By aerospace plane into space and back

During the 1960s, the United States and the Soviet Union were each developing reusable aerospace planes. Russian engineer Oleg A. Sokolov reports on the formerly secret Soviet program.

Did you ever think about the fact that mankind often selects shorter, but less expedient, ways to achieve its aims? More precisely, it always selects the shortest way if it has the means for its realization already in existence, and only some time later will it understand two things: first, that the selected way has some unforeseen consequences, and, second, that there was another, "evolutionary" way which would be more rational, but its realization would require more time, mainly for the development of the means for its realization.

Man going into space is a good example of the above thesis. Indeed, when the means suitable for manned spacecraft injection (military ballistic missiles) had appeared, their designers, who remained enthusiasts of space flight, used them for achieving this great goal. Under a thunder of triumph, it was forgotten, somehow, that these means had been intended for a quite different purpose, and that their feature of passing quickly through the Earth's atmosphere at the initial and end parts of flight, was only a requirement for military operations (the quickness of striking a blow, and passing through an anti-missile defense).

It is interesting that the rocket pioneers of the 1920s and 1930s understood that the Earth's atmosphere could not only be an enemy, but also a friend, on the way to space and back. At that time, there were spacecraft projects to develop gradually modified "rocket planes," which would use the atmosphere as a support for flight, as a supply of oxidizer up to higher altitudes, and as a means for aerodynamic braking during reentry. However, when a means for "direct braking" through the atmosphere was found ready at hand, the old projects were put aside.

True, in the 1950s, the designers of the first manned spacecraft tried to investigate reusable spacecraft with aerodynamic reentry practically simultaneously, both in the United States (the "DynaSoar" project) and in the Soviet Union. However, a simpler means of reentry had been found near at hand—ballistic reentry capsules based on missile warhead technology—and use of even a part of the aerospace idea was, again, temporarily forgotten.

But this idea was not forgotten by *all* designers at that time. I would like to discuss the most advanced attempt of Russian designers to develop a real aerospace system, because I was lucky enough to be a participant in this work.

