

CONTEMPORARY ACHIEVEMENTS IN ASTRONAUTICS:
SALYUT-7, THE VEGA PROJECT AND SPACELAB

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16. Abstract The anthology's articles relate the latest achievements in Soviet aeronautics? the new stage in the space program to study Venus using Soviet automated space probes, and the next space mission by cosmonauts to the Salyut-7 station. Information is also presented on flight of the Spacelab orbiting laboratory created by Western European specialists. ORIGINAL PAGE IS OF POOR QUALITY			
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SALYUT-7: THE FOURTH MAJOR EXPEDITION
(CHRONICLE OF THE FLIGHT)

V. N. Kubasov

The Baykonur steppe long ago grew accustomed to the roar of rockets being launched. And so today, June 6, 1985, above a massive concrete pad towers the next 49-meter silver arrow, still surrounded by platforms and service supports. /3*

Two and a half hours before launch, the crew arrived at the rocket to occupy their places in the cabin of the Soyuz T-13 spacecraft. Once again, the crew was headed by Vladimir Dzhanibekov. Therefore, the call name "Pamiry" was again heard in space. This time, flight engineer Viktor Savinykh was flying with him.

Vladimir Dzhanibekov gained renown as early as 1973, when crews were formed to train for the first international flight under the EPAS program. He was commander of the third crew, i.e. one of the backups, and we got to know him well during group training. Then the complicated Soviet program on the Salyut-6/Soyuz orbiting research complex was begun. This program was organically combined with a new stage in the Interkosmos Program, which included flights by representatives of fraternal socialist countries. Vladimir Dzhanibekov visited the Salyut-6 twice: in January, 1978 with Oleg Makarov as part of the first visiting expedition, clearing the way to space with an international crew under the Interkosmos Program, and in March, 1981 with the Mongolian cosmonaut Zhugderdemidiy Gurracha.

Vladimir Dzhanibekov was also on the Salyut-7 station twice. In 1982 he became commander of a Soviet-French crew, replacing Yuriy Malyshev, who had suddenly become ill. Vladimir Dzhanibekov quickly mastered the flight program, studied procedures for conducting various scientific experiments, and learned to work with full mutual understanding with crewmate Alexander Ivanchenkov and researcher-cosmonaut Jean Louis Cretien. In July, 1984 Vladimir Dzhanibekov completed his fourth flight into space, heading a crew with Svetlana Savitskaya and Igor' Volkov. /4

An alumnus of the Suvorovsk School, Vladimir Dzhanibekov had successfully mastered the Suvorovsk principle: the rougher the training, the easier the battle. No matter what he undertook, he did it thoroughly, never missing an opportunity

*Numbers in the margin indicate pagination in the foreign text.

to augment his knowledge and to increase his skill at mastering technology. This helped him more than once in a pinch. For example, on the day before the launch, when the Soviet-French crew had little so-called personal time, his commander, without thinking twice, sent him to the simulator to once again analyze manual docking alternatives, especially from long distances. After two days in space, 900 meters from the Salyut-7, a situation occurred requiring a switch to manual control. Until then, manual docking had been done only at distances no greater than 200 m, but Vladimir Dzhaniybekov unhesitatingly made the decision, took the controls into his own hands, and docked the craft at the station.

Victor Savinykh was two years older than his commander, although to look at him, one would think just the opposite. In good physical shape, graceful, impetuous, he still showed no sign of graying, unlike Vladimir Dzhaniybekov. Victor Savinykh was born in the country near Kirov, and he came (as he himself says) from peasant stock. Throughout his entire childhood and youth he dreamed of nothing but the heavens, especially about space. He graduated from Perm' Technical School for Railroad Transport, and worked building the railroad in Western Siberia. After the army, he entered Moscow Institute for Geodesic, Aerophotographic, and Cartographic Engineers and, after his graduation, joined our design bureau. There he began to take part in development of optical devices for control systems on manned spacecraft and space stations.

Victor Savinykh spent a lot of time at the cosmodrome. Together with other specialists, he prepared the first Salyut, and later other stations, for flight there. He was attracted to space not by idle curiosity, but by his keen engineer's mind. Victor Savinykh made his first flight with Vladimir Kovalenko, spending 75 days in space. Aboard the Salyut-6 they made two expeditions, one of which, Soviet-Mongolian, was headed by Vladimir Dzhaniybekov. So the Pamirs already had experience working together in orbit, although this was the first time they would be launched together.

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"Prepare for launch!" The first launch command resounds. Commands follow in quick succession, and after the command "Ignition!" the first jets of flame appears from rocket engine nozzles. The growing roar fills the steppe. The engines shift first to preliminary mode, then to intermediate, and finally to main. "Lift off!"

"Let's go..." says Vladimir Dzhaniybekov, half assertively, half questioningly, as if inviting the flight engineer along into orbit. "Let's go," agrees Victor Savinykh. The screen at Mission Control displays the words "Actual launch time 9 hr 32 min 52 sec." This was according to Moscow Winter Time.

Space flights have become a familiar phenomenon, but it is still too early to relegate them to the ranks of everyday happenings. As before, each flight reveals new puzzles of the Universe and is a test of the spacecraft itself, which is constantly being improved. And each flight represents a new entry in the history of world astronautics. But what the Pamirs encountered gave their flight special significance.

They traveled to the Salyut-7 which, as we know, had been in automatic flight mode since October 2, 1984. At first, everything had been normal. Upon commands from Earth, the station had been "reporting" the status of its own systems and the dynamics of its motion. So it had gone for 5 months. Then, however, as a result of a malfunction in one of the on-board radio system modules, communications with the station had been cut off. The Salyut-7 lapsed into silence and became a virtually uncontrollable object.

Only cosmonauts could restore the station to normal operation. But they had to get to the station, which, in this situation, was an extraordinary task. The station usually participates in the docking process: it "answers" radiosignals, and orients its docking module to the approaching spacecraft. Now, a whole new ballistic approach pattern had to be developed, the transport ship properly prepared and fitted with the required equipment, and the crew and mission control specialists trained. And this was done in just three months.

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In two days of independent flight, the Soyuz T-13 corrected its orbit several times, gradually approaching the Salyut-7 station. Final approach operations began on the morning of June 8. After the next trajectory correction, they were separated by only about 10 km. From that moment, as prescribed by the program, cosmonauts Vladimir Dzhazibekov and Victor Savinykh became actively involved in the control process. Vladimir Dzhazibekov deployed the ship so that its lateral axis pointed toward the Salyut-7, which was clearly visible through the porthole of the descending craft, like a bright star on the background of the black sky. The optical guidance system permitted sufficiently accurate monitoring of the station's position.

Victor Savinykh entered data from measurements into the onboard computer. Using the results of several such "reports," the computer calculated the craft's flight trajectory around the station, and the automatic equipment executed the last correcting maneuver. At a distance of 2.5 km, the crew switched to manual control. Using a laser rangefinder and the onboard computer, the Pamirs reached a point 200 m from the station and stopped to better evaluate docking conditions. The station was not lit very favorably: it glistened too brightly

under the Sun's rays.

Having consulted with Mission Control specialists and having received permission, Vladimir Dhzanibekov began the final stage. He brought the ship a little closer, flew around the station and arrived at its connecting compartment. Tracking the docking process at Mission Control, we saw this picture with the help of the Soyuz T-13's TV camera. The Salyut-7 station appeared before us unusually foreshortened. According to how its image rotated on the screen, we almost physically felt the maneuvers of the craft, which was completing truly supreme flight in space.

Then the picture became more normal -- the station's docking module appeared on the screen and gracefully moved toward rendezvous. There remained 30 m..., 20 m..., and there /7 the range of television visibility ended. However, radio communication continued, maintained by floating measuring points -- USSR Academy of Sciences ships. There was still time before it entered the Earth's shadow to achieve docking. Otherwise, docking would have to be postponed, and the craft would have to "hang" a safe distance from the station. The craft had a night-viewing device so that the cosmonauts could monitor remotely in darkness.

"Contact. Mechanical hookup." announce the Pamirs. The quiet of anxious anticipation in Mission Control's main room is replaced by applause and jubilation. At 12 hr 50 min Moscow Summer Time, the craft's docking pin touched the station's receiving cone. The catches activated, and the two space craft began to draw closer until firm mechanical contact was made between them.

The craft froze at the station's dock, merging with it into a single orbiting complex. There was a growing desire to open the connecting hatches as quickly as possible, and it seemed that checks on the docking seal take too long. In this case, this desire was even stronger, since on the other side of the threshold of the general compartment was the station, about whose condition the Earth had received no information whatsoever for three months. Something could be learned about the station even before the hatches opened, if certain sensors could be hooked up to the craft's imaging system. Designers had provided this capability after hookup of electrical receptacles located on the end frames of craft and station. However, the Pamirs' attempts were futile. Since sensor switches could be powered only by the station's onboard net, this meant that it was without power.

Even as the Soyuz T-13 approached the station, we noticed that two of its coaxial solar battery panels were not parallel, as they should have been for normal operation, but were turned

almost perpendicular to one another. This meant that the panels' orientation system was not functioning. There could be many reasons, including lack of voltage in the power system.

Meanwhile, meticulous checks of the linkup showed that it was tight, and the Pamirs opened the craft's hatch. Now, only one door, the station's hatch, separated them from the orbiting home which had never met envoys from Earth with so cold a welcome. Usually, by the time a crew arrived at the unmanned station, Mission Control had turned on the heat in general compartments, since, in autonomous flight, instruments could withstand lower temperatures than those required for normal human life. Now, the greeting was cold also in the literal sense: the lack of electricity robbed the station of the ability to maintain required thermal conditions.

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As a result, the station and everything on it were surely frozen. This case was considered as one of the extremes, and the Pamirs were outfitted with specially sewn heated suits, thermal caps, fur boots, and woolen underwear. Pressure in the connecting compartment was close to normal. The Pamirs brought it level with the pressure of the craft's atmosphere. Observing safety measures, the cosmonauts opened the hatch into the half-darkness of the lifeless station.

Vladimir Dhzanibekov was the first to step over the threshold. "What's the temperature?" Earth impatiently asked. "A kicker, guys," the commander blurted. "Let's try to turn on the light," he continued, already back to business. "We gave the command. No reaction." Checks of the receptacles in the connecting compartment showed total absence of electrical current.

Before the next hatch (to the station's working compartment) was opened, the Pamirs opened the pressure leveling valve and took an air sample through it. No one knew what the atmosphere there was like, but the malfunction in the radio equipment could have occurred because of fire. However, analysis revealed no harmful substances. Thus, the last barrier to the cosmonaut's entry into the station's main space was removed.

In the working compartment, they encountered subzero temperature and strange silence. The station's buffer power batteries were completely drained. This was the worst possible scenario. Could they bring the station back to life under these conditions?

Until the flight of the Soyuz T-13, power engineering specialists had categorically asserted that, if the electrical system failed and the batteries' capacity dropped to zero, it would be impossible to restore the station's working capacity.

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What else could the Pamirs do? Define specific malfunctions, try to find their causes, and, with clear conscience, return home feeling that they had done their duty.

It wasn't just that the work, or even simply being aboard the lifeless station, presented a mass of problems. The atmosphere recycling system would not activate, since there was no power. And, in just one day, two men could create a hazardous concentration of carbon dioxide gas in the general compartments. The water on the station had frozen; the Rodnik water supply system was not working.

Victor Savinykh called the first chapter of his book "Earth Waits and Hopes" (a fitting slogan for this flight), published by Perm' Book Publishers in 1983, "Our Friend, Mission Control." "For cosmonauts aboard a station," the first chapter says, "Mission Control is a reliable, faithful friend that exists for our benefit. We have a great deal of faith in the high qualifications of Mission Control specialists and in their comradely support."

Yes, Mission Control often comes to the rescue, and now, after preliminary analysis on Earth, it recommended a temporary ventilation scheme for the Salyut-7's compartment to the Pamirs. Nonetheless, on the insistence of the doctors, only one cosmonaut was permitted to be in the station, and then for no more than two hours. Meanwhile, the other was to be in the craft -- for insurance.

Using the Soyuz T-13's orientation engines, the cosmonauts turned the Salyut-7 to provide maximum light on the solar battery panels. However, even then there was no current in the power supply system. Consequently, the buffer batteries were disconnected from the solar batteries, and this made it impossible to charge them and restore the entire system.

The specialists found a safe alternative and developed the appropriate procedure for it. The work was time-consuming and monotonous. The Pamirs learned it and divided the circuitry connecting the buffer batteries and supply busses into separate wires. Turning them on and off tens and hundreds of times, they identified numerous wires, and eliminated malfunctioning batteries from further operation. Out of eight batteries, two were malfunctioning. The other six, fortunately, were still capable of charging. The Pamirs made special cables, and, on June 10 directly connected the first backup battery to the solar panels. The control system and the Soyuz T-13's control engines oriented the orbiting complex to the Sun as required.

