Soviet Rocket Technology

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THE AIM OF THIS PAPER is to depict the background of well known and not so well known Soviet achievements and failures in the field of space technology, irrespective of whether it agrees or disagrees with numerous existing books, pamphlets, articles, and rumors on the subject.

In June 1959, I received, from an influential Western (not British) organization, an invitation to testify before a powerful constitutional body and in the press that the Soviet Sputniks, Laikas, Luniks, etc., were no more than "rude Communist propaganda"—a "Big Red Lie." A few months later, while looking at the capsule of the Mercury Project at the McDonnell Aircraft Corporation, St. Louis, Missouri, a well known scientist and educator said to me: "Well, here we have something new, real, and outstanding, while the Russians make only propaganda announcements." Then, in April, 1961, a few hours after Major Gagarin's successful re-entry and landing in the USSR when I refused to give "Yes" and "No" answers, my interviewer in a Los Angeles hotel stated boldly that "the so-called Gargarin's Space Flight," too, may well prove to be "another Russian hoax." Finally, in a document (in front of me as I write) prepared for official use, a Western intellectual advises his superiors that, according to results of his "first-hand study," the Russian and "other Eastern Slavonic nations" appear to be "much less inventive and imaginative" in science and technology than the Anglo-Saxon nations.

I could enlist dozens of publications, radio broadcasts, and even TV plays, in which the cold war sergeants, some of them known as "Russian experts," depict the Soviet Union as the old Tsarist Russia with its notorious longbearded Muzhiks and Oblomov-like intellectuals, with no real scientific and technological progress.

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But the realities are quite different. The October Communist Revolution destroyed, abolished, and replaced *that* Russia by a fundamentally different state organization called the Union of Soviet Socialist Republics, or simply the Soviet Union, in which there are no private or even semi-private industrial companies or corporations, research establishments or laboratories, educational establishments, or technological publications. Everything and everybody in the USSR belongs to the State and is employed, financed, directed, and controlled by the State. The latter itself "belongs" to the Central Committee of the Communist Party of the Soviet Union.

The second basic difference is that the Soviet Union is a country of a single and permanent official *Ideology* (Marxism-Leninism) serving a single and permanent national purpose, or aim, or sense of life, or destiny (Communism). Whoever you may be and whatever you may be doing, your efforts are predetermined, once and forever, by this single and permanent aim. And so are the efforts of the entire Soviet people. Tsarist Russia, on the other hand, was a jungle of philosophies and ideologies with no uniting national purpose.

There are, of course, many other differences as well but, ad hoc, these two are the decisive ones. They make the USSR not only the country of a dictatorship with a very high degree of centralization but also one of the most dynamic state formations in modern history, or perhaps the most dynamic, knowing clearly where it wants to go, and why and how. And this is precisely what puts such fields as aeronautics and space technology in an advantageous position in comparison with those in, say, the United States and the United Kingdom.

The general philosophy, purpose, and history of the Soviet Space Technology began, however, long before the October Revolution. Russian engineers and scientists, N. I. Kibal'chich, K. I. Konstantinov, N. S. Sokovin, A. P. Fyodorov, K. E. Tsiolkovsky,[1] I. V. Meschersky, and others, independently, had put forward ideas, projects, and the theories of rockets as far back as 1881-97. Daniell Bernoulli, Leonhard Euler, Lomonosov, Ostrogradsky, Gromeka, Bobylev, Petrov, Mendeleev, Mayevsky, Meschersky, Zhukovsky, and many other members of the St. Petersburg Academy of Sciences or professors of Russian institutes and universities, had created and maintained excellent traditions in mathematics, theoretical mechanics, and theoretical physics. K. I. Konstantinov's publications *On Military Rockets* (1856) and on *Military Rockets in European Armies* (1855) were particularly well received. Professor I. V. Meschevsky's book on *The Dynamics of a Point of Variable Mass* (1897), laying down the foundations of what we call today "Theoretical Rocket-dynamics," attracted great atten-

[1] Ed. Note: American orthographic practice uses the form "Ziolkovsky."

tion from scientists and engineers and gave a powerful impulse to the later studies in the field.