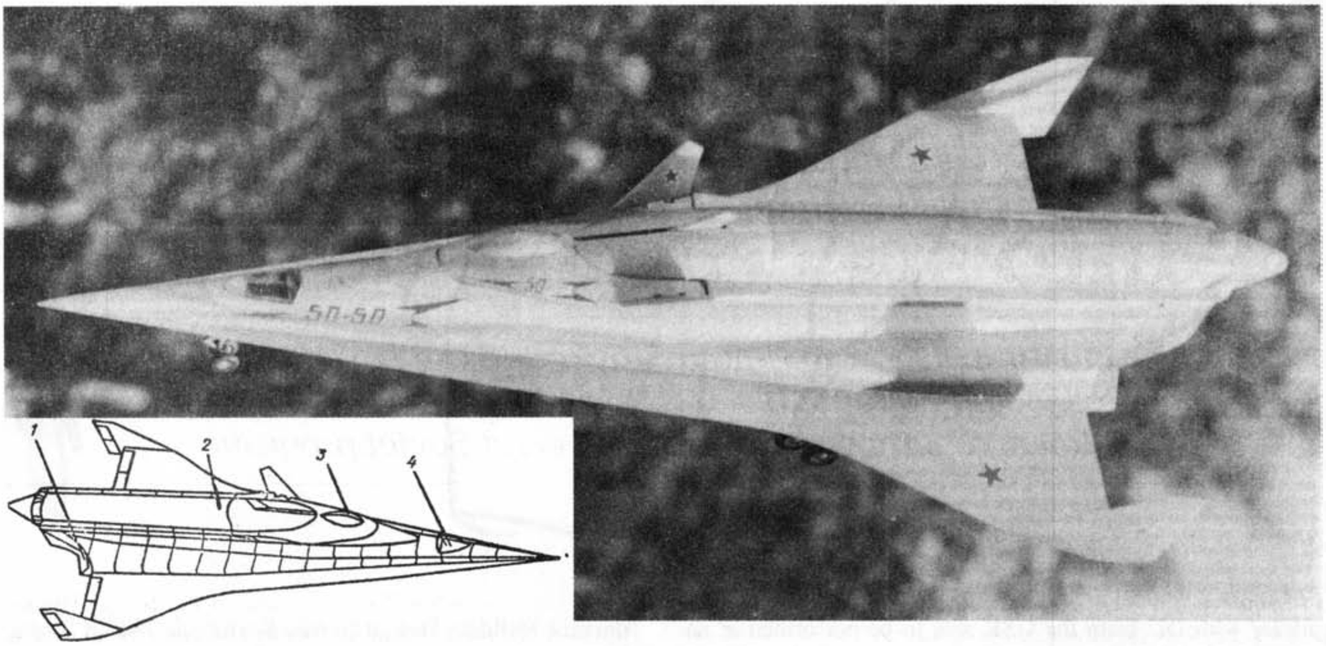
The 1960s: the 'Spiral' aerospace plane

First of all, let us define a real (or "pure") aerospace system: It is a system intended for the injection of spacecraft into near-Earth orbit, and the return of the spacecraft to Earth. It uses the Earth's atmosphere as much as possible, both for support for the flight during launch and reentry, and as a supply of oxidizer (atmospheric oxygen). Therefore, the system should have a return spacecraft, and also, because "g," or gravity loads during injection and reentry should be minimal due to the profile of flight, it is most suitable for manned missions; because of the "aviation nature" of the system, it provides opportunities for reusing system elements, or the system as a whole. Of course, it is preferable that this system be single-staged; however, multi-staged versions are also possibilities.

Just such project development was begun in the Soviet Union in the early 1960s. This development was performed in the Soviet aviation industry, and it could be assumed to have been an attempt of Russian aviation designers to make their "own way into space" (because the main way had been occupied by adherents of "pure rocket" technology).

The initiator of this development was Dr. Gleb Lozino-Lozinsky, who was, at that time, the Deputy General Designer

FIGURE 1
Spiral and the 50/50 vehicle configuration



1. GSP, hypersonic airplane booster
2. DU, additional booster 3. Orbiter 4. GSP cockpit

of the famous MiG (Artem I. Mikoyan Experimental Design Bureau) aviation firm, and this enterprise was appointed as lead developer of the project, which received the name "Spiral." Today, Academician Lozino-Lozinsky is well known as the general designer of the space shuttle Buran orbiter. The preliminary draft program of the Spiral project was signed in 1965, and funding was provided.

The final goal of the Spiral project was to give Soviet cosmonautics, in the mid-1970s, a multi-purpose aerospace vehicle for manned, low-Earth-orbit missions. Practically, it was a competitor to the Soyuz "pure rocket" space system, whose development was also begun at approximately this time.

Sergei Korolev, the Chief Designer of rocket systems and the head of Soyuz development, provided support for the Spiral project in every possible way, and even transferred to Dr. Lozino-Lozinsky all the documentation on the preliminary development of the Russian counterpart of the American DynaSoar ("dynamic soaring") program. The 1950s design was a manned spacecraft having an original body shape and folding wings. For its body shape, Korolev gave it the nickname "Lapotok" (a small "lapot," or bast sandal, was an old Russian national shoe). The documentation of its development was very useful during selection of the Spiral spacecraft body design.

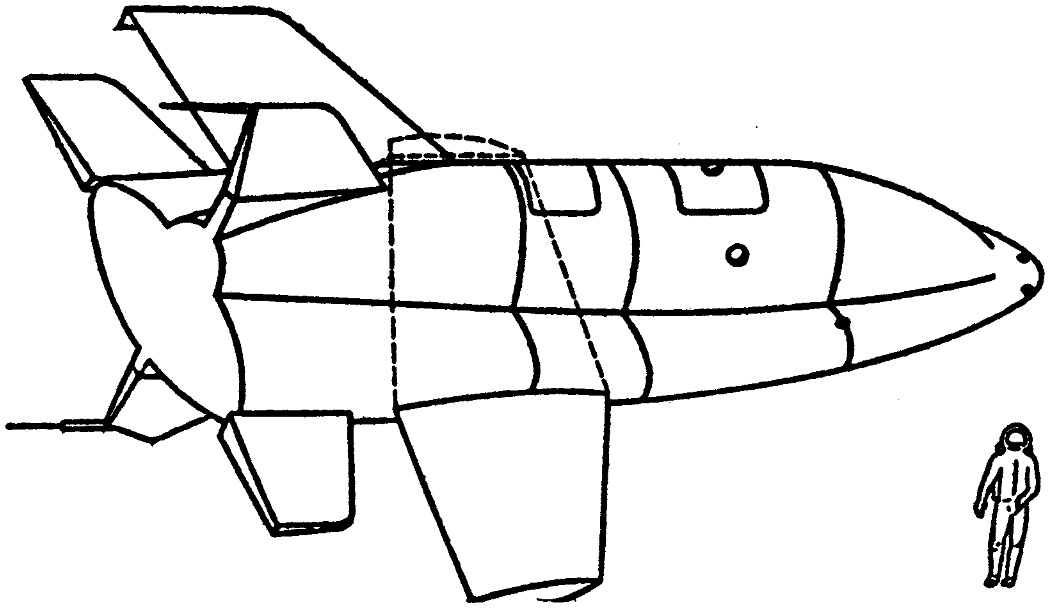
What should the Spiral system be, according to the preliminary draft, and what stages in its creation were foreseen by the program?