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Several hours later, the first battery was partially charged. This made it possible to turn on the telemetry system

and, finally, the Earth was able to evaluate the status and temperature conditions of the station's equipment. Soon the reason for the power supply system's failure was detected. It turned out to be a malfunctioning sensor, which indicated that the buffer batteries were fully charged. A signal from this sensor disconnects the solar batteries from the buffer batteries after they were fully charged. When the programmable timer issued a command to disconnect the solar batteries, the malfunctioning sensor did not disconnect them. The buffer batteries, unable to recharge, gradually lost all their energy to users. Voltage in the onboard net dropped to zero, equipment stopped working, and, consequently, heat escaped. As a result, the station began to cool and then to freeze.

This could have been avoided if there had been radio contact with the station. Then the malfunctioning sensor could have been immediately disconnected and replaced by a backup. But now the Pamirs had to perform this operation. Having charged the buffer batteries, the cosmonauts restored the normal electrical circuitry for connection for charging. As with any terrestrial structure, in space everything begins with electricity. The onboard net developed current, and the Salyut-7's solar battery orientation and heat control systems began to function. The Pamirs replaced the malfunctioning module in the command radio line and restored normal communications between the station and Earth. Salyut-7 began to come back to life.

Now, the inside of the station had to be heated. But if the station's heat control circuit were turned on immediately, the moisture evaporating from the compartment walls (it was assumed that, as it froze, most of it had condensed on the walls, which had frozen first) could settle on to the colder instruments and electrical contacts. To prevent this, the atmosphere in the general compartments and the equipment installed there were heated first.

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At the cosmodrome, the Progress-24 cargo craft was being prepared. It was to deliver new buffer batteries, fuel for the station's combined propulsion plant, and equipment for repair and preventive maintenance of onboard systems. But before the cargo carrier was fueled, it had to be definite that the station could receive it. The station could link up with Progress only in automatic mode.

On June 13, the crew and Mission Control tested the station's orientation system, approach and docking equipment, and combined propulsion plant. Tests showed that they were completely fit for operation. The unmanned cargo craft's path to link up with the Salyut-7 was clear.

Life on the station got back to normal routine. The

temperature rose, even if slowly. As of June 16, they no longer returned to the craft's general compartments to spend the night. They were based completely in the station, although they still had to sleep in warm clothing. They conserved power: it was used mostly for experiments during the day and to heat the compartments when the crew slept. Having completed restoration and status checks of the station's onboard systems, the Pamirs began scientific research.

Their first major task in this area was to participate in the Kursk-85 international aerospace experiment. This experiment, conducted under the Interkosmos Program, was intended to study the condition of agricultural crops and to develop appropriate methods of predicting their yield using aerospace devices. The USSR Academy of Sciences Institute for Geography was the experiment's organizer and coordinator. Participants included scientific bodies of the USSR Ministry for Agriculture and the State Committee for Hydrometeorology, the USSR Academy of Sciences Institute for Radio Engineering and Electronics, and specialists from Bulgaria, Poland, Hungary, the Democratic Republic of Viet Nam, East Germany, and Czechoslovakia.

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The experiment was conducted on the territory of the USSR Academy of Sciences Institute for Geography's testing grounds, the Kursk Base. Why was preference given to Kursk? First, this is a typical region of intensive agriculture in the black earth zone. Second, various aspects of life in Kursk fields have been described over many years of observations. Third, Kursk Base has highly refined procedures and equipment for integrated geographical research.

The principle of multilevel observations was used in this research. The first level comprised sensors located directly in the soil. The second level was located on remote platforms of portable ground-based equipment. The third was at heights of 50-200 m; here, helicopters and radio-controlled model airplanes circled. An-30 aircraft were on the fourth level, 500-3,000 m. Even higher, on the edge of the stratosphere, the fifth level was occupied by An-30 and Tu-134 flying laboratories. On the space levels, Meteor and Kosmos satellites, as well as the crew of the Salyut-7/Soyuz T-13, Vladimir Dzhazibekov and Victor Savinykh, were making observations.

The Kursk-85 experiment was conducted in three stages. The first was in spring, when agricultural crops sprout (the Salyut-7 was not involved in the experiment then). The second stage was confined to the phase of especially intense plant growth, i.e. the second half of June. The third was scheduled to be completed before the first harvest. The results of the observations were entered into a computer, and a

multidimensional image of the test area was formed in its memory. The scope of the experiment included creation of the largest possible collection of such images, which would presumably be used later as references during computerized decoding of aerospace information.

On June 21-23, the Pamirs photographed the Kursk testing ground using MKF-6M and KATE-140 stationary cameras. It was precisely during these three days that Earth was sending them the Progress-24 cargo ship, which was launched June 24 at 4 hr 40 min Moscow Summer Time. On June 23 at 6 hr 54 min, it arrived at the Salyut-7's unoccupied docking module. By the end of the day, Mission Control had given the go-ahead, and the cosmonauts opened the hatch. The first thing they did was head for the mail. Although the residents of the "house in the stars" converse daily with Earth, are constantly informed of all the news and events, and are able, by means of radio and TV communications, to meet regularly with their families and friends, news hand-written by someone close is still the greatest gift of all to them. /13

Besides unloading the Progress-24 and replacing the station's worn-out equipment, they also conducted research. Studies included visual and instrumental observation of the surface of continents and oceanic water areas, study of the upper layers of the Earth's atmosphere, and technical experiments using Astra-1 mass-spectrometry equipment. This equipment was used to study the atmosphere surrounding the orbiting research complex. As research on previous expeditions had shown, its makeup does not remain constant, but may vary considerably. It depends on running the station's and craft's engines, cosmonauts' walks in space, scavenging mains, opening lock chambers, and other factors. These changes affect the quality of research, since they introduce distortions into the optical information coming on board and also affect the working capacity of the station itself: the condition of protective coatings, the capacity of the solar batteries.

Space is not suitable for human life. Its exploration involves first and foremost creation of conditions necessary for normal, safe habitation by man, keeping in mind that, once he has returned to Earth, he should feel no harmful physical consequences from space flight. Therefore, in addition to constant monitoring of crew health, the program set aside days when medicine ruled exclusively in orbit. During this time, complex or specific examinations of cosmonauts were conducted, e.g. the parameters of the cardiovascular system were defined in a state of rest and under the influence of measured physical load. The onboard clinic, which includes Aelita and Reograf multipurpose recording equipment, permits objective assessment of health, prediction of fitness for working, and timely execution of required preventive measures. So-called official /14

radio conversations occasionally supplement impassive instrument readings.

Here is an example of one such conversation with Earth. The head of the Medical Services Group, Professor A. D. Yegorov, is on the line. He only manages to greet the crew before Vladimir Dhzanibekov's voice is heard: "Hello, Anatoliy Dmitriyevich! How are you feeling?" "Normal," Yegorov answers, restraining a smile. "And how are you?" "Things here are also okay. We are following your recommendations. We use the exercise bicycle regularly, the running track twice a day."

Everything interests the doctors. Work in orbit is hard, especially for the Pamirs. The cosmonauts' nutrition is an important item: space alters the sense of taste and changes one's attitude toward food. One's favorite dish on Earth can taste entirely different. "We are sticking to the rations prescribed," reports Victor Savinykh. "If we allow ourselves a substitute, it's still an equivalent. To keep from getting bored with food, we alternate the menu every two days. Meat and vegetables weren't bad, but now... Our appetites aren't hurting. Everything tastes very good."

On July 8, the Pamirs finished unloading the Progress-24 and two days later finished transferring fuel components to the station's propulsion plant tanks. Water brought by the cargo craft filled the Rodnik's reserves. On July 15 at 16 hr 28 min Moscow Summer Time, Progress-24 separated from the orbiting complex, and, upon order from Earth, entered the dense layers of the atmosphere the next day, ending its existence over the South Pacific far from active sea lanes.

The docking module at the end of the Salyut-7 was not empty for long. On July 21 at 19 hr 05 min Moscow Summer Time, it was occupied by the Kosmos-1669 unmanned satellite. The satellite is quite similar to the Progress-24 cargo craft, but there are some differences. The layout and certain structural elements of the cargo compartment were slightly changed. It carried equipment for research both in independent flight and as part of the orbiting complex. /15

Kosmos-1669 was launched July 19 at 17 hr 05 hr Moscow Summer Time and, according to the schedule followed by Progress crafts, reached the station two days later. It brought new pressurized suits for working in space, since the old ones had worn out, and scientific equipment for installation on the station's outer surface. Containers with additional solar batteries had already come on the Progress-24. The Pamirs had to install them on the third and final solar battery panel on the Salyut-7. The first two panels had already had similar additions.

Installation of additional batteries had been called for during creation of the Salyut-7 as a means of gradually increasing its energy capabilities. Along each of the main panels, the cosmonauts unrolled additional "sheets" (of solar cells) with a surface area of 4.6 m². The additional solar batteries had first been installed by Vladimir Lyakhov and Aleksandr Aleksandrov in November, 1983. Twice they opened the exit hatch, each time installing an additional "sheet" on one of the panels. Referring to their experience, in May, 1984 Leonid Kizim and Vladimir Solov'yev performed this operation on another panel in one try. Now it is the Pamirs' turn.

Unloading the Kosmos-1669 and preparing for the space walk filled the cosmonauts' in-orbit work schedule. The primary goal of the space flight was research with results useful to the national economy. These indices were also used to evaluate the efficiency of the Soviet cosmonauts' in-orbit duty. On July 23, the Pamirs again began photography under the Kursk-85 international experiment. According to specialists, the three stages of the experiment will make it possible to create a rather extensive catalog of agricultural landscape conditions.

The Pamirs also participated in research under the international UNESCO program "Man and Biosphere." They visually observed and photographed biosphere preserves on the territory of the Soviet Union, particularly the Central Black Earth Preserve and the agricultural lands surrounding it.

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Geophysical research from orbit combines the interests of different sectors of the economy. Searching for prospective oil- and gas-bearing regions using space photography is more and more becoming a part of geologists' work. At developers' requests, the Pamirs photographed irrigated lands in Uzbekistan, Turkmenistan, and Kherson Oblast'. Photographs of the southern Urals and regions of southern and southeastern Kazakhstan were needed for preservation as well as by urban developers. The cosmonauts' work schedule included study of the southern regions of the European part of our country, the Transcaucasian lowlands, the Amudar' and Syrdar' interfluvia, ring structures in Central Kyzykumy, the mountain ranges of Pamir and Tien-Shan, and regions of the Baykal and the Far East.

The cosmonauts had a special relationship to Pamir, and its mountains and valleys were very familiar to them: orbiting station crews were trained, and methods of studying the Earth's natural resources from space were worked out there, with the help of USSR Academy of Sciences laboratory aircraft. In addition, the crew's call name was also "Pamir," and Vladimir Dhzanibekov was even born in Tashkent Oblast', a stone's throw from the "Ceiling of the World." And of course, the diverse natural conditions and the abundance of items to be observed made the territory of Pamir convenient for cosmonaut training,

and during work in orbit it served as a testing ground, a unique reference point for studying other regions of the planet.

Nevertheless, the space walk was approaching. The Pamirs had been thoroughly prepared for this work on Earth: they spent many hours in the zero-gravity pool and practicing individual operations, combining them into a single purposeful complex. In orbit, preparation for the walk began July 25. The first task was to test the new spacesuits: take them out of storage, carefully inspect them and adjust their fit, since they were of one size, designed for people of different heights. /17 The Kosmos-1669 satellite brought the station spacesuits that were not just new, but improved. In contrast to the old ones, they permitted increased movement of the shoulder muscles, which expanded the working area the cosmonauts could service. The helmet had protection and two lamps on the sides for work in the dark. Fitted with lights, the spacesuit control panel was located on the chest. Some of the rubber lining had been replaced by stronger rubberized cloth.

The station connecting compartment, the SCC as the cosmonauts called it, served as the lock chamber for the space walk. This compartment also had to be prepared for the task: extraneous objects not required for the walk, protective rings, and other "exit" equipment had to be removed. One safety measure is preparation of the cargo ship for launch. If suddenly, for any reason, the connecting compartment turns out to be improperly sealed after the hatch is closed, the cosmonauts have to move to the craft and return to Earth. This has never happened, and the probability of such a situation is immeasurably low, but safety requirements are strictly observed in space. And, to prevent the loss of research results due to this contingency, the Pamirs moved cassettes of exposed photographic film, magnetic tapes, and observation logs to the Soyuz T-13. Place was made in the craft's general compartments for removing spacesuits.

Work in space requires the permission of doctors. Therefore, one day is allocated for special medical examinations. The flight leaders make the final decision on the basis of results of training. Cosmonauts don the spacesuits, switch on the self-contained power supply, and simulate a walk without opening the hatch. The shift on-duty at Mission Control which will help the crew on the day of the actual walk interacts with it during this time. Victor Savinykh was to cross the threshold of the "house in the stars" for the first time, while Vladimir Dzhazibekov had already been there a year before, when he and Svetlana Savitskaya had tested a manual electron-beam tool for cutting, welding, and soldering /18 metals and applying metal coatings.

On August 2 at 11 hr 15 min Moscow Summer Time, Vladimir Dhzanibekov reported, "The exit hatch is open. Physical condition excellent; pressure in the spacesuits, normal. May we proceed farther?" The cosmonauts had to travel about 4 m along the station's outer surface to reach the solar battery panel farthest from the hatch. Meanwhile, they shared their impressions of their new space clothing: "The spacesuits are outstanding. You can spread your arms as far as you want. My feet are as warm as in felt boots. And the lamps help; you can work in the dark."

