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Chapter 9

The History of Space Science in Ukraine: Rocket Engines and Power Plants*

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Abstract

In this chapter the unknown materials devoted to origins (1952) and development (1952-1998) of the physic-technical department and the scientific research of rocket engines of various purposes and types (with liquid and solid fuel, electric) and space power plants are submitted. The components of the outstanding results which were received at this department on preparation of skilled personnel in the 1950s and 1960s for DBYu are analyzed. This chapter will show the development of faculty for the example of the department of rocket engines which became the leader accordingly on scientific potential and on the teaching level. Information about the teachers which were working as faculty 40-50-years ago will be described. This includes the bases for achievements on a world level on all components of development of rocketry as they were opening. These achievements are compared with the condition of space science in Ukraine after emerging in independence. The reasons for a sharp falling of rates of scientific research in the area of space subjects at universities of Ukraine and the prospect of a way out from existing scientific crisis are analyzed. The mathematical model

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of progress of rocketry is offered. Cyclicity of development of rocketry, connected with non-uniformity of occurrence and introduction of innovations is shown. Periods of recession and growth of rocketry is predicted by analogy to economic Kodratiev cycles on the basis of model.

Introduction

Ukraine holds a special position in the development of rocket engineering in general and rocket engines in particular. Many founders of Soviet space-rocket systems were connected closely with Ukraine, were born and studied there, or arrived and worked there in the space-rocket industry. This constellation of names includes M. Kondratyuk, S. Korolev, V. Glushko, M. Yangel, V. Chelomey, V. F. Utkin, M. Reshetnev, G. Lozino-Lozinskiy, A. Lyulka, V. Budnik, V. Kovtunenko, G. Kisunko, V. Dogujiev, L. Smirnov, O. Makarov, V. Voznyuk, G. Langemak, I. Gvay, Yu. Semenov, I. Ivanov, N. Semenuta, A. Nedayvoda, N. Gerasuta, B. Gubanov, V. Saygak, A. Kostikov, O. Antonov, I. Sikorsky, A. Ivchenko, and other worthies. Korolev, Chelomey, and Sikorsky were students in Kiev. Korolev's follower Semenov, Chelomey's follower Nedaivoda, Doguzhiev (outstanding organizer of Soviet rocket engineer; last premier minister of the Soviet Union), and Kozlov's deputy Saygak (leading designer of the famous "A Seven" missile) all were graduate students in the department of rocket engines at Dnipropetrovsk State University (DSU). Lozino-Lozinskiy and Lulka were graduates of Kharkiv Aviation Institute. Yangel established Design Bureau Yuzhnoye (DBYu). His follower, general designer Utkin (DBYu) conceived the most powerful missiles of the 20th century. Practically all present leaders of DBYu and Yuzhmash were students in the DSU rocket department. One can see that the achievements of the Soviet rocket industry were determined by the activities of the DSU graduates. The DSU rocket department is a unique phenomenon in the world's rocket engineering history. During the 50 years since 1952, it prepared about 20,000 engineers, who worked in all the largest Soviet DBs, in Research Science Institutes from TsNIIMASH up to Paton Institute, and in the ministries [2].

Because the faculty's most typical scientific and educational activity concerned rocket engines, we shall use this department's activity to explore all aspects of the preparation of space-rocket engineers.

Preparation of the Engineers for Rocketry

The Students

There was a special system for selecting students for the DSU rocket department, which took only gold and silver medalists. Selection of the best students from other high schools had been practiced over several years: When J. Stalin signed the decree establishing the DSU rocket department in 1952, there was a group of students gathered from all Soviet universities from all five years in the DSU mechanical-mathematical department. This allowed the young experts to begin designing and manufacturing missiles at once, while simultaneously finishing their education. It is necessary to say that space engineering fanatics entered the DSU rocket department. Studying was hard. Subjects like mechanical drawing, design of mechanisms, machine theory, details of machines, construction of rocket engines, turbines, pumps, and technological equipment demanded a lot of time. Despite the entrance of the strongest, most talented students to the DSU rocket department, only 75 percent who entered their first year completed the university degree program.

System of Education

There was a special training system for the engineers that combined the highest level of university theoretical training (university courses in mathematics, physics, theoretical mechanics, radio engineering, and theory of control) with practical skills properly in engineering universities (design, organization, and test training). Students performed practical, factory work directly in DBs. The diploma was executed and defended at the enterprise. Many educational disciplines formed for the first time. Therefore teaching was combined with the creation of the textbooks. So, the rocket engines department worked out a fundamentals theory and the dynamics of rocket engines. The designer laboratories were equipped with samples of missiles—from the V-2 to new products from DBYu. The DSU rocket department was formed by a galaxy of outstanding people from DBYu into an education system. It also was important that they were teaching how to bring the job to metal, to fabrication. It inculcated a sense of reality and concreteness. Therefore our students became president of Ukraine, premiere-minister of the USSR, general designers of rocket engineering, and leading designers.

The Teachers

Such an education system engaged DBYu and Yuzhmash experts to teach, naturally with utilization of the existing base of young and clever DSU teachers.

Teachers invited from Moscow State University, Moscow Aviation Institute, and Bauman University have played an important part. Engineering experts in the DSU rocket department were prepared by three departments in three directions: missile construction, rocket engines, and missile control systems.