In a final version described in the project draft, the Spiral system was to consist of three main parts: the Hypersonic Airplane-Booster (the GSR, Giperzvukovoy Samolyot-Rasgontshik), and the Orbital Plane (the OS, Orbitalny Samolyot) with the Additional Booster (the DU, Dopolnitelny Uskoritel). The system is shown in **Figure 1.** (A schematic of the "Lapotok" is shown in **Figure 2.**)

The OS, or orbital plane, was the most detailed design in the draft. It was to be a real airplane having a lifting body with two short folding wings. Its mass was to be about 10 tons, with a length of 8 meters and a wingspan of 7.4 meters. For orbital maneuvering, the OS was to have main and spare liquid bi-propellant (nitric tetroxide plus unsymmetrical dimethyl hydrazine, or UDMH) rocket engines, and a system of thrusters with their own propellant supply. The guidance and control system of the OS was designed to be an on-board computer, an advanced solution at that time. The OS could have a small turbojet engine for powered atmospheric flight during landing.

The design of the GSR, the Hypersonic Airplane Booster, was less detailed. It was proposed as a delta-winged manned hypersonic airplane without a tail, having its four multi-mode turbojets under its body, using kerosene or liquid hydrogen fuel. The OS, together with the DU (additional booster), was to be installed onto the "back" of the GSR, with their front and rear ends closed by fairings. The separation of the OS

FIGURE 2
The 'Lapotok' space vehicle, a precursor to the Spiral system



orbiter with DU from the GSR was to be performed at an altitude of 22-24 kilometers and flight speed of Mach 4 (for kerosene fuel), or 28-30 km and Mach 6 (for liquid hydrogen fuel), accordingly.

The draft described the DU only as a two-staged liquid bi-propellant (liquid oxygen plus kerosene, or liquid oxygen plus liquid hydrogen) booster.

Such a system was to have a total mass of about 140 tons, which could inject the OS orbiter with crew of three men into low Earth orbit at an altitude of about 130 km, and in which the OS could perform two or three revolutions with the possibility of a change in altitude and orbital plane. The OS would be able to perform an "aviation" landing at any airfield. The landing device was a ski chassis.

All elements of the system, excluding the DU, were to be reusable.

The program provided for the development of two manned aircraft-analogues for the OS, to be dropped from an air carrier—the TU-95 heavy bomber (the "Bear" by Western designation)—for aerodynamic testing. One of the aircraft would be for subsonic tests, while a second analogue would have a maximum speed up to Mach 6-8. According to the schedule of the program, the development of these two aircraft analogues would begin in 1967 and 1968, respectively. Work on the GSR was scheduled for 1970.

For the first tests, a sub-scale, unmanned experimental version of the OS would be injected into orbit by the Soyuz launch vehicle. In 1972, the GSR manufacturing would be begun, and a first manned orbital flight of the Spiral system would be performed in 1977.

I was involved in the Spiral system development at the end of 1968. At that time, I was working in the Tourazhevsky Machine Building Design Bureau Soyuz (the TMKB Soyuz, or Tourazhevskoye Mashinostroitelnoye Konstruktorskoye Buro Soyuz), an enterprise of the Ministry of Aviation Industry. The TMKB Soyuz was situated 30 km from Moscow in the town of Tourazhevo, and specialized in the development and manufacture of liquid bi-propellant rocket engines, thrusters, and propulsion units for cruise missiles and spacecraft.

The broad scope of capabilities of the Ministry of Aviation Industry had provided an opportunity for the development of propulsion units for aerospace vehicles created by this ministry, and our enterprise received the order for this development. I was not a designer at that time, but was working in the Flight Test Department of TMKB Soyuz. Because our department was responsible for all joint work performed with the vehicle developer during flight test preparation and the carrying out of test firings of the propulsion unit of the vehicle, a team of flight test engineers was formed to take part in this project.

I was not a beginner in the field of aerospace vehicles: Before my graduation from the Moscow Aviation Institute, I had done practical work in the Institute for Theoretical and Applied Mechanics in Novosibirsk, Siberia, where development of a single-stage aerospace plane had been carried out. True, this development was not even a project, it was mostly a theoretical investigation connected with the experimental work of the Institute on a supersonic combustion ramjet. But for this reason, or, maybe, because of my aspiration to take part in all new space developments (it was so interesting for a young engineer; that was still a "heroic" period of cosmonautics!), I was enlisted in the team of the Spiral project. Simultaneously, I took part in work on the N-1/L-3 manned lunar program.

But what of it? Every day had 24 hours, had it not?

So, our designers began to develop a project for the propulsion unit for the OS orbiter. The TMKB had ready designs of propulsion unit elements which were suitable for use in this new system. A general layout was made: a pressurized propellant supply system, one main combustion chamber and two spare chambers with total thrust equal to the thrust of the main chamber, and a kit of thrusters for on-orbit attitude control and stabilization. Our traditional propellant was selected: nitric tetroxide and UDMH.