Having finishing installing the "sheet" of additional solar batteries, the Pamirs moved a safe distance away. On command from Mission Control, the battery was turned 180°, exposing another empty side to the cosmonauts. The second extra "sheet" to be oriented by skilled hands was fixed with equal precision in the recess of the main battery, but exposing it turned out to be difficult. "The pin on the winch won't come out," we hear Victor Savinykh's voice. "If I pull harder, I might damage the glove. Oh, the rope broke. No way to pull it now." "Pamirs, the zone is ending," warns Earth. "We recommend you go to the SCC for tools. We hope that, next time we communicate, everything will have turned out all right."

When the orbiting complex was again within the tracking station's radio range, the Pamirs were already busy with photography. In fact, they still had to do a lot of work before that. Creators of space equipment are interested in the effect space has on various materials, including photocells used to convert solar energy into electricity. In August of the previous year, Leonid Kuzim and Vladimir Solov'yev dismantled part of one of the main solar battery panels, taking a sample for testing on Earth. Now the Pamirs attached an experimental sample at that spot. It was not connected to the station's electrical net, but was intended only to study the mechanisms by which solar cells degrade when exposed to space flight factors.

The Pamirs also removed cassettes with samples of biopolymers and construction materials which had been exposed in space for a long time and installed new samples and instruments. These included a meteoroid dust collector produced by Soviet and French specialists. Its traps had to be open for 2 months, while the Earth crossed the tail of Comet P/Giacobini-Zinner. Afterward, most of the traps would be closed; the rest would record the constant presence (background) of dust particles in circumterrestrial space.

/19

At 5 hr sharp, the Pamirs entered space. Their walk was of great interest for space medicine. For the first time, electrocardiograms of both cosmonauts were being taken and other physiological parameters were being recorded during this

period. The resulting data make it possible to evaluate cosmonauts' state of health and fitness for work at various times outside the station.

Building up the solar battery panels made a significant contribution to the orbiting complex' power. Temperature in the general compartments rose, and possibilities for conducting research expanded. The Pamirs worked almost daily with MKF-6M and KATE-140 stationary setups and with the MKS-M multizone spectrometer. Much was photographed with hand-held cameras. On August 10, the crew made an additional series of visual observations and photographs for the Kursk-85 experiment, and, three days later, began to take part in an aerospace experiment, Gyunesh-85.

The Gyunesh experiment was conducted for the first time the year before during the flight of the third primary expedition. Specialists rated the practical results of the Gyunesh-84 experiment highly. A gold medal of the Exhibition of Achievements of the USSR Economy was awarded for a map of fault lines of the Great Caucasus Ridge, by which one can determine the tectonic structure of rock up to 80 m deep. A similar map of the biological productivity of mountain pastures was also compiled, 50,000 hectares of forest near the city of Zakataly were studied, and areas where forest pests have spread were defined. Erosion zones were established.

Farmers on the largest state farm in Azerbaijan, the Sergo Ordzhonikidze, received maps of the level of ground water and the moisture content of soils in the fields on their farm. Research on the region of the Adzhinour Salt Lake made it possible to develop recommendations for exploiting these lifeless lands. The anticipated increase in pasture area may be 10,000 hectares. The interest which heads of many of the republic's state farms have shown in the solar experiment ("gyunesh" is Azerbaijani for "sun") is understandable.

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One more curious fact: photos revealed traces of ancient human economic activity. This is of interest not only for historians, but for ecologists as well. From these photos, we can today recreate anthropogenic effects on nature.

The Gyunesh-85 experiment was conducted in the area of the Azerbaijan SSR Academy of Sciences Caucasus-Caspian's testing grounds. Its primary goal was further improvement of methods and means to research the Earth's natural resources and to study the environment. During the experiment, oil- and gas-bearing regions of western Azerbaijan and the Caspian coast on the southern slope of the Great Caucasus underwent spectrometry, and the optical characteristics of the atmosphere over the territory of the grounds were calculated. Past experience organizing the experiment and controlling its

progress was taken into account. The level of automation was significantly increased. Instruments installed on airplanes and helicopters, supplemented by personal and mini-computers, constituted, as it were, a single entity with the information-measuring system which obtained and pre-processed exploratory and operative information.

On order of the USSR State Committee for Science and Technology, the Pamirs completed one more experiment, Kupol, in which they evaluated the level of atmospheric pollution over large industrial centers. The object of the studies was Zaporozh'ye, the city of metallurgists. The experiment required strict orientation of the orbiting complex so that its vertical axis would always be aimed at the city during photography. Zaporozh'ye had hardly appeared on the horizon when Vladimir Dhzanibekov deployed the orbiting complex as required, constantly tracking the direction toward the city. Victor Savinykh turned on the Salyut-7's photography, spectrometry, and radiometry equipment, whose optical axis coincided with the direction of the station's vertical axis. The Pamirs photographed the city, flying over it from various directions. From the results of these photos, scientists will construct a three-dimensional portrait of the atmosphere surrounding Zaporozh'ye, indicating the content of specific pollutants in the air and their vertical and horizontal distributions. These photos can be of great help in planning preservation programs.

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Kosmos-1669 carried a Mariya X-ray telescope to the station. This instrument is intended to measure the flows of high-energy protons and electrons using a magnet and recording counters. Charged particles deviate in a magnetic field, and the extent of their deviation defines their energy. The cosmonauts installed the Mariya in the Soyuz T-13's general compartment. Changing the orientation of the orbiting complex, they aimed the instrument at the region of the Universe of interest to astronomers. They studied the mechanisms by which high-energy particles are generated in the Earth's radiation belts and in circumterrestrial space. According to the program of astrophysical experiments, the Pamirs also conducted research on interplanetary media, zodiacal light, and weak galactic and extragalactic sources.

On August 20 at 1 hr 50 min Moscow Summer Time, the craft and the Kosmos-1669 separated from the Salyut-7. But they did not leave the orbiting station immediately. They again activated the radio lock-on system and began automatic approach of the space craft, which continued up to the docking segment. Having thus checked the working capacity of the automatic devices for mutual location and approach (this was required for subsequent link-ups), Mission Control switched the Kosmos-1669 to independent flight and, on August 30, sent it into the dense

layers of the atmosphere.

On September 17, a new call name, Cheget, was heard over the space communication system. By the way, this call name had long been familiar to specialists. Vladimir Vasyutin, Cheget-1, had headed four backup crews. Victor Savinykh was Cheget-2; space research Aleksandr Volkov, Cheget-3. They had all trained for work on the Salyut-7 under the program for the fourth expedition.

/22

An unforeseen circumstance introduced its own corrections into the makeup of the space crew. A pilot who had mastered the spacecraft control equipment and was experienced in complex dockings, not only during training, but in actual space flight, was needed for the flight to the uncontrolled Salyut-7. As we know, the choice fell on Vladimir Dhzanibekov. As regards flight engineer, a similar rational approach was taken. The program of the fourth expedition was divided into two stages: one, repair-restoration, was assigned to Vladimir Dhzanibekov's crew; the second, the so-called "standard", to Vladimir Vasyutin's crew. Victor Savinykh was to be the connecting link throughout the entire program. Therefore, Cheget-2 temporarily changed his call name to Pamir-2.

The empty slot in the Cheget crew was filled by Georgiy Grechko, who can rightfully be considered a veteran of space. Thirty years ago, he came as a young specialist to the S. P. Korolev Special Design Bureau and participated in preparations for the first satellite launch. In 1964 Georgiy Grechko applied to become a cosmonaut and two years later was accepted as one of the first group of spacecraft flight engineers. But then, in 1966, he almost had to give up his dream of space flight.

It happened in the very beginning of winter. As future spacecraft flight engineers, we were taken to the airport for parachute jumping. Everyone landed successfully except Georgiy. He remained lying in the snow, without unfastening his parachute. We ran up to him and hear a groan, "My leg, my leg..." The doctors were categorical: no training whatsoever -- in a word, he was threatened with being dropped from the group. Georgiy Grechko didn't give up. Lying down, he lifted weights, hung on rings, practiced the bars. He came on crutches to Cosmonaut Training Center classes. And his persistence was rewarded. The doctors removed all restrictions. Everyone knows what kind of cosmonaut Georgiy Grechko became from his work on the Salyut-4 and Salyut-6.

/23

Perception of space flight is still an individual matter. Even with an identical amount of training, different people perceive weightlessness, for example, differently. To keep these individualities from affecting the quality of program

execution, it became our rule to include in a crew at least one cosmonaut who had flown before. In the Cheget crew, this was Georgiy Grechko, a veteran both in terms of in-orbit work (he had two space flights lasting a total of 126 days under his belt), and in terms of age (he was 54 in May).

The Chegets were launched on September 17 at 16 hr 38 min 52 sec Moscow Summer Time.

On the eve of their launch, the Chegets in the cosmodrome talked with the Pamirs over the space communications system. Vladimir Dhzanibekov gave them a friendly sendoff. "Boys, you won't find anything special in space. Don't worry. Everything will be like in the simulators. The main thing during rendezvous is to cut the side." In cosmonaut jargon, that means to cut lateral speed as the spacecraft approaches the orbiting complex.

On September 18 at 18 hr 15 min Moscow Summer Time, the Soyuz T-13 spacecraft touched the station's docking module. After careful tests lasting a wearisome three hours, the cosmonauts finally heard the long awaited words, "You can open the hatch." Mission Control made the decision to open the connecting hatches on the basis of crew reports and telemetry data. Vladimir Vasyutin, with a bouquet of orchids, floated into the station first, followed by Georgiy Grechko with a bundle of letters, and Aleksandr Volkov with fresh lemons which had been brought to the cosmodrome from Tashkent. "On Earth they say, 'Mountains will never meet', but in space, Cheget has come to Pamir," punned Georgiy Grechko as he greeted Vladimir Dhzanibekov and Victor Savinykh.

But jokes aside, there was work to be done. Normally good humored and smiling, Georgiy Grechko was unusually stubborn and demanding on the job. At the S. P. Korolev Special Design Bureau, he had proved himself a capable specialist in space flight mechanics, and, in space, his talent as a researcher was obvious in everything he did. He was the first to notice the jagged appearance of the setting Sun, and this gave scientists new clues for studying the Earth's atmosphere.

/24

Before, when two crews met on the station, each had its own experiments. Now, however, all five cosmonauts were united in a common scientific program. They paid a great deal of attention to integrated study of phenomena in the upper layers of the atmosphere. The main "director's" role here belonged to Georgiy Grechko, since he had defended a dissertation on this topic for a Ph.D in physicomathematical sciences last year. Vladimir Dhzanibekov also was involved in studying the atmosphere; his previous flights had produced interesting results in this area. Victor Savinykh helped create optical instruments to be used in space. This area became the topic of

his candidate's dissertation, which he successfully defended just two weeks before the Soyuz T-13's launch. Vladimir Vasyutin and Aleksandr Aleksandrov were thoroughly prepared for the experiments.

Research was done in other areas as well. Scientific equipment aboard the station also included Bulgarian instruments familiar to the reader, Duga electrophotometers and Spektr-15 spectrophotometers, as well as the Czechoslovakian EFO-1 electronic photometer and the MKS-M spectrometer created in East Germany. The Chegets brought a new instrument, a space spectrometer (Skif) from the Belorussian SSR Academy of Sciences Institute for Physics. This brainchild of Belorussian scientists is a device with a display, which permits simultaneous spectrometry of the underlying surface, digital recording on magnetic tape, and photographic tie-in to specific areas of the locale. Now, a cosmonaut could immediately see the results of his efforts. If they turned out to be unsatisfactory, he could adjust the instrument to improve the quality of the next shot.

Specialists were most interested in biotechnological experiments to produce ultra-pure biologically active substances in space flight conditions. To do this, Soyuz T-14 delivered the new EFU-Robot automated electrophoresis unit to the station. Compared with its predecessor, the Tavriya, it is more impressive. Now a cosmonaut simply inserts an ampule with raw material into the chamber and selects the required program; the unit itself signals the end of the process. In addition, there is no need for manual removal of costly milligrams of purified material with syringes -- this operation is also automated. /25

The Svetoblok-T was used in experiments to form a synthetic gel from polyamylacrid solution exposed to light.

The Pamirs and Chegets also took part in developing methods for remote calculation of hydrophysical and biological characteristics of wave surfaces under the Black Sea-85 international experiment, prepared by scientists of Bulgaria, East Germany, Poland, and the Soviet Union. Despite a tight work schedule, the cosmonauts eagerly responded to a request to photograph the area around Mexico City, which had suffered from a very powerful earthquake. It is possible that the resulting photos will reveal shifts in geological structures, which could help in understanding the mechanics of the recent catastrophe in Mexico.

Workdays sped by unnoticed, and it was time to part. On September 25, Vladimir Dhzanibekov and Georgiy Grechko took their seats in the Soyuz T-13 spacecraft, which separated from the orbiting research complex at 7 hr 58 min Moscow Summer

Time. But first, they had to photograph different angles of the Salyut-7, which obediently "posed" under the piloting of Vladimir Vasyutin, who had taken command of the orbiting complex. Then, traveling several dozen kilometers away, the Soyuz T-13 again began to approach, and the station "went silent" as it had three and a half months before on June 8. This time, however, no docking was planned.

