnoye" DO, which became the associate contractor of developments of the Chief Designers V. N. Chelomey (G. A. Yefremov), S. A. Lavochkin (V. M. Kovtunenko), D. A. Polunin, M. F. Reshetnev, N. A. Pilyugin (V. L. Lapygin), S. P. Korolev (V. P. Mishin, U. P. Semenov).

The key figures (super-activists) of the future "Khartron" were its leaders:

- Chief engineers A. M. Ginzburg, B. M. Konoplyov, V. G. Sergeyev, Ya. E. Aizenberg;
- Chief engineers A. I. Gurinskyi, A. F. Sobolev; Chief Designers of directions A. S. Gonchar, D. F. Klim, V. A. Uralov.

The work on the development of rocket and space machine-building was closely connected with pilot production (O. F. Altufiev, G. A. Borzenko, N. V. Matsa, and serial production at Kiev radio manufacturing plant (D. G. Tonchiy, B. E. Vasilenko, V. N. Shmarov), Shevchenko Plant (Yu. I. Zagorovskyi, G. A. Baranovskyi).

The work was carried out in close cooperation with well-known organizations in rocket engineering, such as NII-944 (gyroscopes and control devices, Director V. I. Kuznetsov), Kiev Plant Arsenal (sighting systems, Director S. P. Parmyakov), Moscow Searchlight Plant (power systems, Director V. A. Okunev), NII-4 of the Ministry of Defense of the Soviet Union (Head Military Institute on missile systems).

Under the guidance of the above leaders, a unique style and methodology of the Kharkov school of instrument making has formed, as an informal collective united by common objectives and tasks. The characteristic features of this style were to encourage the initiative of people, full commitment, ambitions with a share of adventurism (it is impossible to ensure novelty of developments without it), in-depth scientific justification of decisions, and courage in the use of modern technologies in the development of new systems.

Such style and methodology ensured the deserved authority and success of the school. Among its achievements are the control systems for missiles R-12, R-16, R-36, 15A30, 15A35, 15A18; launch vehicles 11K63, 11K65, Cyclone, Buran, Dnepr, instruments and systems for space vehicles.

Huge technological reserve and experience allows the Kharkov instrument-making school to successfully work in the market of space equipment at the present time. It is sufficient to mention the international project, Sea Launch, activities for the provision of International Space Station (ISS) flights, launches of the Dnepr launch vehicle, and the development of the control system for the new launcher, Cyclone 4.

VI. Space Machine-Building School

The appearance of the space school at Yuzhnoye Design Office dates back to the end of the 1950s, when it was assigned to be the team to act as a "backup"

to the S. P. Korolev organization, in the creation of the first artificial Earth satellite (AES) [4]. First experience was obtained, which was very useful, after the first appearance of the new launch vehicle (63C1), based on the R-12. As soon as the design studies started on the space launcher, based on the R-12 rocket, the question was raised as to what the payloads would be for it. By that time, the interests of potential customers of space facilities, and general needs of people, turned from unique but rare experiments in space, to large-scale, comprehensive studies of outer space and its using in research and practical applications. That, in turn, stipulated the necessity of the versatility of space vehicle types and a sharp increase in their quantities in orbit.

Continuing competition of the Soviet Union and the United states in the domain of rocket and space engineering also promoted the expansion of the range of works and accelerated the solving of urgent tasks. These circumstances were decisive in meeting the requirement of systematic launches of spacecraft for regular exploration of outer space, accumulation of data on its parameters, and the creation of special space systems functioning in the long-term in the interests of the Academy of Science, Ministry of Defense, and other agencies.

Obviously, the only space company existing in the Soviet Union at that time, with S. P. Korolev at the head, could not ensure the implementation of a national program with the simultaneous advancement or parity with the United States in all directions of space industry. Therefore, the timely and objective decision was taken by the country's leaders to concentrate the efforts of S. P. Korolev on the prestigious near-Earth projects (mainly, manned spacecraft and space stations), and devices for studying the Moon and the planets of the Solar System. In pursuit of this principal decision, the Decree of the Central CPSU Central Committee and the Soviet of Ministers of the U.S.S.R. of August 8, 1960, on the development of the launch vehicle 63C1, provided for the creation of 10 artificial satellites for various applications launched by this vehicle. Six of the satellites were to be developed by "Yuzhnoye" DO.

They received the designation, DS, (Dnipropetrovsk satellite). The purposes of the satellites were numerous. For example, AES DS-1 was meant for a purely scientific purpose; DS-M was equipped with devices for the detection and recording of high-altitude nuclear explosions, as well as measurement of the level of the natural radiation field of the Earth; AES DS-K8 was equipped with devices for measuring parameters of radiolocation stations; AES DP-1 was equipped with devices meant for antimissile and space defense. In addition, designs of unified AES of the DS-U series were developed which provided for a continuity of developments and considerable reduction of costs in serial production.