Konstantin Eduardovich Tsiolkovsky (1857-1935), the man of "great efforts and little rewards," is, however, considered to be the "father" of present Soviet achievements in rocket technology. He gave Russia a spaceship project which was, for 1903, absolutely unique. But being what he was—a mere teacher in a remote provincial school, a technologist rather than a theoretician—his project did not attract the attention it deserved. Besides, Tsarist officialdom's technological dreams did not rise above St. Petersburg's chimneys.

The first wind tunnel in Russia, although a small and rather primitive one, was designed and built in 1890 by the same Tsiolkovsky. But he was not the only enthusiast of aeronautics and astronautics. Professor Nikolai Egorovich Zhukovsky (1847-1921), the "father of Russian Aviation," constructed in 1902 the second wind-tunnel, at Moscow University. Then, in 1904-06, the engineer Dmitri Pavlovich Ryabouchinsky designed and built up the famous Kuchino Institute of Aerodynamics. Finally in 1910-12 in the Moscow Higher Technological College (M. V. T. U.), again under Professor Zhukovsky, one more laboratory was designed and built. Thus, as far as ideas, theories, projects, and aerodynamics laboratories were concerned, towards the eve of the first World War, Russia was no longer a backward country.

Tsiolkovsky continued his research. Zhukovsky was lecturing on problems of general aerodynamics, mechanics of flight, and aeroballistics. Professor S. A. Chaplygin (1869-1942), the author of the well known work on gas streams (1902-04), continued his basic research into problems of theoretical gasdynamics, the importance of which for high-speed aeronautics and rocketry became evident only decades later. Ryabouchinsky, in collaboration with General Pomortsev designed and tested (1916) a tactical military rocket-bazooka. Several Russian scientists, Professor Rynin among them, began writing and publishing popular books and articles on rockets and space travel, etc.

Immediately after the October Revolution, Lenin empowered Professor Zhukovsky to begin the building of a completely new and up-to-date center of aeronautical research, under the name "Tsentral'nyi Aero-Gidrodinamicheskii Institute" (Ts. A. G. I.), the Soviet NACA; this was initiated in 1918 and completed partly in 1924 and fully in 1927.

Equally important was the creation (1919) of the now famous Zhukovsky Academy of Aeronautics in Moscow, with its ever improving teaching and experimental facilities. Today there are in the USSR 15 such or comparable academies, institutes, and higher colleges, exclu-

sively of aeronautics and space technology, plus a great number of aerospace tekhnikums (i. e., technical colleges), plus a number of departments and chairs of aeronautics and astronautics in universities. Each of these has laboratories of its own. All the 15 institutions are not only teaching but also doing basic research. Thus the problem of preparation of aerospace scientists, engineers, technologists, and technicians was solved drastically and effectively. The consequence is that, in my opinion and experience, the present Soviet aerospace *intelligentsia* is not only the most numerous but also the most directed and the most effective in the world.

This is not all. The "Pyatiletkas" (i. e., five-year plans of industrialization) gave the USSR a modern aerospace industry, which, in turn, created favorable conditions for the creation of huge research establishments. One of these is the "New Ts. A. G. I." (built in 1933-38), with superb wind tunnels and other facilities. A second is the "Newer New Ts. A. G. I.," the Institute of Fluidmechanics of the Academy of Sciences in Novosibirsk (built in 1959-60), with academicians S. A. Khristionovich and M. A. Lavrentev in charge. Then there are the Central Institute of Aerospace Propulsion Systems (Ts. I. A. M.), the All-Union Institute of Aerospace Materials (V. I. A. M.), the Flight Research Institute (L. I. I.), the Scientific Testing Institute of the Soviet Air Forces (N. I. I. V. V. S.), the Scientific Testing of Air Armaments (N. I. I. A. V.), the Scientific Institute of Air Instruments (N. I. I. A. P.), the State Scientific Research Institute Number One (NII–No. 1) (Rockets), the Baikanur launching base (the Cape Canaveral of the USSR), etc., etc. Do not have illusions: both by their quantity and quality, they are all as impressive and powerful as those in any other country in the world. What is even more important, their activities are well planned, well coordinated, well aimed, and absolutely free from financial worries.