Because this experiment was conducted, landing took place not, as usual, on the day they separated, but the next day. On September 26 at 13 hr 51 min 58 sec, the Soyuz T-13's descent vehicle successfully completed a soft landing on the Kazakhstan steppe, 220 km northeast of Dzhezkazgan. Once, Vladimir Dhzanibekov had been considered a master of short flights; now he numbered among his accomplishments an extended, 112-day-long assignment in orbit. /26

This is how the first stage of the fourth primary expedition was completed and how the second stage of the program, to be carried out by the remaining cosmonauts, began in space.

On September 27, 1985 Baykonur sent the heavy Kosmos-1686 satellite into orbit. At 12 hr 42 min Moscow Summer Time the powerful Proton booster rocket was launched, carrying as its nose cone the fourth craft in this series. The first, the Kosmos-929, had successfully passed 200-day-long flight tests in 1977. The second, the Kosmos-1267, docked in 1981 with the Salyut-6, on which a program of manned flights had been completed until then. The Kosmos-1267 was used to carry out several dozen maneuvers, and the orbital altitude of the entire orbiting complex was repeatedly raised.

The third ship, Kosmos-1433, was a combined cargo carrier and tug. In 1983 it brought the Salyut-7 more than 3 tons of various cargo for the second primary expedition. Cosmonauts Vladimir Lyakhov and Aleksandr Aleksandrov gave high marks to the energy capabilities of the new craft and evaluated the merits of the significant increase in living space in orbit: space in the living compartments immediately increased by a factor of 1.5. The Kosmos-1443 system including a return vehicle which then carried 350 kg of payload from the station to Earth.

The fourth craft, the Kosmos-1686, did not have a cargo-return vehicle; it was built as a scientific module. It carried more than a ton of special equipment for various studies in the interests of the national economy. Moscow, Leningrad, and Yerevan' Universities, the Estonian SSR Academy of Sciences Institute for Astrophysics, and other organizations participated in development of the vehicle.

In addition, the Kosmos-1686 was also used as a heavy cargo carrier. Its compartments held 5 tons of cargo for the Chegets. This cargo included replacement modules, foodstuffs, and materials and equipment to support the crew's vital activity and its work in space.

On October 2 at 13 hr 16 min Moscow Summer Time, the satellite rendezvoused with the docking module on the station's connecting compartment. The TV screen showed how the image of the Salyut jerked and shifted to the side: the disturbances were a little greater than during linkup of the Soyuzes and Progresses. This time, however, joining forces were greater, and the docking frames of the station and the heavy craft were drawn together with a force of 40 tons.

Using an apparatus installed on the Kosmos-1686, the Chegets performed geophysical research, studied the flows and spectra of charged particles in circumterrestrial space, and recorded data on artificial clouds, the gas composition of the Earth's atmosphere, and its spectral and optical characteristics. During the experiments the satellite oriented the entire 48-ton Salyut-7/Soyuz T-13/Kosmos-1686 "package."

The Chegets' working schedule allocated considerable attention to visual observations and photography of various areas of dry land and oceanic water areas. As an extension of previous research, they followed the continuation of fracture zones in western branches of Tien-Shan.

In October the Earth and the orbiting complex revolving around it crossed the tail of Comet P/Giacobini-Zinner. For us on Earth, this event could be marked only in terms of the increased number of "shooting stars" in the nocturnal sky. A meteoroid collector installed on the station's outer surface by Vladimir Dhzanibekov and Victor Savinykh opened its traps and, over two weeks, recorded the particles accompanying the comet.

Speaking of the fourth primary expedition, we have to talk about Victor Savinykh's work in particular. Along with Vladimir Dhzanibekov, he thawed out the frozen station and resuscitated it, and, as a result, it completely regained its working capacity. Georgiy Grechko valued the Pamirs' labor victory thus, "When we entered the station, we understood that its inhabitants not only were neat, but had good taste and were capable of making things comfortable. There were no traces of former malfunctions. We even joked that those guys had made up the whole story about the silent, frozen station." /28

Vladimiar Vasyutin's illness complicated the Chegets' work. At first they hoped that the inflammation could be treated with medicines on board. Doctors prescribed "bed rest" for Vladimir Vasyutin, and the flight program designed for

three had to be carried out by two, Victor Savinykh and Aleksandr Volkov. So, Victor Savinykh, the more experienced cosmonaut, assumed the bulk of the work, including the duties of the ailing commander.

Nevertheless, the flight regrettably had to be curtailed. This decision was dictated by human considerations, when concern about a man and his health take precedence. The cosmonauts mothballed the station and satellite, preparing them for travel in automatic mode. Of course, not all the tasks called for in the program were completely finished. Nevertheless, the results of the research are impressive in their scope.

For example, using photography and spectrometry equipment, the Pamirs and Chegets shot 16 million square kilometers of the Earth's surface and regularly carried out astrophysical, technological, technical and medico-biological experiments. In toto, 400 research sessions were conducted using 85 instruments and assemblies created by specialists in the USSR, other socialist countries, and France.

On November 21, 1985 the Chegets said farewell to the station and moved to the Soyuz T-14. Mission Control officially shifted the duties of craft commander to Victor Savinykh. There followed careful checks of hatch seals and spacesuits, and the command to separate was issued. At 10 hr 16 min Moscow Winter Time, independent orbital flight began, and, on that same day at 13 hr 31 min 00 sec, the descent vehicle smoothly landed 180 km southeast of Dzhezkazgan.

THE VEGA PROJECT: THE FIRST STEP IN RESEARCH

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Vega-1 and Vega-2 automatic interplanetary stations (AIS)*, launched in December, 1984 from the Baykonur cosmodrome have completed the first stage of their planned flight program, research of the planet Venus. /29

As we know, the choice of travel trajectory with a flyby of Venus so that the AIS would reach Halley's comet made it possible to use one spacecraft to solve three problems at once. The first was to conduct basically new, comparatively long experiments to study the circulation of Venus' atmosphere and its meteorological parameters using a floating aerostatic sonde. Then, study of the planet's atmosphere, cloud layer and surface would continue using a descent vehicle. Finally, Halley's comet would be studied from a flyby trajectory, including producing TV images of its core at a distance of about 10,000 km.

The planet Venus occupies a special place in the Soviet space program. A little more than 20 years ago, it was hypothesized that Earth's "sister" is its duplicate, that it is only a little warmer there, and that it has a hydrosphere and, perhaps, a biosphere. But, alas, these hopes proved unjustified. Climatic conditions on Venus turned out to be too severe. Direct measurements from spacecraft showed that the temperature on its surface is just a little below 500°C, and, of course, there are no oceans there, since water would have boiled off long ago. The atmosphere's density at the same level is only 14 times lower than the density of water. Even the compositions of Earth's and Venus' atmospheres are different.

It is precisely these differences which provoked the considerable interest in research on the "morning star." We would like to discover their causes, to understand how its atmosphere and climate evolved. This would make it possible, probably, to make more correct conclusions about possible future changes in the Earth's climate. But, in addition to climatological, there are two other extremely important aspects: geological and cosmogonical. Information about the geological structure of solid bodies on all terrestrial planets is needed to recreate a picture of the early stages of the Earth's evolution. This is the only way to understand the processes by which minerals form. /30

*Editor's Note: "automatic interplanetary stations (AIS)" should be "automated space probe (ASP)"

Cosmogony is the branch of science which studies the origin and development of the Solar System. Highly valuable information for cosmogonic conclusions is contained in the composition of the atmosphere. Extremely important are data on the quantity of inert gases and their isotopes, since they include many relicts, i.e. things preserved from the time the planet formed.

Venus is studied with regard for all three aspects. The first path to this planet was laid by the Soviet AIS Venera-1, launched February 12, 1961. Thus, even before man's first spaceflight by Soviet citizen Yu. A. Gagarin, Soviet aeronautics entered interplanetary orbit. The AIS flew close to Venus. It was followed by the flight of the American Mariner-2 spacecraft. Venera-2 and Venera-3 were launched in November, 1965. And, finally, the historic voyage of Venera-4 -- a natural continuation of previous Soviet AIS flights to Venus. Venera-4 operated right in the depths of the planet's atmosphere, to altitudes of about 20 km from the surface. For the first time, data obtained by direct measurements of the atmosphere's temperature, pressure, and chemical composition, virtually inaccessible by astronomical observation equipment, were transmitted to Earth. To evaluate the entire significance of these first experiments, it is sufficient to say that, until Venera-4's flight, the uncertainty in evaluating pressure and temperature at the planet's surface had reached almost three orders of magnitude.

Flights of Venera-5 and Venera-6, ending in parachute landings into Venus' atmosphere on May 16 and 17, 1969 greatly clarified and supplemented data obtained by Venera-4 and expanded the area of direct measurements down to the surface. The results of these flights were used to create a model of Venus' atmosphere which underlay the design of future Venusian landing vehicles. The problem of landing descent vehicles on the planet's surface and operating them in the most severe environmental conditions was solved as early as the flights of Venera-7 and Venera-8. Thus, Venera-8 functioned on the planet's surface for about 1 hr.

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The gamma-spectrometer installed on Venera-8 made it possible to obtain the first data on the nature of Venusian surface rocks at the vehicle's landing site. The illumination of the planet's surface by solar light was measured. This made it possible to prepare an experiment to obtain a TV panorama of Venus' surface.

A new stage in research on Venus began in June, 1975 with the launch of Venera-9 and -10, which reflected all the positive experience of their predecessors. For the first time, two artificial planetary satellites were put into orbit around Venus, and two descent vehicles landed simultaneously in

different regions of the planet. At the same time, a complex, integrated experiment was carried out to study the characteristics of the planet on the surface, in the atmosphere, in the cloud stratum, and in space surrounding it.

Both satellites, similar in design and scientific equipment makeup, as were the subsequent Venera-11 and -12, belonged to a new generation of Soviet unmanned planetary craft. As a result of these flights, a large amount of scientific data was obtained which greatly expanded our understanding of Venus. For the first time, panoramas of the surface at the descent vehicles' landing sites were transmitted to Earth.

An essentially new step in Venus research was the cycle of investigations carried out by Venera-13 and -14. Before them, the primary target of research by unmanned vehicles on Venus had been the atmosphere, and work really had never gotten as far as the ground. One of the main tasks of Venera-13 and -14 was to determine the chemical composition of rocks on Venus. For the first time in history, drilling was done on another planet, while, within the vehicle, a precise instrument studied the elemental composition of the ground in two regions of Venus separated by about 1000 km. The physico-chemical properties of rocks on Venus' surface were studied. /32

Several panoramas of the surface were obtained. For the first time, Earth's inhabitants saw close-up "color portraits" of far-away Venus. In addition, a large system of instruments was investigating Venus' cloud cover and its atmosphere. The integrated program of studies carried out using Venera-13 and -14 had no equal in terms of the breadth and quality of the experiments.

Venera-15 and -16 had a basically new assignment. They were to study Venus' surface and atmosphere remotely from artificial planetary satellites. The primary goal was cartographic photography of the northern hemisphere with a spacial resolution of 1-2 km.

By now, many of Venus' puzzles had been solved. Nevertheless, just as many questions remained unanswered. Their solution became the task of integrated research carried out on the planet by Vega-1 and -2 automatic interplanetary stations. Having made the 6-month, 500-million-kilometer flight, the stations reached the vicinity of the planet in the beginning of June. Two days before each station's arrival at the planet, the descent vehicles, which divided into a landing vehicle and an aerostatic sonde, separated from them (fig. 1).

It happened this way. Shifting the descent vehicle's center of gravity relative to the center of symmetry gave it the required orientation during travel in the atmosphere.

After secondary space speed was cut upon signals from the g-force sensor, the lid of the parachute container fired, and its lift parachute began to operate. Then the blasting cap of the explosive charge cut the descent vehicle's heat shield sphere in half, and the upper half, together with the aerostatic sonde, move upward.