As a whole, the period of 1958–1964 was marked by the stage of school formation. In a very short period of time, specialists managed to solve a number of complex technical and organizational problems. The main thing is that space topics were formed and held as one of components of the thematic field of operations. Second, experience was gained in development, manufacture, launching, and orbital operation of a number of science and defense-specific satellites, and strong cooperation was established between allied enterprises and organizations. Third, foundations were laid for transition to the implementation of larger-scale space projects. Fourth, a staff was formed and took a specific organizational shape, smoothly combining experienced engineers and executives with excellent training in the development of space technology, with recent graduates who were striving to make their contribution to space machine-building. A peculiar work style was developed, the major feature of it being the passion and longing for new knowledge. The super-activist was Vyacheslav Mikhailovich Kovtunenko, and his closest associates of this stage were Yu. A. Smetanin, N. A. Zharikov, M. B. Dvinin, M. I. Kormiltsev.

The next stage of development of the space machine-building school was the period of 1965–1971. Its team faced new challenges. The range of developments and their complexity was growing. Standing out was the task of designing AES for the space system of radio-technical observation ("Celina" project). It was distinguished by a number of original scientific-technical solutions, which ensured record-breaking system "life (about 30 years and 80 launches). Also, at this time, military-specific AES were being upgraded for the purposes of missile and space defense.

The same period witnessed the ascent of the international space orbit program, when the "Interkosmos" program was launched. This program covers the development of scientific equipment by the Academy of Science of the Soviet Union, German Democratic Republic, Czechoslovakia, Sweden, France, and India (projects 1-IK, 2-IK, 3-IK, "Arkad"). Due to the increasing complexity of tasks, enhancement of the level of scientific support of developments was included in the agenda. V.M. Kovtunenko set up, within the special sector for issues of technical mechanics at the Academy of Science of the Soviet Union, a department engaged in researching the aerothermodynamic characteristics of space vehicles entering the Earth's atmosphere. The department became a scientific link of the V.M. Kovtunenko school. At the same time, relations with the Dnipropetrovsk State University were strengthening.

V. M. Kovtunenko chaired the Air and Gas Division at the Department of Mechanics and Mathematics which trains specialists for the "Yuzhnoye" Design Office, and experienced professionals from the design office were actively in-

volved in lecturing at the division for flight vehicle manufacture. Thus, the task of preparing successors for Kovtunenko's school was solved. Having grown strong from the scientific, technical, and organizational viewpoint, the space school of "Yuzhnoye" Design Office was on the eve of new achievements and intellectual and industrial uplifting (1972–1990). Among the most significant works of this period were projects for the development of automatic universal orbital stations (AUOS), projects based on these stations for the benefit of the Ministry of Defense of the Soviet Union and the Academy of Science of the Soviet Union, and the international project "Interkosmos" (AES Oreol-3, Coronas, Typhoon, Koltso, Ariabata, Bhaskara, Ocean). Kovtunenko's space school met with wide recognition in the international space community. After Ukraine gained independence, the fact that the country had a strong space potential became the reason for shaping and affirming its foreign policy image as a modern space state. The scientific and technical level of this potential is evidenced both by the total outcomes of successful activities in the space industry (71 space vehicles were created, 401 AES entered Earth orbit), and by the intellectual qualities of the staff. At different times, the space sector was headed by members of the Academy, V. M. Kovtunenko and S. N. Konyukhov, corresponding member of the Academy of Science of Ukraine V. I. Dranovskiy, Dr. Sci. in Physics and Mathematics B. E. Khmyrov. The staff nourished prominent scientists and specialists—four Doctors of Engineering, over ten Candidates of Sciences, and twenty awardees of superior state prizes. This potential is growing stronger and lays the foundation for the future achievements of Ukraine in the space sector of the international community.

In conclusion it should be mentioned that Ukrainian research and development schools of space machine-building established in the middle of the 20th century retain their creative potential. Their image, confirmed by long-term successful activities, ensures a highly competitive ability and demand worldwide. A testimony to this, is the efficient participation in international projects (Vega, Antares, EgyptSat, Cyclone-4), and a strong presence in the international market of space vehicle launch services (project "Sea Launch—Zenit," "Land Launch—Zenit," "Dnepr," "Cyclone").

References

[1] *Called upon by Time: From Opposition to International Cooperation* (Celebrating the 50th Anniversary of "Yuzhnoye" State Design Office) / D.; Artpress, 2004.—765 p.

[2] *I. V. Fedorenko. Rocket Scientists of Ukraine* / I. V. Fedorenko; edited by F. P. Sanin.—D.: Innovatsiya, 2008.—407 p.

[3] *Rockets and Space Vehicles of "Yuzhnoye" Design Office* / D.: Color Graph LLC, 2003.—240 p.

[4] *Design Office of Space Vehicles, Complexes and Systems* (An Outline of Formation and Development) / D.: "Yuzhnoye" Design Office, 2003.

[5] *A. S. Gonchar. Stellar Times of Rocket Engineering* (Memoirs) / A.S. Gonchar.—Kh.: Fact, 2008.