The propellant had an interesting feature: Usually, a high-pressure gas for pressurized propellant supply is stored in special on-board bottles or containers, and provides pressure in propellant tanks through a pressure regulator. The gas pressure in the propellant tanks is maintained at a constant level while it is running. But in the OS propulsion design, the gas for the propellant supply would be pumped under pressure directly into cylindrical propellant tanks having bellows separators. Because the combustion chambers and thrusters were running under a decreasing pressure from the supply, there would be a gradual decrease in the thrust. (Such a method of supply, for us, had the nickname "pig," because the diagram of the supply pressure resembled the snout of a pig.)

Such a solution provided simpler servicing during fueling and, mainly, eliminated the mass of heavy pressurized gas containers, while the relatively short time of orbital flight permitted some decrease in the thrust level.

By the spring of 1969, the preliminary design of OS's propulsion unit had been confirmed and—was put aside. The Spiral program required other, more urgent work.

The illusive BOR

In the Spiral program, the use of the OS scale-model vehicle (a scale 1:2 or 1:3) had been provided, for the purpose of investigating the aerodynamic performance of the aerospace vehicle during reentry into the Earth's atmosphere. Such model vehicles, called BORs (Bespilotny Orbitalny Raketoplan, or Unmanned Orbital Rocket plane), were developed and manufactured in the Flight Test Institute (the LII, or Liotno-Ispitatelny Institut), the largest Russian flight test center, situated in the town of Zhukovsky, near Moscow.

The test vehicles were designed under the management of the omnipresent Dr. Lozino-Lozinsky, with their first experimental flights to be performed along a sub-orbital trajectory, with a transition to orbital flights. Initially, it had been assumed that for their attitude control during reentry into the atmosphere, it would be enough to use a system of reaction gas ejectors supplied by a solid propellant gas generator. A constantly burning gas generator would provide a hot gas supply for a kit of ejectors (nozzles) through control valves. However, a more precise calculation showed that liquid bipropellant thrusters would be necessary. Because of that, our enterprise received an urgent order to develop and manufacture a propulsion unit for the BORs.

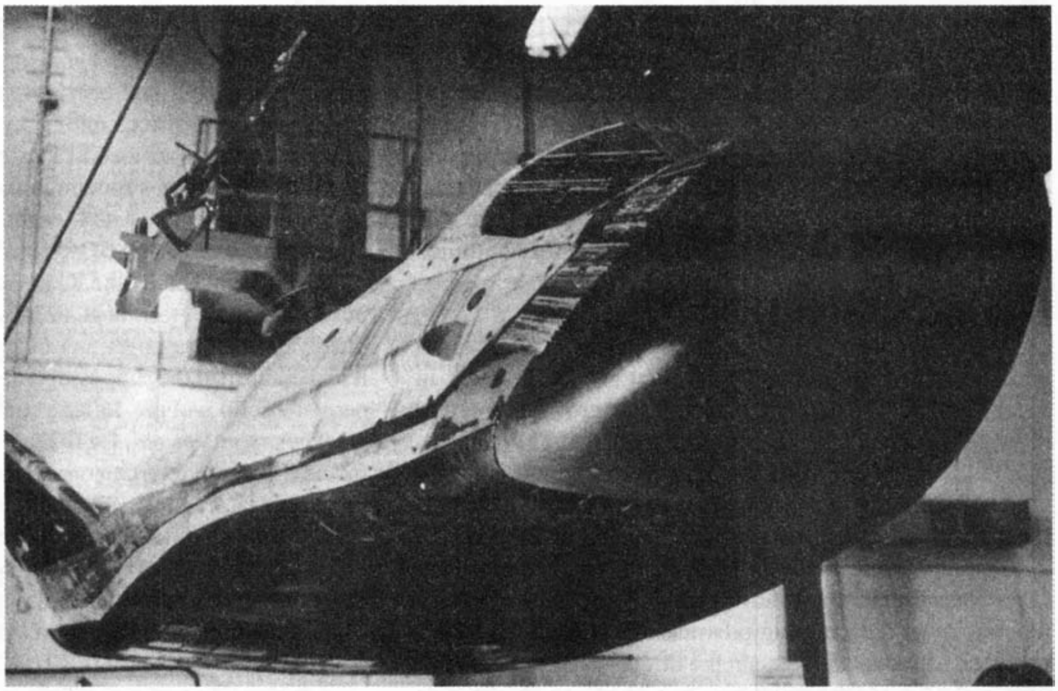
The first BOR (BOR-1) having a solid fuel gas generator propulsion system had been just manufactured, and I was assigned the task of acquainting myself with its design. When I opened the door of the LII's assembly workshop, I nearly trod upon a wooden structure in the shape of a great galosh. "What do you make of it? It is our flight example!" workers cried to me. Indeed, the BOR-1 had a wooden structure!