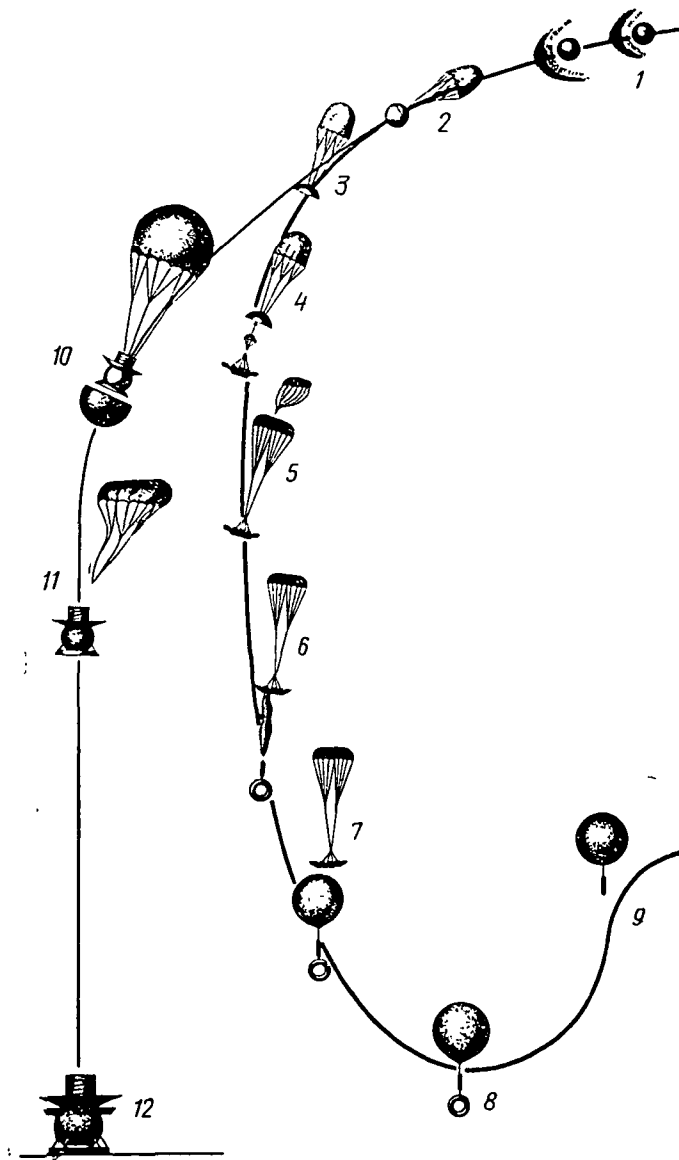


Fig. 1. Descent in Venus' atmosphere. 1) Entry; 2) Deflection parachute deployment; 3) Deflection of upper hemisphere; 4) Probe firing; 5) Aerostat deployment parachute opening; 6) Deployment and filling of canopy; 7) Separation of parachute with filling system; 8) Ballast separation (settlement); 9) Entry into drift altitude; 10) Firing of lower hemisphere; 11) Ejection of brake parachute; 12) Landing.

After the sonde was ejected, the first stage of the aerostatic parachute system was put into operation. At first the probe flew on a stabilizing parachute. It slowed the vehicle, and, having fulfilled its purpose, yielded to the aerostat lift parachute. This main, large parachute, measuring 35 m², finally slowed the container to the required speed. Then the explosive charge opened the aerostat container, which was divided into two halves. The bottom half,

descending, pulled the aerostat's soft canopy and gondola.

The next explosive charge blast released helium from tanks into the canopy. It took the aerostat 250 sec to fill, after which the explosive charges ejected the parachute and part of the aerostat container and tanks. Then the ballast separated, and the aerostat reached drift altitude.

Throughout this entire time the lower half-canopy, together with the landing vehicle, continued descending on the brake parachute to an altitude of 63 km. Here the lower half-sphere separated from the landing vehicle and dropping another 1 km; the braking parachute also fired. The speed at which the descent vehicle was falling reached 20 m/sec by this time, and it decelerated further because of an aerodynamic flap. When it touched the ground, its rate of descent was about 7 m/sec. To absorb the energy of the impact, the descent vehicle had a special device in the form of a thin-walled toroidal jacket which, upon landing, underwent plastic deformation (it also provided the vehicle's orientation position after landing).

Both aerostats were on the nocturnal side of the planet virtually at the antisolar point. Exposed to wind, they then moved to the daytime side. Information was transmitted to Earth for 46 hr. Each traveled about 12,000 km at an average speed of about 250 km/hr. The first aerostat drifted along the equator in the northern hemisphere, the second, in the southern.

Aerostat probing of Venus' atmosphere was done for the first time in world practice, and its importance is difficult to overestimate. It makes it possible to answer several very important questions regarding the physics of the planet which could not be answered using landing systems: in particular, obtaining data on the nature of global circulation of the Venusian atmosphere. In general, this circulation can be considered as a global cyclone, which "rotates" the atmosphere over a period of 4 days (the phenomenon has been dubbed "superrotation").

So far it is unclear, however, what supports such rapid rotation. Temperature is virtually identical on the day and night sides of the planet. Therefore, there is no reason for thermal overcurrents in the atmosphere. Venus itself rotates very slowly on its own axis, and wind speed at the surface measured by landing vehicles, as one might expect, is slow: about 1 m/sec. Studying the circulation of Venus' atmosphere, we can obtain information quite valuable in the applied sense, which will help us better understand the dynamics of our own atmosphere and reveal mechanisms affecting long-period variations in the Earth's climate.

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Note that the latter requires studying not only atmospheric motion on a different scale in Venus' atmosphere, but also the physical principles and consequences of this motion. In other words, in addition to the motions themselves, scientists are interested in temperature and pressure distribution, horizontal and vertical structure of the cloud stratum, optical properties of the atmosphere, etc. Studies of Venus using an aerostat floating in its atmosphere had to yield considerable information to answer these questions.

An aerostatic sonde consists of two systems: the aerostat itself (a canopy made of fluorolon resin-coated fiber) 3.4 m in diameter and a gondola, which is suspended 13 m below the aerostat. The aerostatic sonde weighs 21 kg. As regards the high-pressure helium storage tanks, as well as the parachute, pyrotechnics, and instruments which control all operations for separation from the descent vehicle, deployment of the parachute, unfolding and filling of the canopy and, ejecting ballast, the total weight of the aerostatic system is 120 kg.

The aerostatic sondes floated in Venus' atmosphere at an altitude of about 54 km, where pressure is 0.55 atm; temperature, about 40°C. This altitude corresponds to the densest part of Venus' cloud stratum, where, as it is hypothesized, the effect of mechanisms maintaining the atmosphere's rapid rotation should be particularly pronounced.

The aerostat's gondola has three parts: a conical feed-antenna device; a radio system module and meteorological system housed in metal containers in the form of a parallelepiped and firmly attached to one another; and a power source, also in a metal container. All three gondola units are interconnected by Caprolon bands (cf. figure 2).

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The meteorological system includes instruments to measure the atmosphere's pressure and temperature, vertical component of wind speed, optical density of the cloud stratum, and illumination intensity. All instruments are examined simultaneously every 75 sec, and data are written to memory. Information is collected for 30 min and then transmitted to Earth.

Signals from the sonde were received and the position of the sondes in space and their rate of travel were defined using the world's largest radiotelescopes, combined into a super-long-base interferometer. The essence of interference method is that observations are made simultaneously by two or more radiotelescopes as far as possible from one another. The angular resolution of the observations in this case is determined not by antenna dimensions, but by the distance between telescopes -- the interferometer's base. Thus, one can obtain a resolution 1,000 times better than that of optical

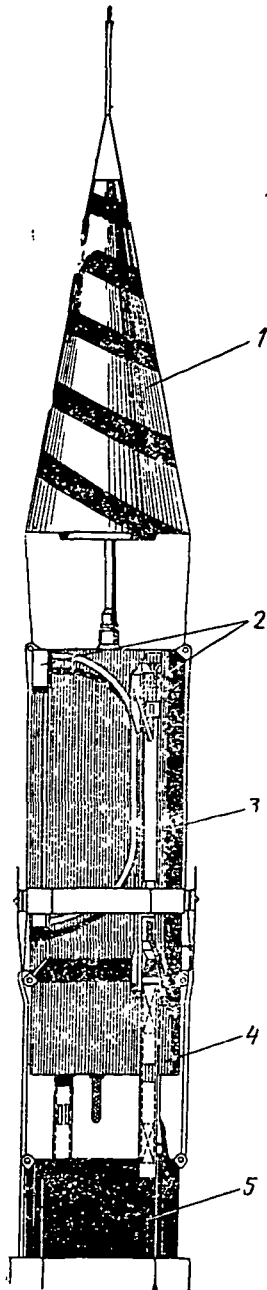


Fig. 2. Aerostat sonde gondola.
1) Feed antenna;
2) Scientific apparatus module;
3) Radiosystem module;
4) Meteorological system module;
5) Power source module.

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telescopes, which makes it possible to track a sonde's movement over Venus' disk. 37

Two radiotelescope networks have been created: Soviet, coordinated by the USSR Academy of Sciences Institute for Space Research; and international, coordinated by the National Space Research Center of France. The Soviet network includes two

70-m radio telescopes in Ussuriysk and Yevpatoriya, a 64-m radiotelescope in Medvezhiye Oзера (near Moscow), two 22-m radiotelescopes in Pushchino (on the Oka) and Simeyz (Crimea), and a 25-m radiotelescope in Ulan-Udze.

The international network includes radiotelescopes with 64-m-diameter antennas: in Goldstone (USA), Canberra and Parks (Australia), and Madrid (Spain); a 100-m unit in Efelsburg (FRG), and several medium-size telescopes in Europe, North and South America, and southern Africa.

Scientific instruments for meteorological measurements on aerostats were developed at the USSR Academy of Sciences Institute for Space Research. Partners in these experiments included French scientists, and along with them, as a sort of subcontractors, American specialists. The fact is that the USA /38 does not participate in the Vega project: the U.S administration cut off cooperation with the USSR in space research. Therefore, American scientists entered the project "under the cover" of French and West German scientific institutions.

All interpretation of the results of experiments conducted using aerostatic sondes is done by an international scientific group whose members are the USSR, the USA, and France. It is assumed that complete scientific results will be available only by January, 1987 -- the volume of information obtained is so great. Therefore, until then, we can speak only of preliminary data.

First, extremely strong (by terrestrial standards) vertical wind gusts, reaching more than 1 m/sec, were recorded. For comparison, we can say that vertical wind gusts on Earth are no greater than several centimeters per second. This evidences highly developed turbulence in Venus' atmosphere at altitudes on the order of 54 km (i.e. the zone where the aerostats were floating).

On the nocturnal side, the aerostat's scientific apparatus recorded variations in illumination intensity and light flashes. What they mean is still unclear. It is possible that it is lightning, since storm phenomena in Venus' atmosphere have also been detected by Venera-11 and -12 descent vehicles. Or it may be volcanoes erupting. But probably it is both: remember K. Bryulov's painting "The Death of Pompei" (lightning over erupting Vesuvius). In any case, it is precisely hypotheses on volcanic eruption which are being used in an attempt to explain the variation in sulfur dioxide content in Venus' atmosphere.

There is no question that the aerostat experiment has become one of the most important scientific-technical

achievements of Soviet aeronautics. It has provided new opportunities to study not only Venus, but, let's say, even Jupiter.

As the aerostatic sondes began to drift in Venus' atmosphere, the landing vehicles descended directly to the planet's surface. Scientific investigations using these vehicles began even in the descent segment. Immediately after the braking parachute opened, apparatus to measure atmospheric pressure, average temperature, and their pulsations was switched on.

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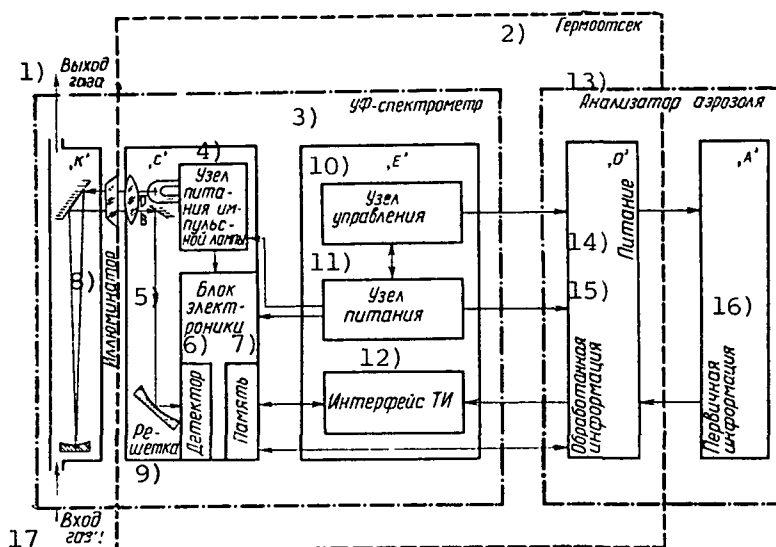


Fig. 3. Schematic of the ISAV instrument.

Key: 1) Gas outlet; 2) Pressurized compartment; 3) UV spectrometer; 4) Pulse lamp power unit; 5) Electronics; 6) Detector; 7) Memory; 8) Porthole; 9) Lattice; 10) Control unit; 11) Power unit; 12) TI interface; 13) Aerosol analyzer; 14) Power; 15) Processed information; 16) Primary information; 17) Gas inlet.

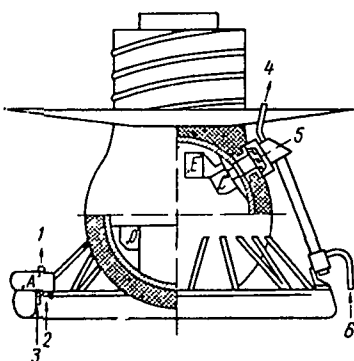


Fig. 4. Setup of individual ISAV units on a descent vehicle: 1) Aerosol outlet; 2) Turbidimeter port; 3) Aerosol inlet; 4) Gas outlet; 5) Porthole; 6) Gas inlet.