If we now have a closer look at the space developments proper, we notice that the Soviet government has manifested its keen interest in the field throughout the entire history of its existence. A special Central Bureau for the Study of the Problems of Rockets (Ts. B. I. R. P.) was created as far back as 1924. In the same year, an All-Union Society for the Study of Interplanetary Flights (O. I. M. S.) was formed in Moscow. In 1927, Ts. B. I. R. P. and O. I. M. S. organized in Moscow an international exhibition of rocket technology. In 1928-30, a number of closed and open conferences of Soviet rocket enthusiasts took place. Each conference discussed the one single major topic: what should be done in order to proceed from theories and projects of rockets to practical rocket technology? This was precisely what the government wanted.

Tsiolkovsky's last major contribution to Soviet space technology was his well formulated and clearly presented idea of a multistage rocket (1929). He was already an old man in poor health, and his activities in the projects of the 'twenties and 'thirties could not be more than symbolic. But the second generation of Soviet rocket engineers was already deep in the field. Boris Sergeevich Stechkin, then still an ordinary engineer of Ts. A.G. I., but today an eminent member of the Academy of Sciences of the USSR and Head of the Department of Aerospace Propulsion at the Zhukovsky Academy, published in 1929 an article on the theory of jet propulsion, which made an important contribution also to the theory of rocket propulsion.

Y. V. Kondratyuk put forward, in 1928, the idea of braking re-entry vehicles by aerodynamic means and proposed the use of ozone as an oxidant in rocket fuels. His book *Rockets*, published in 1929, was a valuable contribution to the subsequent achievements of Soviet space technology. G. A. Tsander (1887-1933) was another rising star. He began working in the field only in 1919, but already in 1926-38 he had become "another Tsiolkovsky." He put forward several original ideas and projects of jet and rocket engines. Two of them, OR-1 and OR-2, with gasoline-air and gasoline-liquid oxygen fuels respectively, were built and tested successfully in 1930 and 1932, developing absolute thrusts up to 50 kg. He also designed jet engines with 5-ton and 600 kg. thrusts. In 1932, he published an important book entitled *Problems of Reactive Flight*. The years 1929 to 1933 were, on the other hand, years of great happenings. Stechkin was arrested and imprisoned for many years. Some of the Ts. B. I. R. P. and O. I. M. S. members were pronounced enemies of the regime. Tsander died. Tsiolkovsky was a retired sick old man. The entire higher educational system and industrial and agricultural economy were in a state of radical reorganization and Stalinization. Ts. B. I. R. P. and O. I. M. S. were disbanded.

Naturally, these happenings confused the work of the Soviet rocket engineers, but this was for a short period only, and the government was far from abandoning its "rocket interest." Quite the opposite: it demanded a doubling of efforts in the field. Professor V. P. Vetchinkin (1888-1950) was asked to form a group of scientists in the Ts. A. G. I., with the aim of studying foreign experience in the field and carrying out basic research on the mechanics of rocket flight. This group began working in 1930. In 1931, a completely new Group for the Study of Rocket Propulsion Systems (G. I. R. D.) was formed in Leningrad. A few years later, the G. I. R. D. became the State Rocket Scientific Research Institute, which is known today as NII–No. 1.

Vetchinkin's group translated into Russian and published numerous

foreign works on the subject, including those by Max Valier and Eugen Sänger. In 1933-35, Vetchinkin himself developed and published excellent theories of rocket flight.

But to return to G. I. R. D., which continued Tsander's and others' projects and initiated new ones. One rocket, built and tested in 1933, powered by a liquid propellent engine, was 245.7 cm. long, 160 mm. in diameter, and 20 kg. in weight. It rose to an altitude of 4500 m. But none of the projects, with the exception of the so called "GRID-X," proved to be successful enough. "GRID-X" was, in fact, a further development of an earlier project by Tsander. Its length, diameter, and weight were respectively, 2.2 m., 0.14 m. and 30 kg. It was fired successfully in November 1933, but did not reach the design maximum altitude of 5000-6000 m.