It was launched by the R-14 (SS-5) missile from the Kapustin Yar rocket test range in July 1969, and before it completely burned up at an altitude of about 70 km during descent, it had confirmed the supposition of the insufficient effectiveness of a solid fuel gas attitude control system.

The propulsion unit for BOR-2 was developed and manufactured very quickly. Our designers took a ready spherical bipropellant tank and gas container from an existing propulsion unit, which was intended for the attitude control and restart of the Proton launch vehicle's upper stage, and placed eight 10-kilogram thrusters at the bottom rear of the BOR vehicle. (A general view of the BOR-2 is shown in **Figure 3.**) Flight tests of the BOR-2 began in 1970.

I did not take part in the flight tests of the BOR-1, because I was occupied by the work on the N-1/L-3 lunar vehicle system, but I enjoyed the BOR-2 flights in full measure. Be-

FIGURE 3
The BOR reentry test vehicle



cause I had had some experience with helicopter flights in an aeroclub, I was appointed a member of the search and rescue team for the BORs during landing.

The BOR-2s were launched from the Kapustin Yar, as was the BOR-1, and they landed near Lake Balkhash in Central Asia, near the territory of the Sary-Shagan test range. After aerodynamic braking and some gliding provided by their lifting body and small wings, they were supposed to descend by parachute. However, as a rule, the BORs tore this parachute, because they had a significant horizontal velocity, and fell a few kilometers from the expected landing point. So, the area of the BORs' possible landing was very indeterminate, while it was quite necessary to find it, because practically all the information received during a flight was not transmitted by telemetry (which was impossible during aerodynamic heating because of the hot plasma layer surrounding it), but was stored in a recording device.

Finding the wooden BOR was more difficult than finding a needle in a haystack (indeed, you could find a needle with radar, or by using a magnetometer), because the Sary-Shagan region was intended especially for falling experimental vehicles launched from aircraft or with missiles, it was filled with the debris of such vehicles.

We used the Mi-1 lightweight helicopter (which had insufficient heating in the cockpit, and in the winter, after a couple of flight-hours, we got out of the helicopter like frozen broilers from a refrigerator) to locate it. In turn, we found our BORs in very unexpected spots.

One of them directly hit a draw-well, which was the only one for hundreds of square kilometers, and another was found practically intact at a railway embankment, which was the sole railway in this part of the world. (A representative of the Air Force, who was also a member of our team, kidded us: "You are using your vehicles wrongly. They should be added to the Soviet Army's armory, and, in case of war, our enemies would quickly lose their railways and sources of water!")

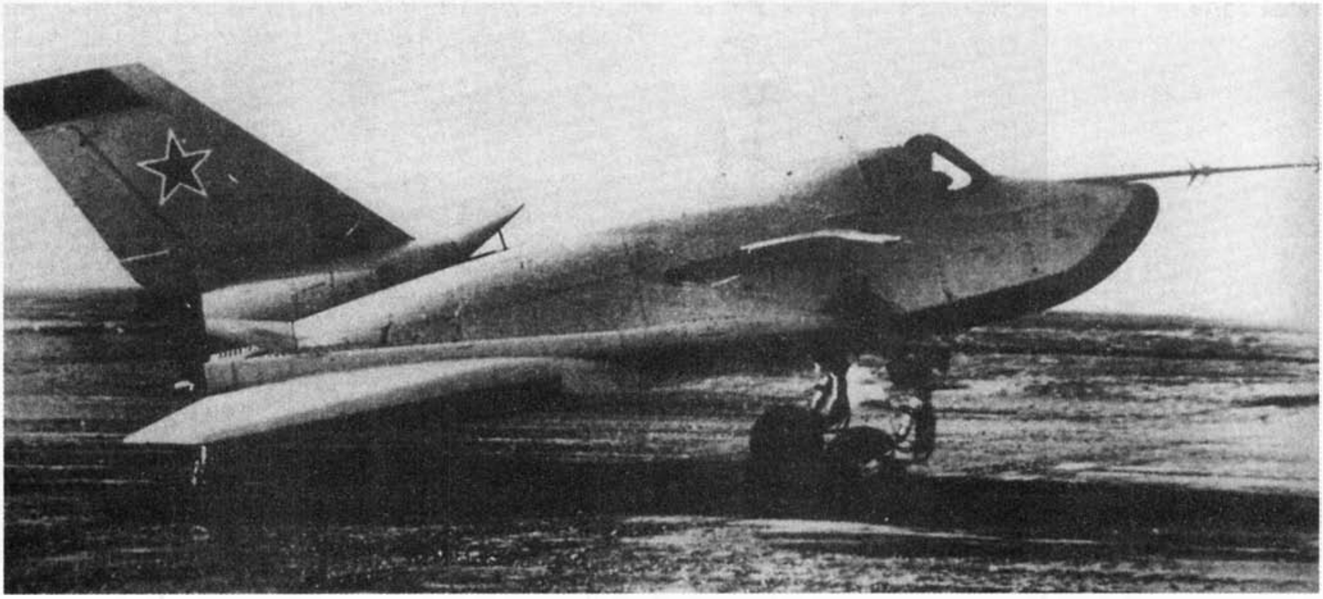
Of course, tests of the BORs were not the only experiments in the Spiral program. There were numerous tests in wind tunnels, various tests of insulating materials, and so on. Flight tests of the BORs had been mainly intended for confirmation of the calculated technical solutions, and it was possible to say that this confirmation was received. However, funding for the Spiral project began to be reduced; the giant pump of the lunar program was sucking out the lion's share of money intended for all of Soviet space activity.