At the first stage, this department was organized by Yuzhmash intellectuals, among them V. S. Budnik and Salov, M. S. Shniakin, G. Ya. Firulin, M. I. Igumnov, and G. M. Pateyuk. Common management of the educational process and of the scientific activity was assigned to senior lecturer N. I. Varich, who was appointed by the first dean of the physic-technical faculty (his first assistant was senior lecturer I. O. Reingard), and to the pro-rector on this faculty, professor F. I. Kolomoyzev.

Department of Rocket Engines

Probably, future historians will name the 20th century as the golden age of Ukrainian space-rocket technology. Really, from N. Kondratyuk (Shargey), the pioneer of rocket technology, to the chief designers who created most of the Soviet military and space rocket types, more than the rest of the world as a whole, their lives were connected with Ukraine anyhow. Here, especially, it is possible to identify a direction to the development of rocket engines, which are one of the most complex units of a rocket. As a matter of fact, they are the hearts of the missiles. In Ukraine, V. P. Glushko from Odessa laid the foundation of this direction in the 1920s.

Mikola Shniakin: Founder of Rocket Engine Building in Ukraine

Mikola Sergiyovich Shniakin, DBYu chief designer of rocket engines, organized the rocket engines department within the physic-technical faculty of DSU in 1952. Shniakin was its first manager and laid the bases of scientific and pedagogical activity among the big group of scientists. These scientists became one of the world's foremost groups, having prepared a few thousand rocket engine engineers. He headed the DSU rocket engine faculty from 1952 to 1953.

Figure 9–1: M. Shniakin in 1930 and at mature age. Credit: author's personal archive. Shniakin (7 December 1901 – 9 May 1996) was born on the Ashkhabad railway station Geok-Tepe in Turkmenistan. His life was connected with rocket technology since 1939, when he began working as the chief of pilot production GDL-OKB, supervised by V. P. Glushko. Shniakin was appreciated highly by chief designers Glushko and Korolev with whom he worked in a Committee for State Security (KGB) "sharashka" (secret research and development laboratory) during World War II and who was deinstitutionalized ahead of schedule "for successful performance of the governmental tasks."

Having worked a long time as Glushko's assistant, Shniakin, was sent in September 1951, together with a group of experts that included I. I. Ivanov, M. R. Gnesin, et cetera, to Dnipropetrovsk for organization of liquid-propellant rocket engines at the first rocket production plant No. 586. The plant's department of the chief designer was headed by V. Budnik. Budnik's deputy, Shniakin, had been appointed by the chief of a department of the liquid-propellant rocket engines (LPRE) too. Shniakin's deputy, I. I. Ivanov, became head of the thrust chamber group. The LPRE DB and a test complex were created under Shniakin's management.

In 1949 Shniakin organized the department of rocket engines among the physic-technical faculty at DSU based on his teaching experience at Bauman Moscow State Technical University (MSTU). From 1951 to 1955 he headed the rocket engine chair at DSU. Shniakin laid the foundation for scientific and pedagogical activity of the big scientific group, which became one of the world's greatest and prepared a few thousand rocket engine engineers. Shniakin worked as the DBYu chief designer's deputy for four years. He returned to Khimki in the Moscow region in 1955, was deputy chief designer of the "Energomash" DB then chief engineer of "Energomash" (1955–1967).

Yuriy Mikolaevich Grizodub: Founder of Rocket Engine Dynamics

Grizodub was the second manager of the rocket engines department. He was born on 6 June 1922 in the village of Kolodiagne in the Kiev region. In 1939 Grizodub entered the Moscow Aviation Institute (MAI) and graduated in 1944. As one of the capable students, he remained there for postgraduate study. He carried out scientific research in close cooperation with design offices and scientific research institute (CIAM, NIITP). Non-stationary processes in rocket-engine hydraulic systems of rocket engines were a theme of his work. Grizodub first analogized the distribution of electromagnetic waves in transmission lines with distribution of waves in pipelines. He defended the dissertation at MAI in 1947. The level of his work was so high, that Grizodub was awarded the scientific degree of "Dr. Sci. Tech." in 1948.

Figure 9–2: Yuriy Mikolaevich Grizodub. Credit: author's personal archive.

Beginning a new faculty in DSU demanded a highly qualified staff of doctors and of science candidates. Therefore, DSU leaders offered Grizodub the post of rocket engines department manager in 1953. A true scientist's appointment to an academic post in a university always stimulates development of scientific research, which is the basis for improvement in the quality of education. For DSU, which had only a few doctors of sciences in that postwar period, the presence of a talented scientist on the staff stimulated development of university science. In the beginning, Grizodub staffed the department with young employees. He personally undertook management of numerous post-graduate students (10 people).

At DSU, Grizodub continued his intensive engagement in science and established the department's direction for science for all subsequent time. It was the nonstationary processes of rocket engines. For a short time, as manager of the rocket engines department, Grizodub wrote some manuals (automatics and a feed of engines, jet engines, dynamics of flight, pumps and turbines) and created a departmental laboratory base [4]. Heavy illness did not allow Grizodub to work and compelled him to leave the university.

Vitaliy Antonovich Makhin and Becoming of Department

During his very short time as a DSU professor, Grizodub did not have time to prepare for change itself among teachers with a scientific degree. The search for a suitable candidate to become department manager, therefore, began. The Ministry of Education (V. M. Poliaev) nominated Vitaliy Antonovich Makhin, a young senior teacher from the Leningrad Military-Mechanical Institute (LMMI). He had graduated from MAI in 1947, studied in postgraduate MAI, and defended his master's thesis in the same place.