The active majority of G. I. R. D. consisted of the third generation of Soviet rocketists, i. e., those who were educated under the new regime. V. P. Glushko, S. P. Korolev, M. K. Tikhonravov, A. C. Kostikov, Yu. A. Pobedonostsev, L. S. Dushkin, and others, who are today leading figures in the design and production of Soviet rockets, sputniks, and spaceships, began their efforts in G. I. R. D. The years have since proved that they were vigorous, imaginative, inventive, and able, although some "experts" insist that "dictatorship paralyzes talents."

For instance, Tikhonravov designed, built, and tested successfully (1934) a liquid fuel rocket. I knew this rocket and its further versions fairly well and would like to say that, for its time, it signified a remarkable jump forward. The rocket was supposed to be secret, but in 1945 my group found its drawings in the Nazi Air Ministry. Tikhonravov not only developed interesting rocket projects—he also published many valuable articles and a book *Raketnaya Tekhnika* (1935) full of detailed information on rocket design.

A. G. Kostikov, on the other hand, dedicated his talent and energy to the development of small military rockets named "Katyusha," The work of his group began in 1936; in May of 1940 "Katyusha" was accepted for mass production and was widely used during the Soviet-Nazi War.

S. P. Korolev's work on rockets began in the early 'thirties. In 1934 the Ministry of Defence of the USSR published his book *Rocket Flight in the Stratosphere.* During the following years he worked in the Ministry of Aircraft Production, then in the Ministry of Armaments, and in the Rockets Research Institute, continuously in charge of rocket research and development. In 1945 he was made responsible for the further development of the German V-2. Some years

later his group designed an intercontinental ballistic missile, the successful launching of which was announced on 27 August 1957. Today he is one of the chief designers of rockets for carrying Sputniks and "Vostok" capsules. An active member of the Soviet Communist Party, an excellent organizer, a Lieutenant-General of Aviation, a Hero of Socialist Labor, a Corresponding Member of the Academy of Sciences, a highly imaginative and inventive engineer with tremendous concentration—such is this leading rocket engineer of our times.

Then there is V. P. Glushko, one of the outstanding experts in the field of powerful liquid fuel rocket motors. He too entered this field in the early 'thirties. Together with G. Langemak, Glushko published (1935) a book on *Rockets, Their Construction and Application*, which influenced the future of this field. The authors also played an active role in the work of such rocket organizations as the Aviation Engineering-Technological Society Aviavnito (1934-40) and Osoaviakhim. In 1935 they presented papers at the All-Union Conference on the use of rockets for the study of the upper layers of the Atmosphere. The various contributions were published in a book entitled *Reactive Motion*, which could be obtained by anyone at home or abroad.

Pobedonostsev, a gasdynamicist and former member of the Ts. A. G. I. staff, joined NII—No. 1 in the late 'thirties and worked full-time on the aerodynamic problems of rockets. After the war, for several years, he was in charge of a large group of German engineers who worked on the Peenemuende V-2.

Among the younger Soviet rocket engineers, I should like to mention I. A. Merkulov, I. S. Dushkin, and A. H. Lyul'ko. In 1935, while an aeronautical engineering student, Merkulov designed, built, and tested (1936) a two-stage rocket. Its first and second stages were propelled, respectively, by gunpowder motors and a "uniflow" jet-engine. In 1937, a further version of this rocket was mounted on a conventional air force fighter, as a booster, and showed good results. In March 1941, at the Zhukovsky Academy of Aeronautics, I was visited by I. S. Merkulov and L. K. Baev. They put on my desk a completely new project for a two-stage rocket. Undoubtedly, this was much more advanced than anything I had seen before. There was a general feeling that the two bright young men must be given a chance to go ahead with their idea, but the Soviet-German War, which began two months later, made this impossible.

Then there was, of course, Lyul'ko, a promising Zhukovsky Academy graduate. His first contribution was his Diploma Project (1938), which turned out to be quite a step forward. The authorities gave him good

opportunities, and he continued working on his top secret propulsion system during the war years. But then, in 1945, my group found full drawings and detailed descriptions of the project in the Luftwaffe Ministerium in Berlin. This was a shock for us and very bad luck for Lyul'ko. Today, however, he is once again working in the field.