Besides the BOR tests, the only other part of the Spiral project that was realized was the development of subsonic aircraft, the analogue of the OS orbiter.

The 1970s: the Spiral Analogue

By the time the OS started development, it had become the EPOS (Experimentalny Pilotiruemy Orbitalny Samolyot, or Experimental Manned Orbital Plane), because the final goal of the Spiral program had been revised, and, instead of creating an operational aerospace system, it had been aimed at gathering experience only on the use of elements of such a system. The Analogue (its official name) had the shape of the EPOS (former OS), with wings fixed in an unfolded position

FIGURE 4
Full-scale version of the Spiral orbiter first flown in 1965



(contrary to the BORs, which had wings fixed in a folded position), and a small turbojet. Initially, the chassis had wheels, which later were replaced by skis. A 1960s forerunner of the Analogue is shown in **Figure 4.**

The Analogue flight tests began in May 1976 with short flights over a runway. On Oct. 27, 1977, test pilot A. Fastovets performed the first flight, dropping the Analogue from the TU-95 heavy bomber. In 1978, five more such flights were conducted.

However, this liturgy was celebrated without a bishop. In 1976, Dr. Lozino-Lozinsky was appointed the General Designer and General Director of the newly established Molniya (Lighting) Design Bureau, whose main task was the creation the Soviet counterpart to the American Space Shuttle orbiter. Dr. Lozino-Lozinsky took with him practically all his colleagues who had been involved in the Spiral program, and also transferred to the Molniya Design Bureau all plans concerning the BORs; they would now be used for the development of the Buran orbiter.

The BOR-3 project, which would have been an orbital version of the BOR-2 (with a telemetry unit for data transmission during an orbital flight, braking engines, and a modified parachute system), was re-designed into the BOR-4 version, which was intended to test thermal insulation for the Buran. These BOR-4s were launched under the names Cosmos-1374, -1445, -1517, and -1614, from 1982 to 1984. The follow-on versions of BORs (BOR-5 and BOR-6), with the shape of the Buran (in a scale 1:8), had been developed by the Molniya Design Bureau, and six BOR-5s were tested in suborbital flights.

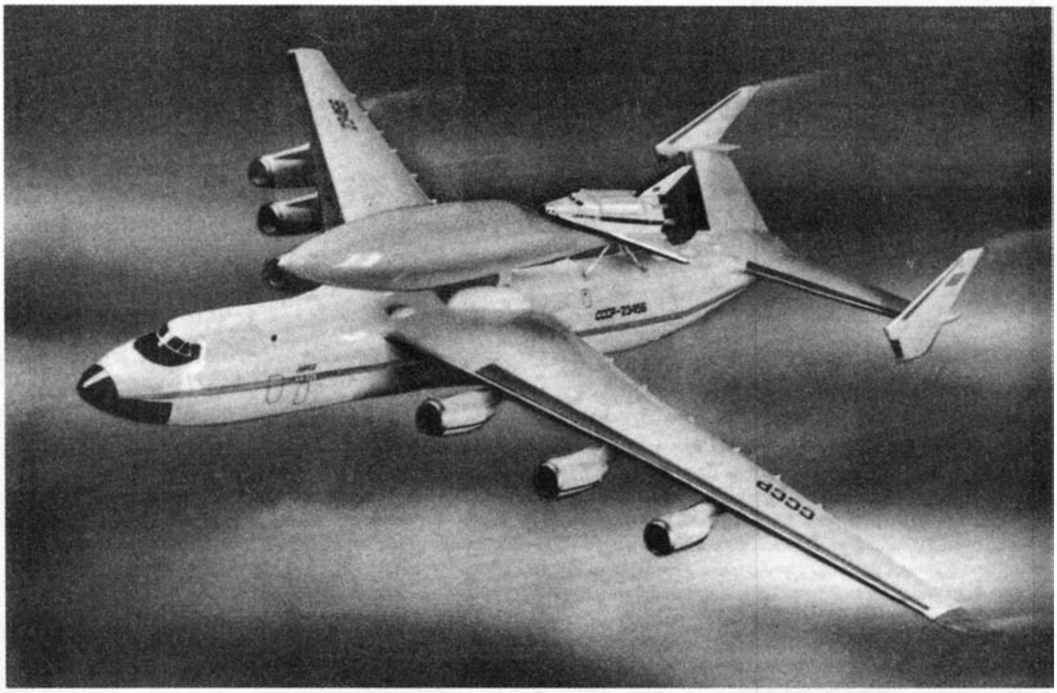
However, such a "reanimation" of the BORs' use, bore no relation to the Spiral project, which was officially abandoned in 1978. Now, the development of aerospace systems in the Soviet Union would go by way of copying the American Space Shuttle, which was only a quasi-aerospace system because of its pure rocket launch. But, some time later, it was found that even if a cat has taken the monastic vow, it continues to dream about mice.