In 1955, Makhin began to study nonstationary processes in rocket engines. A theme of his thesis for a doctor's degree was the transient processes of shut down in LPREs.

Figure 9–3: V. Makhin (on the left) with lecturers on holiday demonstration.
Credit: author's personal archive.

The momentum arising after a command on shut down of the engine (a pulse), was determining dispersion of head parts of a rocket and, consequently, was extremely important for LPRE burning high-boiling fuels. Therefore, during defense of his doctoral thesis in CNIIMASH in 1962, he had to endure certain pressure from Korolev's side, since the latter's rockets with low-boiling fuel components did not have this problem. After defending his dissertation, Makhin released the confidential book on modern methods of calculating processes in LPREs. It was an understandable student description of the most complicated design procedures for heat exchange from the combustion chamber walls (developed by Vitaliy Mihaylovich Ievlev) and calculation of radiant heat exchange in the combustion chamber (developed by L. Frolov) (both of whom worked in NIITP). Therefore, Evgeniy Konstantinovich Moshkin, one of the patriarchs of research on nonstationary processes in rocket engines, acting as the official opponent, noted it as proof of the applicant's high level of professionalism. He was supported also by S. D. Grichin, the chief of department TsNIIMASH, and by V. P. Beliakov, director of Zagorskiy NII. His work got unanimous support from council members.

Successful development of dynamics of LPRE has received in scientific works and lectures in the beginning of the post-graduate student, and then of the senior lecturer of department of rocket's engines, Ivan Ivanovich Morozov, of the graduate LMMI. The dynamics of LPRE valves was a theme of his dissertation. He was the first who applied the approaches to solving similar tasks in electrical engineering to nonstationary processes in rocket engines. He was the first who outlined the contents of a "Dynamics of LPRE" course. Unfortunately, there was an opinion in the Soviet scientific environment that the subordinate teacher or researcher should include the chief as author on published works. Frequently, it was not considered a sin for the chief to do it. This quality was fostered in Makhin, and the first very serious conflict on this ground almost disorganized the department. At the end of the 1950s, computer facilities did not exist. Consequently, calculating the thermodynamic parameters of combustion products in the chamber for prospective new fuels was very labor intensive. Hundreds of students in the department were involved with calculating the combustion process of the different fuels to enable construction of the I-S diagram. These materials (we shall tell directly, carried more practical than scientific value, not saying that students conducted the calculations) were processed by all faculty members, but one, Makhin, decided to print them. This caused a conflict that resulted in most of the department's teachers leaving. Makhin was forced to restore the personnel structure. The professed principle that "until now I sought glory, now let glory seek me" played a malicious joke on Makhin. In Dnipropetrovsk the academic scientific division formed with a confidential rocket direction in 1967. The prospect of becoming a member of an academy of sciences appeared, and Makhin went to work as chief of the engines department in the Dnipropetrovsk branch of the Institute of Mechanics. The department team was formed with new people, who only were beginning their scientific careers. Therefore, acquisition of scientific results demanded time and hard work from each scientific employee, including from the department chief, a doctor of sciences. As a result, there was a conflict, and Makhin returned to the university. Within a few years, he returned to his native land in Russia.

Lecturing by highly qualified teachers, headed by senior lecturer Gennadiy Sergeevich Shandorov, provided a high level of preparation for experts on rocket engines. Shandorov read all the basic, general technical disciplines: gas dynamics, thermodynamics, heat transfer, and aviation engines. He was the leading expert on the study of processes inside fuel tanks, where the products of combustion come in from the liquid gas generator. But, the tragedy that happened to him was a reflection of the unethical level among some on the teaching team that caused reprisals and resulted in "sharagka." One of teachers, who left the department as a token of protest against Makhin's misappropriation of another's work, himself appropriated Shandorov's scientific results for his own doctoral thesis. Shandorov, despite being a good-natured character, was indignant. There was a scandal. Shandorov had started "to press" from a different direction, and special services started to threaten. Not having sustained such pressure before, Shandorov committed suicide. It was a big loss for the faculty. The new generation of teachers, who came after the majority of the faculty had left the department, managed in a short time to take advantage of the successful conjuncture in rocketry, to achieve candidacy quickly, to complete doctoral theses, and also to ensure a very high-level educational process.

Figure 9–4: Professor V. M. Serebriansky, Assistant Professor V. I. Misura. Credit: author's personal archive.

Professors V. M. Serebriansky, O. M. Kapulkin, and V. O. Gabrinez, and associate professors V. I. Misura, V. V. Ignatenko, and Yu. V. Dronov made an especially big contribution to preparation of engineers for rocketry.

Scientific Research as a Basis of Quality Preparation of Engineers

After Makhin left the post of managing faculty, a young scientist (the author) managed this department for 30 years (after practical scientific study at the University of Grenoble in 1968). It was a successful time for expansion of scientific work, because successes in rocketry (the beginning of the satellite, Yuri Gagarin's flight, flights by other cosmonauts, and landing on the Moon) were instilling confidence in Soviet omnipotence concerning these techniques.

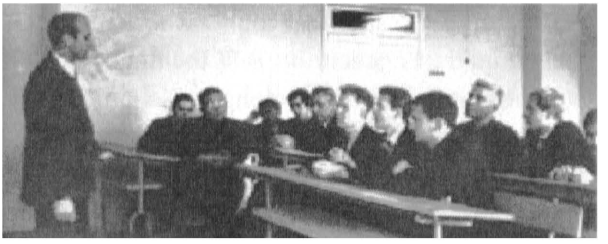

Figure 9–5: Meeting of the department of rocket engine building, 1958. In the first line of the second row is senior lecturer G. S. Shandorov (left). Credit: author's personal archive.