The first Soviet experimental rocket fighter, roughly of the Me-163A [2] type and size, was designed by V. F. Bolkhovitinov in 1939-40; built in 1940-41 it was transported to one of the Moscow military aerodromes for flight tests in October, 1941. The rocket motor of the fighter was designed in 1937-38, built in 1938-39, and tested in 1939-40 by Dushkin, who is, undoubtedly, one of the leading figures behind the present Soviet aerospace technology. I have good reason to believe that he is now about to finish a long and hard task on a new rocket propulsion system which will give the USSR new advantages capable of surprising the entire aerospace world. He began with an engine of the calibre of the well known HWK-109-509 and finished up with a monstrously powerful rocket engine.

It may well be asked why, if the USSR had so many rocket scientists, technologists, engineers, projects, and prototypes, there were no rockets and jet aircraft until much later, after the war? There are reasonable explanations:

(1) it is not true at all that there were no rockets in the Soviet Union; "Katyushas" of several types were in mass production and wide-scale use in 1941-45;
(2) the main industrial centers of the USSR had been either occupied by the Germans or evacuated to the East, and this caused serious delays;
(3) resources and efforts had to be concentrated on the immediate needs of defense;
(4) the Soviet industry was still young and inexperienced;
(5) as admitted by the XXth Congress of the Communist Party itself, Stalin and his lieutenants had committed too many mistakes in preparing the country's defenses.

Now about the post-war period. One reads and hears time and again that the present Soviet space achievements are due to "hundreds of German rocket scientists and engineers deported from Peenemuende and Berlin to Russia."

But what are the facts? Peenemuende, Berlin, and other rocket centers were destroyed by Anglo-American bombing, fully or partly. At least 130 leading rocket scientists and technologists, with their theories and projects, were evacuated and later taken to the United States. Wernher von Braun and General Dornberger were among

[2] Ed. Note: German Messerschmitt.

them. The underground factory of V-2 rockets in the Harz Mountains was captured by the U. S. Army, quickly dismantled, and sent, together with its staff, to the United States. Nothing was left behind.

And the USSR? Let me put facts right: the USSR did not get a single *leading* V-2 rocket engineer or administrator, not a single complete rocket factory, and not a single new project. "This is absolutely intolerable," said Marshal Stalin some time later to Colonel-General I. A. Serov, in my presence. "We defeated Nazi armies; we occupied Berlin and Peenemuende; but the Americans got the rocket engineers. What could be more revolting and more inexcusable? How and why was this allowed to happen?"

The only thing that could be done in the circumstances was to sort out the ruins, put pieces together, and study them. Well, we succeeded. With the help of ordinary German engineers, technicians, and workers, we restored not only the general picture but also some laboratories and workshops. Some time later, all this was transported to the USSR, where work was resumed on a wider basis.

What were our impressions of Peenemuende? This is an extremely interesting question, and I would like to answer it frankly. We were quite clear on three things:

(1) in the field of original ideas and rocket theories, the USSR was not behind Germany; in some respects it was even ahead of Peenemuende;
(2) in the field of practical technology of rockets of the V-2 calibre we were definitely behind the Germans;
(3) having seen and studied Peenemuende, we came to the conclusion that there were in the USSR rocket engineers as able and gifted as elsewhere.

I mentioned this in my detailed report to G. M. Malenkov and to the C.-in-C. of the Soviet Air Forces. One year later, in March 1947, I made the same statement at the meeting of the Politbureau and of the Council of Ministers of the USSR. In this sense, we, the Soviet aerospace scientists and technologists, were not worried by the fact that the leading rocket engineers of Peenemuende were in the U. S. A. What we badly needed was the practical technological experience, and this was obtained much sooner than was anticipated. With the help of hundreds of German workers and ordinary engineers who were transported to the U. S. S. R. in 1945-46, V-2 production was fully restored, with some improvements as compared with that at Peenemuende.