One of the main problems in studying Venus' cloud stratum is precise definition of photochemical processes responsible for its formation. On the basis of indirect data obtained previously, it has been hypothesized that it consists basically of sulfuric acid (with a concentration of 75-85%) mixed with chlorine. Nonetheless, we still have no direct calculations of sulfur content in the cloud stratum. We also do not understand in what form chlorine is present in clouds.

The answer to these questions is extremely important for understanding Venus' global geochemistry. This requires reliable and complete information both on the atmosphere's and the cloud stratum's chemical composition and on the properties of the particles which form them. The Vega-1 and -2 descent vehicles carried a set of instruments which supplemented each other in these measurements.

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Investigations of the cloud stratum and atmosphere were conducted using active spectrophotometry methods. Soviet and French specialists participated in development of an instrument (known as ISAV) for these purposes (fig. 3).

The atmosphere's composition was determined using a UV spectrometer to measure absorption of emissions by its gas constituents. The fact is that gases which make up Venus' atmosphere have strong absorption bands in the UV region of the spectrum. The instrument functioned in the following sequence. Light from a UV emission source entered the atmosphere through a sealed porthole in the landing vehicle's hull. By means of an optical device, it twice traveled a path of about 1 m, absorbing atmospheric gases, and returned through the porthole to the instrument's analyzer (fig. 4).

Thanks to high spectral resolution, the ISAV was able to clearly record the complex structure of the absorption bands and reliably identify the absorber. The instrument's sensitivity was sufficiently high at 60-km altitudes and increased as it descended. The instrument's spatial resolution in the cloud stratum was about 10 m; on the planet's surface, about 50 m. The data obtained make it possible to define the three-dimensional structure of the distribution of UV-emission absorbers in the atmosphere and, at the same time, to detail the picture of photochemical cycles responsible for formation of Venus' cloud stratum.

The ISAV also included an analyzer intended to study the planet cloud stratum aerosol. Atmospheric gas with cloud particles was blown through the instrument. A thin jet of this gas intersected a focused light beam traveling from an incandescent halogen bulb. Four photoreceivers measured the power of the light flow, which flying particles dispersed forward, to the right, to the left, and backward. The

intensity of the light dispersing forward, to the right, and to the left, depends almost entirely on particle size, while dispersion backward depends on size and refractive index. The shape of a particle and its orientation determine the ratio of light flows dispersing to the right and left.

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The results of dispersed light measurements were used to determine particle diameter and refractive index and to evaluate particle shape. Data on seven randomly selected particles were transmitted to Earth every second.

The density of the aerosol component was determined with a resolution of 10-20 m in terms of height by a turbidimeter, which measured light flow dispersphere located 3-10 cm below the instrument.

The chemical composition of Venus' atmosphere and cloud stratum was studied using a new gas chromatograph with SIGMA-3 pyrolytic cells developed by Soviet specialists. It was intended both to determine the atmosphere's chemical composition and to carry out direct analysis of the content of sulfuric acid in the planet's cloud stratum.

To increase the reliability and accuracy of the experimental data obtained, the instrument had three different types of detectors. The instrument made it possible to reliably separate oxygen, carbon dioxide gas, carbon oxysulfide, hydrogen sulfide, sulfur dioxide, and water vapor. The gas to be analyzed was pumped through pyrolytic cells and then, according to the given program, traveled to chromatographic columns. Information from detectors traveled through the information processing and output unit to the telemetry system.

Catalytic breakdown of sulfuric acid into carbon was carried out to chemically analyze the aerosol and to determine the quantitative content of sulfuric acid. When the aerosol is pumped through the pyrolytic cells, it settles onto a carbonized fiberglass filter. Then, blown by the gas carrier and heated, the sulfuric acid aerosol, reacting with charcoal, breaks down into water vapor, carbon dioxide gas, and sulfur dioxide. Analysis of this gas mixture makes it possible to determine the concentration of sulfuric acid in the sample.

As the instrument operated, it analyzed the atmosphere and aerosol three times at altitudes of 65-49 km from the planet's surface. In particular, the instrument reliably determined the presence of sulfuric acid as a chemical compound in Venus' clouds.

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The aerosol's chemical composition was analyzed by X-ray radiometry with a PTI instrument (phase transition indicator)

developed by Soviet specialists. The essence of the method is that exposure to X-rays with a certain energy excites an atom of the subject chemical element and, returning to its initial state, this atom gives off an X-ray quantum whose energy is typical for an atom of the irradiated element (fig. 5 and 6).

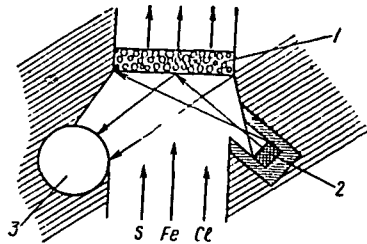


Fig. 5. Diagram of an experiment with the PTI instrument: 1) PT filter; 2) Radioisotope source; 3) X-ray detector.

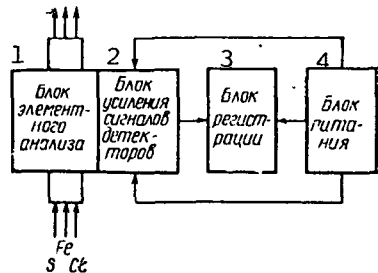


Fig. 6. Functional diagram of the PTI instrument. Key: 1) Element analysis unit; 2) Detector signal booster; 3) Recorder; 4) Power unit.

As the vehicle descended in the atmosphere, aerosol settled onto a special acid-resistant filter and was irradiated by a radioisotope source. Simultaneously, typical X-ray emission by the aerosol's chemical elements was measured. Later the instrument converted the kinetic energy of the photon into a voltage pulse, whose amplitude was proportional to the energy of the recorded photon and corresponded to a certain chemical element. The voltage of the outlet analog channels was proportional to the amount of aerosol settled on the filter.

The experiment produced an altitude profile for sulfur and chlorine content. Measurements showed that clouds on Venus have a complex layered structure. Thus, the Vega-1's descent vehicle detected no less than 5 tiers of clouds. There was also a suspicion that Venus' clouds contain iron compounds.

Data on the aerosol phase of Venus' cloud stratum (the distribution of the number and size of particles in terms of altitude) were also obtained using an aerosol spectrometer (LSA) developed by Soviet specialists. The instrument's photoreceiver recorded halogen lamp emission dispersed by aerosol particles. The optical system made it possible to record radiation only from a predefined area of space. The calculating zone's dimensions were set rather small so that, given permissible concentrations of aerosol particles, not more than one particle would enter it at the same time. The number of pulses counted over the assigned interval provided information on aerosol density; the amplitude distribution of the impulses, on particle distribution in terms of size.

With data obtained from the ISAV, it was possible to establish that the concentration of particles measuring at least 5 microns in the upper layers of the cloud stratum was about 100 cm^{-3} ; below 40 km, to $1,000 \text{ cm}^{-3}$. Particle size diminished, and, below 40 km, their diameter was less than 1 micron.

Venus' clouds were studied by mass spectrometry method using a Malakhit-V unit intended for collection, separation by fractions (correspondingly by particle size) and mass spectrometry analysis of each aerosol fraction in Venus' cloud layer. The instrument used a so-called hyperboloid mass analyzer, whose operating principle is based on the capability of certain electrical fields to separate ions in terms of specific charge (fig. 7).

Reaching the apparatus together with the atmosphere sample, the aerosol was divided in a separator into two groups according to particle size. Each particle group was collected onto filters and subjected to pyrolysis. Gaseous products of pyrolysis went to the mass analyzer, where molecules were ionized by an electron beam, and ions were separated according to the magnitude of the specific charge. Then the focused ion flow went to detectors, where it was converted into voltage pulses. The counter/coder counted voltage impulses and coded them for transmission to the telemetry system.

The programmer provided double (at altitudes of 60-56 and

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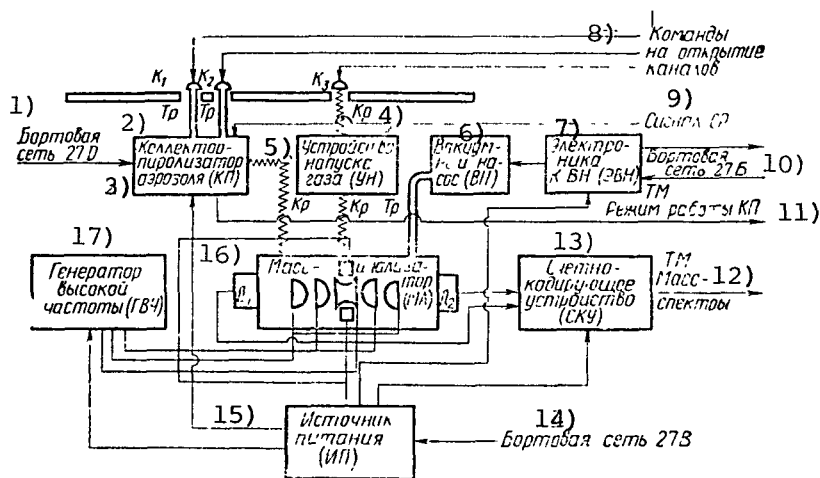


Fig. 7. Functional diagram of the Malakhit-V.

Key: 1) Onboard 27-V net; 2) Transistor; 3) Aerosol collector/pyrolyzer; 4) Crystal; 5) Gas admission unit; 6) Vacuum pump; 7) Electronics for vacuum pump; 8) Commands to open channels; 9) Signal; 10) Onboard 27-V net; 11) Collector/pyrolyzer operating mode; 12) Mass spectrometer; 13) Counter/coder; 14) Onboard 27-V net; 15) Power source; 16) Mass analyzer; 17) High-frequency generator.

56-48 km) sampling and recording of 8 aerosol spectra, as well as analysis of atmospheric gas at altitudes of 32-25 km. Scientific information was transmitted from the mass spectrograph to Earth over 72-contact telemetry channels. The experiment was carried out by Soviet and French specialists.

The atmosphere's water vapor content was determined using a VM-4 hygrometer developed by Soviet specialists and based on use of thermoelectrolytic and coulometric sensors. The operating principle of the moisture-sensitive element in the thermoelectrolytic sensor is based on the relationship between the elasticity of the water vapor above the surface of a saturated salt solution and temperature. Moisture evaporates under the sensor upon exposure to heat released as current flows between electrodes and is absorbed from the environment due to the salt's hygroscopicity. As a result of these processes, equilibrium humidity and temperature are established in the sensor, the latter being the output parameter of the thermoelectrolytic sensor.

The operating principle of the coulometric sensor is based on electrolytic breakdown of water into hydrogen and oxygen and measurement of the increase in the volumetric percentage of hydrogen in the gas. A coulometric tube is used to break down water; thermal conductivity method, to measure the increase in the volumetric percentage of hydrogen.

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The instrument operated at altitudes of 65-30 km, including the cloud stratum, haze, and part of the lower atmosphere. The operation of two sensors with overlapping ranges produced an unambiguous cross section of the atmosphere in terms of water vapor content with a resolution of 2-4 km vertical.

Vega-2's landing vehicle was used to analyze the chemical content of the soil at the landing point, i.e. the concentration of basic rock-forming elements from magnesium to iron inclusive, as well as certain heavier rare elements, was determined. Investigations were conducted using a BDRP-AM25 spectrometer by X-ray radiometry analysis. The latter is based on the relationship between characteristic radiation excited by an isotope source and the content of the element being analyzed in the sample. Element concentration was determined in a sample of rock from the Venusian soil delivered by the soil sampler to the analysis area.

The soil sampler is a miniature drilling assembly capable of taking samples by drilling rock of virtually any hardness. Drilling depth and the volume and mass of the rock sample depend on the assembly's specific operating conditions.

During the first few minutes after landing, samples of rock were taken, the gas atmosphere surrounding the sample was

removed, and it was carried via a sluice channel into the landing vehicle. Then the rock sample went to the soil receiver for irradiation by the radioisotope source and subsequent analysis. Fluorescence was recorded by a detector whose signals traveled to a multichannel pulse analyzer. Information accumulated in the analyzer was periodically output to the telemetry system for transmission to Earth (fig. 8).

The chemical composition of the planet's soil was determined by X-ray radiometry analysis for the first time on Venera-13 and -14. The landing site of the new vehicle was many hundreds of kilometers away from the previous sites, and this time landing was accomplished for the first time in a high mountainous region. Soil analysis at various points on the surface makes it possible, on the one hand, to judge how varied the types of rock on Venus are and, on the other, to more accurately construct models of the chemical interaction of surface and atmosphere. Initial data have already shown that the composition of the soil differs from that studied at previous landing sites.