Financing of scientific research at DSU was practically unlimited. Therefore, the rocket engine department vigorously undertook creation of a scientific laboratory for research on the dynamics of a new type of engine (the electro-rocket) and on the dynamics of thermal processes in a rocket (nuclear systems with a change in phase condition of the working medium).

In DBYu-3, Professor V. Kovtunenko organized wide cooperation in 1971 on creation of the television global scout (TGS) observation system [1]. It was anticipated that TGS would observe everything that threatened the safety of the country. A powerful power plant would be needed to support on orbit for a long time a satellite with a mass of a few tons. Such a plant should be nuclear, and the engine holding TGS in an orbit should be electric rocket propulsion (ERP). Forty years ago numerous ERP schemes, only ideas, were known. The DSU department of rocket engines received two large tasks: ERP creation and research on processes in a nuclear power plant (NPP) with turbo-machine transformation (except for fast reactors). The greatest call stood in ERP use and in NPP liquid alkaline metals (potassium, sodium, and lithium). For this work, the physical and technical laboratory complex or CPPL was constructed. For 20 years, the DSU rocket engine department created the unique experimental base for research on heat and mass transfer processes in NPP and on the characteristics of ERP. Other no less complex tasks were transferred to Kharkiv Aviation Institute, Kharkiv Physical and Technical Institute. Over 100 employees were working in the DSU scientific laboratory. Tens of laboratory employees defended doctoral dissertations in science. Practically all types of ERPs have been made and tested over 20 years. At the 56th IAF Congress, the foreign organizations presented a lot of the reports on ERP, actually repeating DSU's results. Many of them are far below our level of achievement.*

The scientific community in the Soviet Union and beyond its limits recognized the research that the department of rocket engines was conducting. Employees of the rocket engines department repeatedly made reports at various levels of conferences (see photos).

Figure 9–6: Conference on electric rocket thruster, DSU (1990). Left to right—Professor M. V. Belan (Kharkiv Aviation Institute), Professor Semashko (Institute of Atomic Energy, Moscow), Professor V. F. Prisniakov (DSU), O. P. Hanuov, Professor O. I. Morozov (Institute of Atomic Energy). Credit: author's personal archive.

Figure 9–7: Participants of meeting on problems of space-rocket technics, Dnipropetrovsk, DBYu, 1979. First row, left to right: Donskoy, Zamishliaev, V. N. Soloviev, B. M. Petrov, Yu. B. Hariton, V. P. Glushko, V. F. Utkin, N. A. Pilugin, E. V. Kachalovskiy, O. M. Makarov, G. S. Titiov, Kovalis, and V. D. Kruchkov. Credit: author's personal archive.

* In 1998 the academician Prisniakov was discharged from office by bureaucrats "from the big road" and without any bases have deprived with management of chair and the scientific laboratory created by him. Now the laboratory created on the initiative of Kovtunenko was practically destroyed, and the chair was divided [1].

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<tr><th colspan="5">Applied Sciences</th></tr>
<tr><td colspan="2">Propulsion chemical</td><td>Electric propulsion</td><td colspan="2">Space power systems</td></tr>
<tr><td colspan="3">Nonlinear dynamic</td><td>Solar, SPS</td><td>Nuclear, turbo-machine</td></tr>
<tr><td colspan="2">Shut down LPRE</td><td>Analyze of thruster types</td><td>Degradation solar batteries</td><td>Steam generator on potassium</td></tr>
<tr><td colspan="2">Analyze accident</td><td>Outside electric field thruster</td><td>Photoconverter</td><td>Cavitation centrifugal pumps on potassium</td></tr>
<tr><td>Control burning</td><td>Instability</td><td>Plasma-ion thruster of Kaufman type</td><td>Solar arrays with concentrator</td><td>Condenser cooler</td></tr>
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Heat processes with change phase</th></tr>
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<tr><td colspan="2">Evaporation</td><td></td><td colspan="2"></td></tr>
<tr><td colspan="2">Boiling of liquid metal</td><td></td><td colspan="2"></td></tr>
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Table 9–1: Advanced Research Heat Processes in Power Engine Systems. (Department of Rocket Propulsion, DSU, 1968–1998).

Figure 9–8: The World Congress on Heat and Mass Transfer, Tokyo, 1974: A. Gukauskas (Lithuania), Nevstrueva (IVTAN), V. Prisniakov (DSU), V. Grigoriev (MEI), Yu. Kuznetsov (VTI). Credit: author's personal archive.

Figure 9–9: Session of Council on heat and mass transfer, Dnipropetrovsk, 1994. Credit: author's personal archive.

Components of Success of Physic-Technical Faculty of DSU

The physic-technical faculty, organized at DSU in 1952 under J. V. Stalin's order, quickly became the center for preparation of rocketry engineers in Ukraine. Undoubtedly, the successes that created Satan, the most powerful military rocket, and Zenit, the advanced ecologically faultless rocket, depended substantially on those experts prepared for DBYu by the physic-technical faculty at DSU. Financing of DSU depended on the successful work of the physic-technical faculty. It is necessary to say that party and state authorities were most attentive to this faculty's interests. Heads of the most supreme rank repeatedly visited DSU and the physic-technical faculty. That fact had extremely great value; DSU had direct submission to the allied ministry (from Ukraine, only DSU ranked among the leading Soviet universities, standing at number 33). Special influence on improving the quality of preparation of rocket engineers was given through participation in methodical council of the allied ministry on rocketry.