The 1980s: MAKS

When, in the mid-1980s, a competition was announced in the Soviet Union for preliminary designs of an aerospace plane in order to determine the directions of possible cosmonautics development, Dr. Lozino-Lozinsky presented a very detailed project for an aerospace system. It was a further development of the Spiral project, making use of prior experience and existing hardware: The super-heavy cargo aircraft Mria would be used as an air carrier (instead of the GSR) for a space plane which had the shape of the Spiral's orbiter, but had twice the mass and was installed onto an expendable propellant tank (an adoption of the Space Shuttle external tank solution).

Two main engines adopted from the Soviet Energia launch vehicle core stage would be installed in the space plane, supplied with liquid oxygen/hydrogen from an expendable tank. Such a system would inject the space plane, with a crew of four and a payload of 3.2-3.6 tons, into low Earth orbits, with different possible inclinations to the equator. A

FIGURE 5
MAKS concept



crew and a payload of 2 tons could be returned to Earth. An overall view of this system, which some time later received the name MAKS (Mnogotselevaya Aviationno-Kosmicheskaya Systema, or Multi-Purpose Aviation Space System) is shown in **Figure 5.**

This project was subjected to strong criticism. In particular, it was assumed to be a technical mistake that a "pure aviation" solution, introducing a pilot into the control circuit during the orbital injection part of the trajectory, had been taken. However, the main criticism was that the Buran-Energia system had been successfully developed, and nobody wished to spend money to develop another system. Moreover, Dr. Lozino-Lozinsky was accused of "underground" development of the MAKS project at the expense of Buran funding—which was quite true. Even the Mria airplane ordered by the Molniya Design Bureau as a transporter for the Buran had some features suitable only for use as a "flying launch site." But these accusations had no consequence.

The MAKS project continued. When, in 1993, after a successful orbital flight of the Buran, this Russian shuttle had been canceled because of economic difficulties, the Molniya Design Bureau proposed the MAKS project for use on a commercial basis. Initially, this proposal had been widely supported by the Ukrainian National Space Agency and by the Ukrainian Antonov Aviation Design Bureau, the developer of the Mria airplane. Some foreign firms were also interested in this project.

However, official support and funding from the Russian government was absent, the Ukrainians had no money, and potential foreign customers did not hurry to invest their money, either. Moreover, some space specialists and officials said that the Ukrainians intended, under cover of this project and its funding, to build another Mria airplane (there was only one operational) for commercial use as a cargo plane.

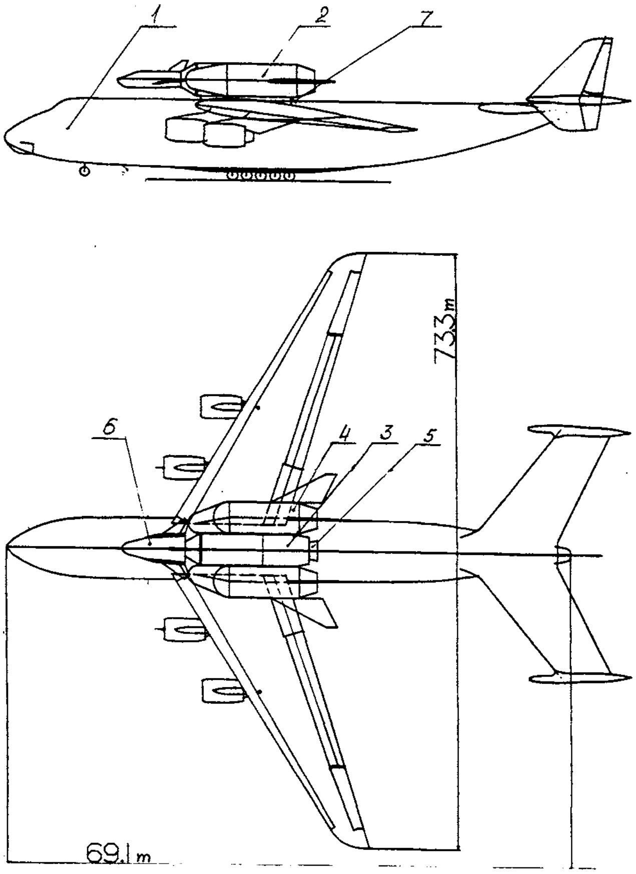
Academician Lozino-Lozinsky (he had received this title after the Buran development) and his colleagues developed a new Russian version of the MAKS project. Its mock-up was first shown at the Paris Air Show in Le Bourget in July 1995. The Ukrainian Mria airplane was replaced by the An-124 Ruslan heavy cargo airplane. These aircraft are in the service in the Russian Air Force. (True, they are not in production at present, but their equipment is maintained at the Aerostar aviation enterprise in the town of Ulianovsk in Russia.)