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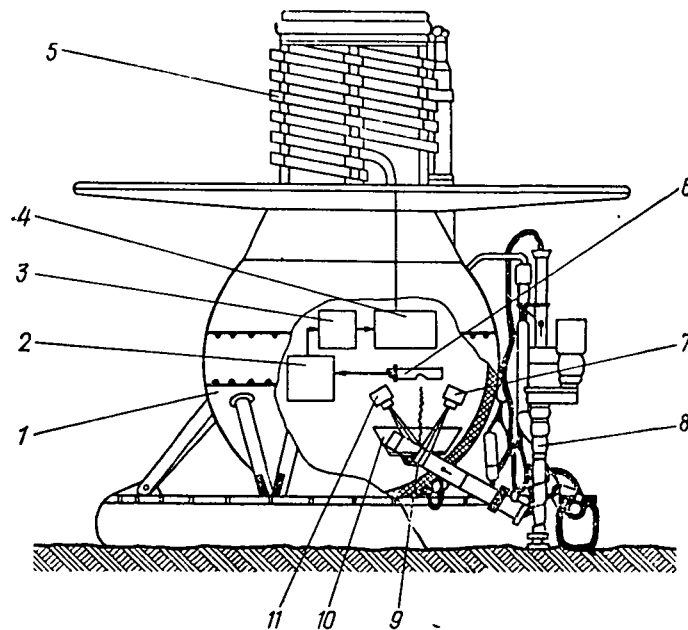


Fig. 8. Delivery of a soil sample by the soil sampler to the analysis area and arrangement of main X-ray fluorescence spectrometer modules. Key: 1) Landing vehicle hull; 2) Booster and switching module; 3) Pulse amplitude analyzer; 4) Telemetry system; 5) Antenna; 6) Detectors; 7) Plutonium-238 source; 8) Soil sampler; 9) Sample; 10) Soil receiver; 11) Iron-55 source.

The results of determination of the elemental composition

of Venusian rock in different regions on its surface make it possible to draw important conclusions about conditions under which geological structures form and erosion processes progress and to estimate the possible mineralogical composition which, in turn, allows us to judge processes by which the planet's atmosphere and surface interact.

To determine the nature of Venusian rocks in terms of the natural radioactive elements (uranium, thorium, potassium) they contain, Vega-1 and -2 descent vehicles also measured the flow and spectral gamma-ray composition of Venus' surface rocks at the landing sites. /47

Under conditions on Venus, spectrometry measurements are a natural method for studying rock content which does not require sampling or even removing the sensor from the vehicle's pressurized compartment. Experiments conducted earlier showed the high effectiveness of the gamma-spectrometry method during geochemical investigations of the planet and made it possible to obtain one-of-a-kind information on the composition and nature of Venusian rocks.

The GS-15STsB gamma spectrometer installed on Vega-1 and Vega-2's descent vehicles consists of a detecting module and an impulse amplitude analyzer. Gamma quanta emitted by radioactive elements contained in Venus' rocks enter the crystal, and cause scintillations (brief flashes) in it which are recorded by a photo-multiplier. Pulses developing in the photo-multiplier, whose amplitude is, on the average, proportional to the energy of the gamma quanta entering the crystal, are additionally amplified by the spectrometric amplifier and go to a multichannel amplitude analyzer for recording.

At first, measurements were taken as the vehicle descended in the planet's atmosphere to record the background gamma radiation resulting from the presence of radioactive elements in the construction materials of the spacecraft and of the instrument itself. After landing, both background radiation and radiation from the subject rock were recorded. The instrument's high efficiency, rapid action, and memory capacity made it possible to take measurements over the entire anticipated range of natural radioactive element concentrations. The program called for the instrument to operate in cycles: collection and storage of information, and output to the telemetry system for transmission to Earth. These were repeated several times. This instrument was developed by Soviet specialists (fig. 9).

In summary, let us stress that, thanks to the launch of the new Soviet Vega-1 and -2, it has been possible to solve many important problems in the study of our nearest neighbor among

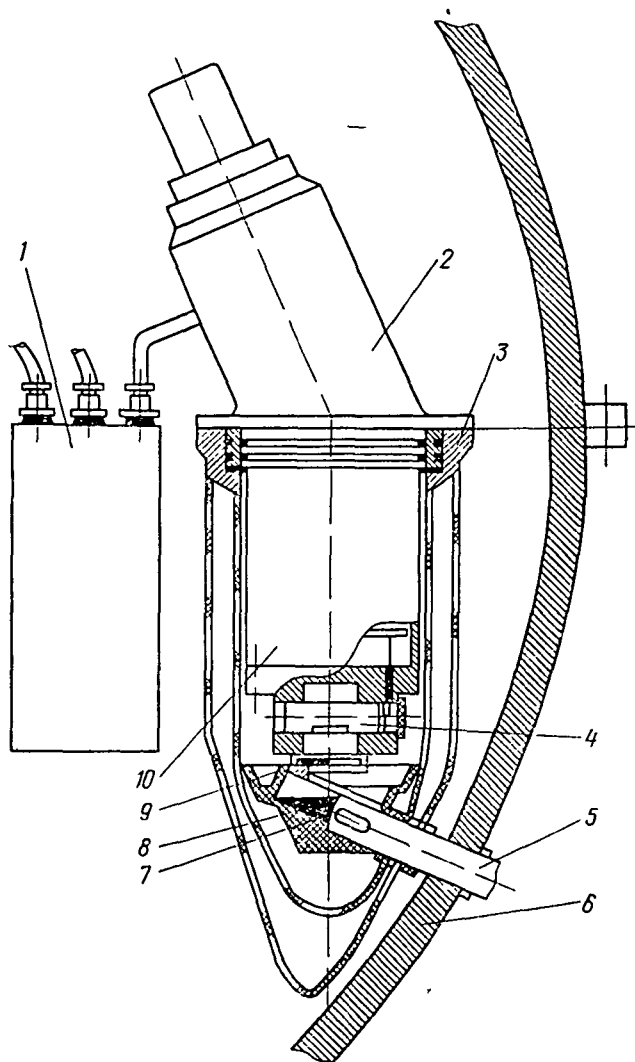


Fig. 9. Schematic of the BDRP-AM25 instrument layout:
 1) Pulse amplitude analyzer;
 2) Detector module cover;
 3) Detector module body;
 4) Counter; 5) Sluice;
 6) Landing craft hull;
 7) Subject sample; 8) Soil receiver; 9) Radioisotope source; 10) Electronic module.

the terrestrial planets, Venus. For the first time, information was obtained on the dynamics of its atmosphere using aerostatic sondes. For the first time, the content of sulfuric acid in the planet's atmosphere was calculated directly, and additional data were obtained on the composition and structure of clouds. New data were obtained on minor impurities in the atmosphere. Finally, the elemental composition of the soil at the descent vehicle's landing site was determined.

Complete processing and analysis of the resulting data will make it possible to approach the still hidden secrets of the planet on a new, essentially higher level of cosmogony and planetology.

FLIGHT OF THE SPACELAB ORBITING LABORATORY

D. Yu. Gol'dovskiy

Creation of the Spacelab orbiting research laboratory, intended for use in manned flights aboard multipurpose cargo spacecraft (space shuttles), marks a definite achievement in space technology. This year, the laboratory has completed three flights (one of them under a program devised by West German specialists with the participation of West German and Dutch astronauts).

Spacelab, developed by the Western European Space Agency ESA makes it possible to conduct scientific research and technical experiments in space in the most varied disciplines. Pressurized laboratory modules in which an artificial atmosphere is created are like a miniature orbiting station where scientific and experimental equipment can be set up, plants and experimental animals kept, and research on astronauts conducted. Special air locks make it possible to carry instruments from the nonpressurized module into open space. Non-pressurized laboratory modules include platforms on which scientific instruments and equipment are mounted and which are designed for operation in space vacuum, as well as prototypes tested for the effects of aspects of near-Earth space, primarily vacuum and radiation.

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Spacelab is set up in the payload compartments of American space shuttles, does not separate from them, and returns in them to Earth. This gives the laboratory both advantages and disadvantages as compared with orbiting stations designed for self-sustained flight. An advantage is that the laboratory can be used repeatedly (according to specifications, it is rated for 50 space flights), while equipment for new experiments is installed on Earth. This is much simpler and more convenient and provides much broader capabilities than does replacing or installing new equipment delivered by a cargo craft to a free-standing orbiting station. The disadvantage of the Spacelab as compared with a self-sufficient station (in addition to its relatively small size and weight, which are dictated by the space shuttle's carrying capacity and the dimensions of the payload compartment) is the very short time it spends in orbit (the record is still 10 days), which makes it impossible to use it for longterm experiments.

Spacelab, which was manufactured by ESA and cost this organization \$1 billion, was transferred without charge to the USA's National Aeronautics and Space Administration (NASA). There was some, but clearly inadequate, compensation, whereby

ESA program experiments were conducted without cost and an astronaut selected by the ESA flew free of charge the first time the laboratory was put into orbit. This deal, disadvantageous to the ESA, provoked criticism in scientific and political circles in Western European countries which are members of the organization. For example, W. Merbol'd, who participated in the first Spacelab flight, stated that this arrangement "cannot be considered a good basis for cooperation." He pointed out that Spacelab can be used up to 50 times, while, as compensation for building the laboratory, the ESA has received only "half a flight." In Merbol'd's opinion, further cooperation between the ESA and NASA on this basis would not be worthwhile.

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The criticism had an effect. An agreement signed in 1985 on a new joint ESA and NASA program, which provides for the ESA's participation in creation of an American prolonged-habitation orbiting station by 1994-1995, is beneficial not just to the Americans.

Spacelab's design was quite successful. This is evidenced by the fact that NASA bought a second from the Western German concern MBB/ERNO, the lead organization in creating Spacelab. It actually purchased the unit, paying \$240 million, rather than obtaining it for free as it had the first. A political problem arose because of this purchase. The agreement between the ESA and NASA on transferring the first laboratory without charge states that the USA will use it for peaceful purposes only. This agreement does not cover the second laboratory, and, as western observers noted, the USA can easily use it, for example, to test laser weapon guidance systems under the so-called "Star Wars" program. Moreover, it is impossible to check on U.S. compliance with the agreement on peaceful use of the first laboratory. And it will be completely impossible to determine whether the laser weapon guidance system was tested on the first or second laboratory.

By this time, Spacelab has completed four flights aboard American space shuttle. These flights have been designated Spacelab-1, -3, -2, and D-1. The Spacelab-3 flight took place before Spacelab-2 and Spacelab D-1, since the precise guidance system for scientific instruments which the laboratory was to carry during Spacelab-2 was not ready in time. During the flight of the Spacelab D-1 (D for Deutschland -- Germany), experiments were conducted under an FRG program for which that country paid several tens of millions of dollars.

The flight of Spacelab-1. This flight took place from November 28 to December 8, 1983. Spacelab, consisting of one elongated, pressurized module (EPM) and one non-pressurized module (NP), was carried by the space shuttle Columbia into an orbit with a perigee altitude of 246.5 km, apogee

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altitude of 248.3 km, and inclination of 57° (the flight lasted 10 days 47 min 23 sec). There were six aboard: Craft Commander J. Yang, Pilot B. Shaw, Orbital Operations Specialists O. Herriott and R. Parker, as well as astronaut-experimenters B. Lichtenberg and W. Merbol'd. Except for Merbol'd, mentioned above, all were American astronauts. Work in the laboratory went on round-the-clock in two shifts: each three-astronaut shift worked 12 hr.

Spacelab-1's flight program called for conducting a total of 70 experiments (see table), which have been detailed in the booklet "Modern Achievements in Cosmonautics," (Moscow, "Znaniye" Press, 1983). This program was not completed, basically because of malfunctions in onboard research and experimental equipment. Astronauts had to spend half their time repairing and restoring the working capacity of the equipment. NASA named O. Herriott the flight's scientific director; R. Parkerr, B. Lichtenberg, and W. Merbol'd were "topflight repairmen." Certain extremely interesting experiments, including those under the ESA program, either could not be conducted or could not be anywhere nearly completed. NASA promised to included these experiments in the program of one of the 1985 flights, but then they were postponed indefinitely and, but for a minor exception, have yet to be conducted.

However, despite the fact that Spacelab-1's scientific program was not completely carried out, according to American specialists' estimates, 50 times more information was obtained on this 10-day flight than on the American orbiting station Skylab over the 24 weeks astronauts operated it in 1973-1974. It is quite important that during Spacelab-1's flight it was possible to transmit scientific and other information to Earth in real time and to ensure communication among the experiments' directors and astronauts onboard throughout a significant part of total flight time. This became possible thanks to a TDRS retranzlator-satellite. During Spacelab-1's flight, it provided two-way communications between the shuttle and Earth for 137 hr 31 min out of a total flight time of 248 hr. It is true that it had initially been planned that the flight would be provided with two such retranzlator-satellites, but the second has still not been put into orbit.

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The flight of Spacelab-3. This flight, like that of Spacelab-1, was repeatedly postponed due to interruptions in the space shuttle's schedule. It was also carried out at an inoptimum time for certain astronomical observations, which had an effect on the flight's scientific results. It took place from April 29 to May 6, 1985. The Spacelab laboratory, consisting of one EPM and a non-pressurized truss structure for mounting two astronomical instruments, was carried by the space shuttle Challenger to a near-circular orbit at an altitude of

NUMBER OF FLIGHTS AND PERCENT COMPLETED
DURING THE FLIGHT OF SPACELAB-1
(IN TERMS OF DIFFERENT SCIENTIFIC DISCIPLINES)

Scientific discipline	Number of experiments			Resources freed, %		% completion
	NASA	ESA	Total	Time	Energy	
Space biology and medicine	7	9	16	50.8	11.2	90
Plasma physics	2	4	6	21.5	14.9	88
Atmospheric physics	1	3	4	1.0	12.4	65
Earth observation	-	2	2	2.7	3.5	"
Astronomy	2	2	4	8.9	4.9	90
Solar physics	-	2	2	0.2	2.4	"
Space manufacturing and materials science		35	36	14.9	50.7	86
Total	13	57	70	100	100	80

352 km and an inclination of 57° (the flight lasted 7 days 00 hr 9 min). There were seven aboard: Craft captain R. Overmaier, Pilot F. Gregory, Orbiting Operations Specialists D. Lind, N. Tegard, and W. Thornton, as well as astronaut experimenters L. van den Berg and T. Young (all American astronauts). D. Lind and T. Young were physicists; N. Tegard and W. Thornton, doctors; L. van den Berg, a chemical engineer. As during the flight of Spacelab-1, work went on around the clock in two 12-hr shifts. Shifts overlapped (when both were awake) 4 hr a day.