Figure 9–10: Visiting DSU of the first secretary of Central Committee KPU, V. V. Scherbizkiy, 1976. Left to right: pro-rector on scientific work, DSU, M. F. Nosovskiy; pro-rector on study, DSU, V. F. Prisniakov; secretary of Communist Party committee, E. A. Abramovskiy; rector, DSU, Mossakovskiy; V. V. Scherbizkiy; the first secretary of region committee O. F. Vatchenko; the first secretary of city town committee, V. F. Boyko. Credit: author's personal archive.

Figure 9–11: Meeting of the state committee of the USSR by education, G. O. Yagodin. Credit: author's personal archive.

Figure 9–12: Guest session of methodical council on rocket engines in Dnipropetrovsk, 1988. Left to right: V. M. Kudriavzev, V. F. Prisniakov, V. E. Alemasov (director of department of Kaza Aviation Institute). Credit: author's personal archive.

The physic-technical faculty was the largest in the university, and it had the greatest authority. It was headed by the most skilled teachers, by fine methodologists who knew the educational process very well. The quality of preparation of the engineer was at a very high level. The character of the faculty was determined by Dean Igor Konstantinivich Kosko (the well-known expert on studying longitudinal fluctuations of a rocket) and Vice Dean G. S. Shandorov, who were giving a lot of attention to the educational process. The organizational activities of these teachers already laid the foundation for DBYu's successes in the 1950s to 1960s.

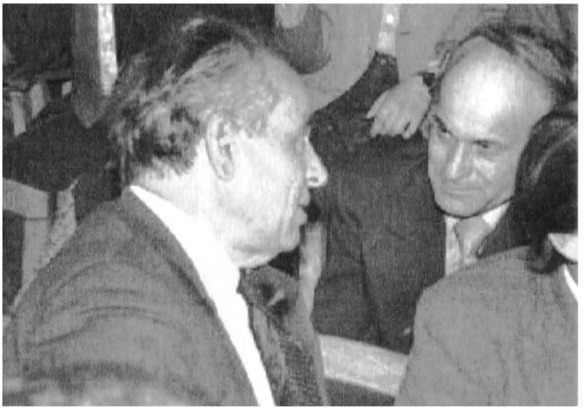

Figure 9–13: Dean of the physic-technical faculty, I. K. Kosko (left). Credit: author's personal archive.

Among teachers of faculty the senior lecturer, Veniamin Evgenievich Davidson, pawning the fundamental bases of gas dynamics and aerodynamics in the future engineers was distinguished. He was the largest methodologist in the field of gas dynamics. He worked from the date of the basis of faculty until now. His unique book on gas dynamics problems is basic to the study of this discipline throughout the former Soviet Union.

Figure 9–14: Presentation to V. E. Davidson of the Professor diploma (left). Credit: author's personal archive.

Students very much liked Professor M. I. Duplischev, the department's manager of rocket designs. He worked as Yangel's assistant and, in a second job, as a teacher on the physic-technical faculty. In 1960, Duplischev took up work managing the DSU faculty. He issued the first USSR monograph on unguided rocket shells (in two volumes).

Figure 9–15: Congratulations to M. I. Duplischev (second person from right) on anniversary. Credit: author's personal archive.

With expansion of the number of students training at DSU, its administrators' ambition grew. Based on the rising wave of rocketry, the dean of faculty wanted a separate institute. A conflict resulted between the rector and the dean. DBYu sided with the rector. But the subsequent reorganization of faculty did not lead to its development, as new heads considered the post of the dean as a springboard for career growth. There was an intellectual degradation of faculty administrators. In the emerging independent Ukraine, former military men were "ruling" the physic-technical faculty. So, there were personnel reasons for the loss of high rates of faculty development, which in due course appeared to be a deciding factor in the struggle with financial difficulties that arose after the Soviet Union's dissolution. At the present time, a DSU rector has decided to destroy the rocket engine and other departments.* The physic-technical faculty is dying at the age of 60 years.

Reasons for the Decline of Space Science in Ukraine

Interstate Reasons

The development of space science in Ukraine was determined, in many respects, by DSU in conjunction with DBYu, but other reasons for its decline also exist. Analysis of the development of rocketry in Ukraine over the last 50 years shows how it is possible to decline from outstanding results to full wreckage of space science.

At the instant the Soviet Union disintegrated, Ukraine was the world's leader in rocket production. In DBYu, general designer V. Utkin had created as many new types of ballistic missiles—from traditional to solid propellant and cryogenic rockets—as all similar organizations throughout the world combined. If Ukraine, for these 16 years, had chosen two or three perspective directions in space science and had escaped forward (we could have made it with our ingenious, I shall not be afraid of this word, "scientific" staff), instead of imitating support for absolutely all space-rocket directions, we would be cheap "space carriers" like the United States and Europe. Now, we cannot offer anything (except the engine of "lunar landing" which was made 40 years ago) for programs of flight to the Moon and Mars. Our projects interest nobody, because they have no serious revolutionary breaks. And scientific research has an unsystematic, not coordinated, character. One must admit that even rich Europe, having started to

* In 1998 Kuchma passed the department of rocket engines to the candidate of sciences of overpensionable age, who was the girlfriend of his wife. For 11 years this casual person on a post of head department has brought one of the strongest departments in the world to its closing.

create its own rocketry, has divided spheres of manufacture: France is engaged in liquid engines and missile carrier; Germany in electric rocket engines; and Holland in microgravitation. These countries, first of all, have created their own space programs coordinated with other states, as a rule, including a five-year plan, a roadmap for 25 years, and a strategic vision for 50 years within a context of tendencies of world development and a national science-and-technology policy.