The size of the orbital (space) plane was diminished, because the payload of the Ruslan airplane is less than the Mria's payload capacity, and it actually became nearly the good old OS orbiter of Spiral. Even the DU (additional booster) arose again, instead of the expendable propellant tank of the MAKS. The second stage of the new Russian Angara heavy launch vehicle in development would be used for the final injection of the orbital plane into low Earth orbit. Such a system can have a crew of two and a payload up to 1-2 tons, and return the crew and a payload up to 1 ton to the Earth. The general design of this system, called Angara-Molniya, is shown in **Figure 6.**

The takeoff of this cluster, with the installation of the

FIGURE 6

A schematic of the Angara-Molniya aerospace system



1. Ruslan AN-124 air carrier
2. Second stage of the Angara launch vehicle
3. Oxygen core tank of the Angara second stage
4. Hydrogen side tank of the Angara second stage, with a wing
5. Main rocket engine of the Angara second stage
6. Molniya orbiter, or space plane
7. Support truss

orbital plane together with the Angara stage at the "back" of the airplane body, will require a modernization of the Ruslan airplane. In particular, the tail unit should be made two-finned. The second stage of the Angara launch vehicle should be modified also: It should get wings for some aerodynamic support during takeoff from the air carrier and, possibly, for a return to the Earth for reusability (a further improvement of the system). Its main oxygen-hydrogen rocket engine (the RD-0120, the same one which had been used in the Energia launch vehicle and was intended for the MAKS) can be replaced by the RD-701 tri-propellant rocket engine.

When I showed a mock-up of the Angara-Molniya to visitors at the Paris Air show (this mock-up was installed at a display of the Angara launch vehicle's developer, the Khrunichev State Research and Production Space Center, the place of my present work), and I explained to them the prospects for the future use of this system, I thought that at a future air show it would be possible to show an operational version of the Spiral space plane. However, the process of development of the world's launch vehicles and spacecraft is turning, once again, off the road leading toward the creation of a real aerospace vehicle.

For now, it is enough to remember that the Space Shuttle initially was conceived as an aerospace vehicle, i.e., a spacecraft having aerodynamic takeoff and landing. Instead, we can see only two operational *quasi-aerospace* systems at present: the Space Shuttle, having a rocket launch and aerodynamic landing, and the expendable American Pegasus lightweight launch vehicle, which has an "aviation" launch from an air carrier.

When will we be able to see a flight of a real aerospace system? I think, when such a system becomes necessary. What are the main distinctive features of an aerospace system? Reusability, mostly suitable for manned missions; an opportunity for injection into any orbital inclination; and the possibility to use airfields instead of cosmodromes. (True, such airfields should be of high caliber, intended for heavy airplanes, but their number in the world is large enough, and much larger than the number of cosmodromes.) The necessity for the use of aerospace systems will arise when many people are at work at numerous near-Earth space stations, engaged in the production of super-pure and rare materials and substances in microgravity conditions, the assembly and servicing of interplanetary spacecraft, and even enjoying holidays in space.

I think that at that time, our "usual" launch vehicles will remain only as a means for the delivery of heavy expendable payloads, and projects like the Delta Clipper will take their place in museums as technical curiosities. (Indeed, is it not enough that only rocket engines, rather than aerodynamic structures, are used for "braking" in the atmosphere? Should they be used also for braking during a landing in an atmosphere without *any* aerodynamic support? It is very suitable for the Moon, but we are living on the Earth, thank God.)

When will this time of real "rendering habitable" of near-Earth space begin? It will be possible in the beginning of the 21st century. The development of space technologies and joint international space projects, including scientific and commercial ones, pave the way toward that, while the end of the Cold War provides the political basis for such a direction of mankind's activity.

Of course, the use of aerospace systems is a matter for the future. But when the need arises, the hardware will be ready. You have read here about the direction of this work in Russia, but such work is in development in the United States, the United Kingdom, Germany, and other countries.

Would you like to book an airplane ticket to space?