From September 1949 there existed in the USSR full scale serial production of big single-stage rockets (the greatly improved versions

of the V-2, under the name "Pobeda") with maximum range about 900 km. and with a fairly reliable guidance system. This production was under Soviet administrators and engineers, by Soviet workers, from Soviet materials, on Soviet soil. Some of the Germans had been sent home. The others continued working on isolated problems in isolated places, under Soviet scientists. To generalize, I would say that the Peenemuende V-2 level of 1944 (before the Anglo-American air raid) was reached by the USSR roughly in 1946-47, while in 1949-50 it was far above that level in terms of both quantity and performance. The first Rocket Divisions (armed with V-2's and "Pobedas") of the Soviet Armed Forces were formed in 1950-51. The exploration of the upper layers of the atmosphere by V-2 type rockets began in the autumn of 1947. From 1949, it was continued by "Pobedas."

This leads me to the question addressed to me dozens of times in various countries. Are the present Soviet space achievements due to mere good luck or to something else? Well, the Soviet philosophies do not believe in "good luck." Of course, if it comes it is welcome, but the Soviet Sputniks, Luniks, and Vostoks are the children of knowledge, not luck. More than that, the Soviet philosophies demand that any education and scientific knowledge must have an aim, a purpose.

The aims of Soviet space technology are twofold, strategic and space exploration. Bearing this in mind, Marshal Zhigarev, then the C.-in-C. of the Soviet Air Forces, in the autumn of 1946, in Berlin, said to me "We must admit that our V-2 type rockets do not satisfy our long-term needs; they were good to frighten England, but should there be an American-Soviet war, they would be useless; what we really need are long-range, reliable rockets capable of hitting target areas on the American continent. This is an aim that should dominate the mind and efforts of your rocket group." On 14 March 1947, in the Kremlin, at a meeting of aircraft and rocket designers, G. M. Malenkov, in turn, made it quite clear to us that the program of V-2-type rockets did not conform to the long-term aims of the country. "No, Comrades," he said, "I am not happy with our V-2's; we cannot rely on such a primitive weapon; besides, should there be another war, it would be a war not against Poland; our strategic needs are predetermined by the fact that our potential enemy is to be found thousands of miles away."

One day later, on 15 March, at a meeting of the Politbureau and of the Council of Ministers of the USSR, I. V. Stalin made the aim even clearer. "Under Hitler, German scientists have developed many interesting ideas," he said with utmost seriousness. "This 'Sänger

Project' seems to represent one of them. Such a rocket could change the fate of the war. Do you realize" (Stalin was looking into my eyes) "the tremendous strategic importance of machines of this sort? They could be an effective straightjacket for that noisy shopkeeper Harry Truman. We must go ahead with it, comrades. The problem of the creation of transatlantic rockets is of extreme importance to us."

Such was the general line, and so were formulated the strategic needs of the country. Accordingly, the Soviet government undertook a number of steps which changed the scale and pattern of rocket production. On 15 March 1947, Stalin personally suggested, and the Council of Ministers agreed immediately, the formation of a special State Commission for the study of the problems of long range rockets (Pravitel'stvennaya Komissiya po Raketam Dalnego Deistviya, PKRDD). It consisted of Colonel-General I. A. Serov (1st Deputy Minister of NKVD, Chairman), Professor-Colonel G. A. Tokaty-Tokaev (Chief Scientist and Deputy Chairman, from the Soviet Air Forces), Professor M. V. Keldysh (member, from the Ministry of Armaments), Professor M. A. Kishkin (member, from the Ministry of Aircraft Production), and Major-General V. I. Stalin (member).

This was an extraordinary decree. It signified a turning point. It was made known to the rocket groups already in existence and influenced their further work very sharply. Towards the end of 1947, as A. G. Kostikof put it, "everybody wanted to design a transatlantic rocket."

In November and December 1947, the state of rocket technology in the USSR was roughly as follows:

(1) the problem of small military rockets had been solved fully and completely;
(2) rockets of the V-1 calibre (but of different types) and of V-2 type were already in serial production;
(3) rockets of the "Pobeda" type were in a state of design;
(4) there were, as far as I knew, already *two* draft projects for long-range rockets. One of them, known as "project TT-1," was developed by my group and presented to the Government in September, 1947. It was a three-stage liquid fuel rocket for extremely high altitude and orbital flights. Had the group been allowed to continue its work without interference from outside, the USSR might well have succeeded in putting a Sputnik round the earth sometime in 1950-52. But for reasons which had nothing to do with the project itself or with our professional qualifications, we found ourselves in a difficult position. Towards the end of 1947 our work was paralyzed. Some of us were compelled

> to seek refuge in the West, and others were arrested; the rest had to wait. Here I should like to mention that Professors Keldysh and Kishkin did not take part either in the project or in our tragedy.