The country that actually has determined world rocketry successes, having given the world more than 30 outstanding designers (see Introduction), having created the most powerful SS-18 Satan rocket, having created the most advanced and powerful nonpolluting rocket, Zenit, just now prepares with Canada to launch its own satellite.

The following two examples confirm this. First, in April 2009 the international symposium on "Space: The Human Dimension" was happening at Dnipropetrovsk. Ukraine submitted 150 reports for it, and other states submitted only two, which reflects the true rating of Ukraine as a rocket state. Analysis of the Ukrainian reports shows that all space science is devoted to practically worthless, small improvements of rocketry of 40 years remoteness. No fundamental work has been submitted. Now comes the second example. The annual International Astronautical Congresses precisely trace the space rating of various countries by granting their representatives the right to state their scientific achievements at plenary sessions. In 1996, during the 47th Congress in Beijing, Ukraine was among three countries (the others being Russia and the United States) asked to address problems of forecasting the development of rocketry in the 21st century. Ten years later, in 2006, the Congress in Valencia included 60 representatives from 16 countries (see Table 9–2). The Ukrainian representatives were never invited after 1996.

Country	**United States**	**Russia**	**France**	**Canada**
Number	14	3	4	8
Country	**EKA**	**England**	**Italy**	**China**
Number	13	1	2	2
Country	**Spain**	**Luxembourg**	**Holland**	**German**
Number	5	1	1	4
Country	**India**	**Switzerland**	**Argentina**	**Japan**
Number	3	1	1	2

Table 9–2: Participation in Plenary Sessions and Lectures on the Most Important Achievements. (57th IAC, 2006).

It is possible to speak about absence of financing. But universities, for example, had all the bases for continuation of basic research in the space sciences. In the name of petty interests, however, imperious illiterate officials destroyed the whole of the scientific schools. As regards the preparation of experts, a sharp decline in quality has taken place. Recently, in an interview, the main designer of the Satan, the world's most powerful rocket, said that now "the physic-technical faculty of our university prepares experts not of such a level as is necessary for us."

Influence of Globalization

It is possible to allocate the economic, military, technological, personnel, and psychological reasons for rocketry's heavy presence in Ukraine. All have been influential. In the military arena, ballistic missiles have ceased to be necessary to Ukraine; their reequipment into carriers of space objects could happen only in the presence of corresponding demand for sending payloads into orbit. But winning new markets was very difficult without an operational experience in market conditions. Political orientation to the West could not be supported by financial injections sufficient for survival of rocket manufacturing. In the personnel area, the absence of demand for rockets has led to unemployment and to disqualification of the workers making rockets. Graduates of schools preferred to go into professions providing work and guaranteeing decent earnings. Perestroika has activated a less talented layer, one less capable of creativity, whose main priority is private interest state. In fairness, one must admit the world community tried to stop the degradation of space expertise in Ukraine, tried to involve the space potential of Ukraine in the European research program.

All this is true, but there are also other reasons, which are related to the increasing globalization of Earth. The economic crisis, which has burst out today, has touched all advanced countries. The world community has recognized, based on M. Kondratiev's analysis almost 100 years ago, that crises have a cyclical character of 250 years of economic development. Since Kondratiev's prediction in 1920 of world economic crises, recognition of the existence of a particular cycle began with the crisis of 1929–1930 and finished with the present crisis. A recently submitted mathematical model of Kondratiev's cycles [6] shows the determinative role of innovations for scientific and technical progress in a given epoch, but those innovations are the pulse for development only until a certain time. After their "full application," a period of regression comes, which demands creation of new determinative innovations (new initial conditions).

Globalization of the economy tends "to smooth" arising difficulties by borrowing innovations from other countries, rendering impossible the wavy character of worldwide progress that took place in the hypo-globalization period. All innovations take root everywhere more or less simultaneously; and when they are used, new innovations are required.

Determinative Innovations in Rocketry (Initial Conditions)

Rocketry, despite the confidentiality until recently of its many achievements, has a global character. At any rate, the transition from the lowest to the supreme, from less perfect to more perfect, has taken place. Therefore, it is possible to speak about progress as concerns the whole system (as was considered in the model of the world economy in) [6], and about the separate elements of the system. We apply the approach [6] to the description of progress in rocketry. The works [7–9] have shown that rocketry, and any branch, develops cyclically. Thus, in the second half of the 20th century, progress in rocketry slowed down. Rocketry has reached technical saturation. Technical problems have been solved basically; military problems have been minimized, and questions of cost and economical use of rockets have given out on the agenda. Really, the determinative factor in periodic fluctuations of progress is the magnitude of an initial determinative innovation. K. Tsiolkovsky delivered the fundamental results; W. von Braun delivered the practical results for military purposes, and S. Korolev for space science. Theirs were innovations of the first level. Thereafter, the individual tasks concerning the economic and practical efficiency of rocketry were being solved. Yangel's ideas about the mortar's launching from a silo were very essential in the area of military use of rockets, and also their practical realization by Utkin in DBYu [10]. The essential solution for military purposes was railway launching (also by Utkin in DBYu). Another innovation of the highest level (again in DBYu) was the fully automated launching of rockets in the world of the, such as the R-36 and Zenit, which concerned not the actual design of a rocket but requirements for people to service the rocket.

Modeling the Progress of Rocketry

Modeling the technical progress of this or that branch in general and of rocketry in particular consists in connecting the growth of efficiency of this or that branch observable at a macro level to an event, such as technical development of concrete productions, at a micro level [12, 13]. Technical progress can be treated as a process of creation of technical innovations (novelties), on the one hand, and as a process of their distribution in the system of rocket manufacture on the other. Models of the diffusion processes, reflecting the dynamics of the distribution of innovations to time, usually apply.

Let $n(\tau)$ be the level of distribution of innovations at the moment of time τ as measured by the number of subjects using new technologies in the system of rocket manufacture at that particular moment; N equals a level of production corresponding to full satisfaction of needs of spheres of its possible application. The speed of distribution of innovations can be described by a model of diffusion corresponding to a so-called curve of Pearl [13]. Taking into account that the process of developing and introducing innovations is similar to supply and demand in the marketplace (only on special goods—innovations), we shall take advantage of development [14], according to which *the supply* is proportional to the existing level of the introduced innovations $n(\tau)$ and *demand* is proportional to the square root of this break (instead of proportionality of the break between the final constant N and the current level of its use $n(\tau)$ as accepted by Pearl)

$$dn(\tau) / dt = r\, n(\tau)\sqrt{N - n(\tau)} \qquad (1)$$

where r represents some constant factor of proportionality that takes into account the human factor.

After transition to normalize the size of innovations $\eta(\tau) = n(\tau) / N$, it is possible to present the solution of this equation as follows (at $\bar{\tau} = \tau / \vartheta$):

$$\frac{1 - \sqrt{1 - \eta(\tau)}}{1 + \sqrt{1 - \eta(\tau)}} = a \exp\left(r\sqrt{N}\tau\right) = a \exp\left(\bar{\tau}\right) = A \qquad (2)$$

The constant of integration a is from *the initial conditions,* determining start of the process of innovations after occurrence of basic ideas in the field of space science and rocket technologies. Therefore, the initial critical value of a germ of technological innovations η_0 turns to independent and deciding force of progress, which for the first cycle (as in our case) is determined by an expert estimation. We shall take over $\eta_0 = 0.2$ (as taking into account the results received by Tsiolkovsky and von Braun. We shall take 1954 (the year of DBYu's formation, which is close to the wide expansion of works on creation of rocketry samples) as the beginning of a cycle.

Knowledge of η_0 allows us to receive the following expression for a constant of integration

$$a = \frac{1 - \sqrt{1 - \eta_0}}{1 + \sqrt{1 - \eta_0}}$$

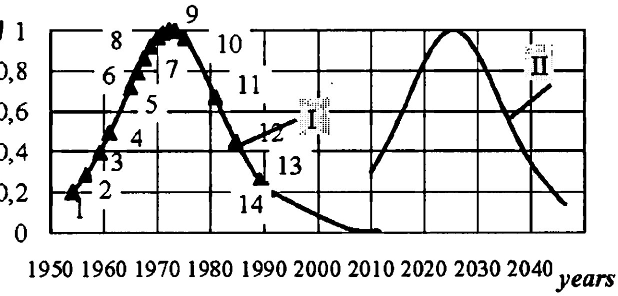

Figure 9–16: Curves of progress in function from one calendar year values of a germ of technological innovations η_0. I–0.2, II–0.3: 1—organization of DBYu, 2—the first satellite, 3—launching of SV to the Moon, 4—flight of Yu. Gagarin, 5—coming of the person in Space, 6—landing on the Moon, 7—flight to Venus, 8—landing of people on the Moon, 9—flight to Mars, 10—launching of rocket SS-18, 11—flight Space Shuttle, 12—launching of Zenit, 13—launching of Energia, 14—launching of combat complex from a railway form.

The diagram of progress $\eta(\bar{\tau} = \tau / \vartheta)$, designed under the formula (2), is submitted in Figure 9–16 at various values of initial value of parameter η_0.

Determination of the Size of a Wave's Half-Cycle

A sufficiently intricate problem is determination of characteristic time $\vartheta = \sqrt{N / r}$.

The parameter ϑ represents a cumulative constant of time of the individuals who are determining an occurrence and introduction of innovations in rocketry. We shall take this size as equal to the period of the big biological cycle of the individual. The most active people who provide a society's progress are choleric persons and sanguine persons [15]. This type of temperament corresponds to the following period of the big biological cycle of the individual, as established by B. J. Tsukanov [15]:

$$\vartheta = 8.51\tau_\mu = 6.38\,years,\ where\ \tau_\mu = (0.7 - 0.8) \approx 0.75$$

Thus, the half-cycle of the epicycle (time of the rise of rocketry until the moment of the beginning of decrease) depends on individual characteristics of the most active politicians, scientists, and economists. Further, at average magnitude τ_μ size of the period of the big biological cycle of the most active individuals in a society* we shall accept in round figures equal $\vartheta \approx 6.4\,years$. Taking into account that saturation by rocketry innovations is reached at the end of a half-

* The author acknowledges that there is a speech here about the period of a biological cycle of the individual which determines a half-cycle of growth in the economy.