You may guess that, politically and ideologically, I am not an admirer of the Soviet Government. I have always disagreed also with many of its practical acts. But this does not prevent me from having a high opinion of the Soviet Government where rocket technology is concerned. I am in no doubt whatever that no other government contributed to space technology as effectively as the governing officials of the USSR. They made up their minds a long time ago. They instructed the corresponding learned bodies to work out a single long-term national program of space technology. They have never been reluctant in providing the necessary sum of money and supporting facilities.

The consequences? We know them all. Already in 1949-50 rockets of the "Pobeda" type were in actual production and use for both military and space exploration purposes. In 1954 the second of the above-mentioned multi-stage rocket projects was accepted (we shall call it "Project USSR-1"). In April 1956, several "USSR-1" missiles were ready for test. In August, 1957, *TASS* announced to the world that the Soviet Union had fired successfully a transcontinental ballistic missile. Finally, on 4 October 1957, Sputnik I began circling the Earth.

None of these events surprised me, because there was in the USSR a general policy and a national plan of space research and development. I certainly felt sorry for some Western nations with no such policy and plans.

Here, again, we could learn from the experience of "those Russians." They realized a long time ago that rocketry is the elite of modern science and technology and cannot be successful under non-experts. Accordingly, all Soviet ministers, deputy ministers, top administrators, planners, and co-ordinators of aerospace efforts are distinguished aerospace scientists, technologists, and engineers. It is therefore easy for them to understand each other. They do not need to be accompanied by advisers and consultants at governmental meetings. If we add to this the fact that there exists a single central Commission for the co-ordination of all the space research and development work throughout the USSR, which also consists of eminent experts in the field, then it will be clear that Soviet space technology has every reason to be as successful as it is today.

When one analyzes accomplishments and studies numerous publica-

tions, broadcasts, etc., one begins to see that Soviet space technology moves into the future with great confidence. It does not step forward until everything that has gone before is fully worked out. No experiment or design is undertaken unless the theoretical aspects of the problems have been studied. Rightly or wrongly, the Soviet philosophies assert that the field is too complicated, too expensive, and too important to be allowed to grow in any other manner. This explains, at least partly, why the Soviet Union has so few failures in rockets and sputniks.

The progress emerges logically from the general program of space research, which is based on the idea of a systematic step-by-step expansion of efforts. The same general trend can be observed in total rocket thrust, in size of vehicle, etc. I should expect, for instance, that during the next three or four years or so the total thrust of the heavy Soviet liquid-propelled carrier rockets will be nearly doubled. I personally believe that this can be achieved not in a single rocket motor but by combining powerful rocket motors with special-purpose jet and ramjet engines. This is one of the fields of intensive investigation in the USSR at present. Such a sharp increase in the total thrust, of course, would mean that the problem of delivery of H-bombs by long-range rockets would be solved fully and finally.[3] It would also mean that, for exploration purposes, the USSR would be able to put into orbit much more sophisticated sputniks.

A rocket engineer will understand immediately that the combination of rocket motors and jet and ramjet engines will require practically a new rocket vehicle. Soviet designers are working on it now. On the other hand, the multi-stage vehicles already in existence are still far from being perfect. This became particularly clear after Gagarin's and Titov's flights. Hence the conclusion that during the forthcoming years a good proportion of effort will be absorbed by further improvement of existing vehicles.

It is also known that there has existed in the USSR, for a number of years, a powerful group of scientists and engineers which works on the problem of a real spaceship. There is no specific information on the progress of this project, but if I may be allowed to advance a rough guess, I would say that it is not behind the corresponding American project.

Finally, there are good reasons and indications to believe that the USSR is now working very intensively on the project for placing a permanent space-station round the earth. The general ideas of the

[3] Author's note: These words were written in August 1961.

project are not new; but whether it is supposed to house people or to be an automatic station, remains unknown. However, exploiting once again the basic philosophies guiding Soviet space technology, I would suggest that it will be a purely automatic station.

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