cycle of a wave of growth equaling *T/2* and corresponds to equality to zero of a derivative $d\eta(\tau)\,/\,d\tau\,/\,\vartheta$, it is easy to receive the following relation:

$$T/2=\vartheta\ln 2a=-\vartheta\ln\left(2\frac{1-\sqrt{1-\eta_0}}{1+\sqrt{1-\eta_0}}\right) \qquad (3)$$

As can be seen from Figure 9–17, the cycle's period grows with an increase of parameter η_0. It is interesting to know some limiting value of the period of fluctuation of progress for a case when there is a full change of technological innovations and η_0=1. Obtaining of a limit of function (3) by known ways from mathematics gives the following magnitude:

$$T_\infty=-2\vartheta\ln 2=8.8\ \textit{year}.$$

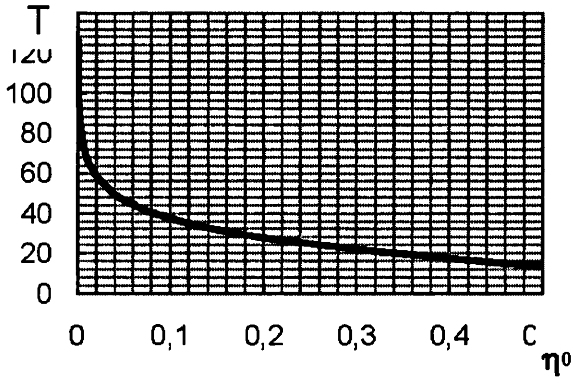

Figure 9–17: Relationship of cycles' period from the initial critical value of a germ of technological innovations η_0.

Obviously, the received value can explain the empirically accepted duration of a Soviet five-year planned economy.

About the Size of Initial Critical Innovations η_0

It is quite allowable to accept the structure of individuals determining scientific-technical activities in the area of rocketry and their individual characteristics by constants (changing very slowly in comparison with the period of fluctuations); the size of initial germs of progress and the volume of innovations influence half-cycle waves of initial magnitude η_0. This size can be found more precisely for a concrete time and for the given cycle by a method of expert estimation, or by solving an inverse problem, or by using thermodynamic analogies.

With an increase in the share of initial innovations (or investments into them), the factor a increases, but as it influences a half-cycle wave through the logarithm, its big changes do not strongly affect the size of this half-cycle. For example, at change η_0 from 0.02 until (in six times) ln$2a$ decreases all in one and a half time. Such influence just also explains an appreciable, but not essential (expected owing to significant changes in the structure of the economy) reduction of a half-cycle wave for the last 250 years from 30 to 18 years.*

As a first approximation, it is possible to use an expert estimation of the value η_0, which should correspond to the contents and volume of initial investments in each cycle.

In connection with an opportunity for expert estimation of the initial critical value of a germ of technological innovations η_0, we shall state some reasons about the magnitude of this parameter for subsequent cycles. We took size η_0 for the previous period as equaling 0.2 and for the subsequent as 0.3. Correspondence of the period of a rocketry development cycle can confirm a validity of the accepted sizes η_0=0.2 as a first approximation. For economist M. Kondratiev's cycles, the empirical statistics for 300 years are typed and, consequently, it is possible to establish dynamics of change η_0 from one calendar year [6]. Such statistics can be typed for rocketry in the future. We would like to mention the recent work of B. Ye. Chertok [16] in this connection, where he predicts revolutionary innovations in rocket carriers: "At the same time, new magnetic materials will be developed. Electrical catapults will replace solid and liquid propulsion for launches from Earth and the Moon. High-thrust electrical propulsion using thermonuclear power sources will replace chemical propulsion in many space applications." We cannot contest or object to this quite reasonable forecast, but the parameters of the rocketry development cycle on this or on another way will depend on a critical germ of innovations of the specified direction in the future.

The Analysis

Figure 9–16 shows a process of fluctuation in the development of rocketry. If the beginning of the present cycle is taken as 1954, when both the Soviet Union and the United States had started intensively to develop and manufacture ballistic missiles, its maximum falls at 1968–1975 when the launch of Apollo to the Moon and of the most powerful SS-18 Satan rocket took place. Further achievements were based on improvement of earlier accomplishments. Now, rocketry is experiencing crisis conterminous, in part, with global economic crisis, which is connected with full use of available innovations. By the submitted calculations,

* Certainly, the author must note that the exact determination of these sizes is impossible, and also the time of the beginning or the end of a cycle, or the beginning or the end of crisis. Besides, the geopolitical cycles, for example, war, have an influence on development of a cycle, but the tendency of reduction $T/2$ takes place.

this crisis will last until 2012. Then a new rise will begin based essentially on new innovations. The maximum of this rise will occur at 2026, when we can expect the real steps of development of the Moon and Mars.

Conclusion

A good knowledge of the past always allows prediction of the future. Examination of the development of Ukrainian rocketry allows avoidance of mistakes in the future. Returning of the lost positions for Ukraine is probably only on a way of purposeful concentration of efforts of the scientific staff and of the engineering staff on chosen high-tech art technologies, which are connected with priority directions of scientific and technical progress. Without reforming the system of the organization of science to make it is impossible. University science in Ukraine traditionally is considered second-grade compared to professional academic science. But experience is showing that more than half of all innovations in Europe and America are born in university laboratories and institutes where the intelligence of scientists is combined successfully with the intelligence of the teachers and students. Therefore revolutionary discoveries worthy of the great Ukrainian designers are possible to achieve only by strengthening university science as was done on the DSU physic-technical faculty 50–60 years ago.

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