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The program for Spacelab-3's flight provided for a total of 15 experiments in three areas: space biology and medicine, astronomy, and atmospheric physics. Several experiments were prepared by French and Indian scientists. These countries paid NASA specific sums for the right to set up equipment on the Spacelab-3 flight. For example, under the French program, an experiment to grow mercury iodide in a special furnace was repeated. It was conducted for the first time free of charge on Spacelab-1; now the French National Space Research Center paid NASA \$400,000. Another French experiment, photographing astronomical targets with an ultraviolet camera with a very wide field of view, was also repeated after the Spacelab-1 flight, when, because of unfavorable astronomical conditions, it was only 40% completed. However, this experiment was not conducted at all during the Spacelab-3 flight, since, because of mechanical problems, the astronauts were unable to open the air lock through which the camera is extended from the EPM into space. Because the data-processor failed, the Indian experiment, which called for research on the ionization of heavy nuclei in cosmic rays, was also not completed.

Cages with monkeys and rats in the EPM gave the astronauts many unpleasant experiences. The cages' primitive design caused them to open into the EPM when the animals were being fed and care for. From there, the rest of the food and the animal's excrement entered the cabin. The astronauts maintaining the cages had to wear surgical masks.

On the whole, however, American specialists consider Spacelab-3's flight quite successful. In particular, 13 of the 15 experiments yielded valuable information. Interaction between astronauts and ground personnel made it possible to efficiently carry out repairs on board and to introduce corrections into experiments being conducted if any malfunctions or deviations from design conditions occurred. And there were more than enough, just as during Spacelab-1's flight. For example, at a certain point, the drinking water faucet failed; then liquid began to spout from the urinal in the toilet. Both problems were eliminated, but not without difficulty. The main "repairmen" were T. Young and N. Tegard, but this was hardly their specialty. Remember that the first was a physicist; the second, a doctor.

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Spacelab-2's flight. This flight was also delayed in terms of the original schedule, and it was finally superseded by Spacelab-3. The reason was not only interruption of the space shuttle's flight schedule, but also the fact that the information retrieval system for precise scientific instrument guidance created by the ESA under an agreement with NASA (FRG firm Dornier was the lead company) was not ready. This system, together with the first Spacelab were transferred to NASA free of charge. By the way, the latter ordered another information retrieval system from Dornier, which, as Western observers suspect, can easily be used for precise guidance not only of scientific instruments, but of devices related to laser weaponry during flight tests.

The information retrieval system is installed in a nonpressurized module when the space shuttle's orientation system cannot provide required guidance accuracy (the information retrieval system is accurate to 1"). This system's rotating table can accommodate instruments weighing up to 7 t, while the system itself weighs 1.8 t. The rotating table is fitted with bearings, and it is moved (on command from the onboard computer) by two brushless DC motors. Information from velocity gyroscopes and stellar sensors is also used.

Spacelab-2's flight lasted from July 30 to August 6, 1985. This time Spacelab included 3 non-pressurized modules and a pressurized Igloo container. It was carried into an orbit with a perigee altitude of 196 km, an apogee altitude of 315 km, and an inclination of 50° by the space shuttle Challenger. Nominal apogee altitude was 389 km, and entry into orbit at a much

lower altitude resulted from an emergency at the orbital section, when a false temperature sensor signal caused one of the shuttle's three engines to shut down and it continued flight with only two engines running.

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Spacelab-2's flight lasted 7 days 22 hr 45 min. There were seven American astronauts onboard: Craft Commander C. Fullerton, Pilot R. Bridges, Orbital Operations Specialists S. Musgrave (doctor), E. England (geophysicist), and K. Hennessey (astronomer), as well as research astronauts L. Elton (astronomer) and J. D. Bartow (astrophysicist). They also worked in two 12-hr shifts.

For the first time, Spacelab used a pressurized Igloo container whose shape resembles that of an Eskimo hut. Some equipment to ensure functioning of the orbiting laboratory's scientific instruments was not rated for work in space vacuum. If the laboratory included a pressurized module, as did the Spacelab-1 and -3, this equipment was placed there. But if the laboratory consisted only of a non-pressurized module, the equipment required use of a special pressurized container.

Spacelab-2's flight schedule called for a total of 13 experiments, primarily in astronomy and plasma physics, as well as in medicine, biology, and space manufacturing. Two astronomical experiments were prepared by English scientists. One involved high-resolution recording of space X-ray emissions, primarily toward the center of the Galaxy; the second, recording hydrogen and ionized helium emissions in the solar corona.

Among plasma research experiments, one was scheduled in which a satellite weighing about 400 t with plasma diagnostic instruments separated from the shuttle. For 6 hr, this satellite executed self-sustained flight, sending readings from its instruments to the craft. Then, a remote manipulator was used to return it to the shuttle's payload compartment. In the initial stage of independent flight, the shuttle's satellite flew around it a short distance away, which made it possible to determine the effect of a space craft (the shuttle) on plasma surrounding the satellite. Another experiment to study ambient plasma called for the shuttle's engines to be turned on specially to record "corridors" in ionospheric plasma formed when water vapors in the engines' exhaust jets interact with plasma.

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Among the medical-biological experiments, samples of astronauts' blood were taken for analysis to study the exchange of matter in bone fiber during flight, as well as to observe germination of perennial oat, pine, bean, and sunflower seeds in microgravity conditions. One of the manufacturing experiments called for study of the superfluidity of helium in

zero gravity. All experiments were remotely controlled by operators on Earth or astronauts in the space shuttle cabin.

Note that Spacelab-2, whose primary tasks were astronomical observations and study of ambient plasma, had on board professional scientists: two astronomers, an astrophysicist, and a geophysicist. Medical research was conducted by a doctor. The practice of scientists' flights to conduct experiments in their specialties began in the USA in 1972, when the crew of the last lunar expedition included selenologist K. Schmidt. Judging from statements by NASA executives, this practice is justified, although the scientists often have to spend more time repairing and adjusting equipment than conducting the scientific observations themselves.

During the Spacelab-1 and -3 flights, astronauts moved from the crew space on the space shuttle through a special manhole-shaft to the pressurized laboratory module without spacesuits, since it had an artificial oxygen-nitrogen atmosphere with the same parameters as the space shuttle's crew area. During the space shuttle's third flight, the Spacelab had no such module, and no provision was made for crew members to enter space to maintain instruments in the non-pressurized module.

Ultimately, breakdowns during the first few days of flight forced prolongation of the flight for days to somehow complete the scheduled program. But, while use of instruments independent of the information retrieval system (e.g. the English X-ray telescope) made it possible to conduct all planned observations, use of instruments mounted on the system's rotating table permitted only partial fulfillment of the program (70%, e.g. during recording of hydrogen and helium emission). The primary instrument on the Spacelab-2 flight, an American solar observation telescope, began to function only at the very end of the flight, and these observations were taken over only 16 hr instead of the scheduled 50 hr.

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It is true, as NASA representatives claimed, that solar research instruments on Spacelab-2 obtained more images of this heavenly body and with better resolution in 8 incomplete days than did solar research instruments on the Skylab orbiting station in 1973-1974 in the 171 days in which three groups of American astronauts were on it.

Spacelab D-1's flight. This flight was carried out under a program developed by West German specialists, and the FRG chartered the space shuttle and the EPM for this flight. This charter cost a great deal of money, and no exceptions were made for ESA member countries which had developed the Spacelab. Use of Spacelab, including charter of the shuttle, depending on the

laboratory's makeup, cost \$82 million (EPM + NM, or SPM* + 2NM, or 3NM + Igloo); \$42 million (2NM + Igloo); \$18 million (NM + Igloo). Setting up a rack with equipment in the EPM (or SPM) takes \$5 million. The FRG paid NASA \$64 million for the Spacelab D-1 flight.

In this flight, the orbiting laboratory consisted of an EPM and a platform with scientific equipment produced in the FRG. The racks with equipment for the EPM were made at a plant in Bremen (FRG) belonging to MBB/ERNO. It was precisely this company which was the lead organization in creating the Spacelab laboratory, but now it was doing work for the FRG's Aerospace Scientific Experiment Center, responsible for the Spacelab D-1's program. The estimated cost of this program was about \$175 million, including rental of the EPM, once assembled at that very plant in Bremen. In other words, the FRG, which had to bear a large percentage (53.3%) of the costs to create Spacelab under the ESA, was now forced to pay a huge sum for rental of what was essentially its own laboratory. Remember, this laboratory was transferred to NASA virtually for free -- only for the right to use it on one of its 50 flights. /59

On July 1, 1985 the final stage of tests on scientific equipment for Spacelab D-1, which had been delivered with racks from the plant in Bremen, began at the launch complex at Cape Canaveral in the USA. In addition to NASA personnel, 45 specialists from MBB/ERNO and the Aerospace Scientific Experiment Center took part in the tests.

About two-thirds of the research program during Spacelab D-1's flight was devoted to medical-biological experiments, the most significant among which were Helmet, Hop-and-Drop, Sled, and Biorack.

Helmet. In this experiment, a special dome with moving spots was placed on the head of the astronaut subject, who sat in a swivel chair. The ability of the subject to distinguish natural motion from the motion of the spots was tested. The astronaut demonstrates his perception of motion by a gesture, but his eye movements are also recorded.

Hop-and-Drop. This experiment calls for the astronauts to jump up and down in the EPM or to jump from a certain height. The astronaut dons a system of belts with elastic bands which create acceleration during descent, as under the Earth's gravity. The purpose of this experiment is to study man's reflexes under zero gravity conditions. The fact is that under

*Standard pressurized module, about half as long as the EPM. Its use for the first time as part of the Spacelab orbiting laboratory is slated for 1986.

conditions of the Earth's gravity, when man jumps or hops from a certain height, the vestibular apparatus sends a signal to leg muscles which provide a leg position which damps impact against the floor. Lack of gravity affects sense organs, and this affects muscle performance. Under the experiment, first the subject astronaut anticipates the fall, then it occurs unexpectedly. The functioning of the subject's brain in both cases is compared.

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The Helmet and Hop-and-Drop experiments were developed by American specialists and were conducted for the first time during Spacelab-1's flight.

Sled. The purpose of this experiment is to study man's vestibular apparatus under zero gravity conditions, when an astronaut is in a chair on runners capable of moving along a track 3.2 m long along the EPM. The runners can accelerate either in sinusoidal or linear modes (in the latter case, the runners speed up to the middle of the track, then decelerate over the rest of the track). A change in the chair's position on the runners can create acceleration relative to three mutually perpendicular directions. The runners and equipment connected to them are controlled from a panel on the rack at the back of the EPM, and display equipment is mounted on this rack. Removable sensors, as well as various devices acting on subject astronauts, are fastened to the runners. The astronaut's head is held by a special device including a TV monitor and infrared TV camera placed in front of the subject's eyes. The camera and monitor may be used particularly for this experiment. One of the astronaut's eyes is exposed to variable light signals, while the infrared camera records the second eye's movements, depending on accelerations and other physical effects.

The Sled experiment was developed by ESA specialists (mostly West German) for Spacelab-1, but it was not carried out then.

Biorack. The purpose of the experiment was to investigate the effect of microgravitation and space radiation on various biological targets (plants, insects, bacteria, fibers, cells). Equipment for this experiment includes a cooler (+4°C) and freezer (-15°C) to store biological subjects, two incubators and an isolation box. One incubator can maintain a temperature of 18-30°C; the other, 30-40°C, with an accuracy of 0.5°C. Each incubator has two centrifuges to simulate terrestrial gravity in orbit for reference samples. The isolation box maintains a somewhat lower pressure than that in the EPM to keep harmful materials from leaking into the EPM.

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For the first time, there were eight astronauts (including 5 U.S. astronauts) aboard the space shuttle: Commander G.

Hartsfield, Pilot S. Nigel, Orbital Operations Specialists J. Butchley, G. Bluford, and B. Dunbar (female). The other three (astronaut-experimenters) were not U.S. citizens. These were West German astronauts R. Furrer and E. Messerschmidt, as well as Dutch astronaut V. Ockels. The presence of two West German astronaut experimenters on the shuttle, which had been chartered by the FRG, is entirely understandable. The appearance of the Dutch astronaut in this crew has its own story. When the flight of Spacelab-1 was being planned, the ESA obtained the right to send its own representative into space. After a contest in which candidates from all ESA member countries participated, two candidates were ultimately chosen: W. Merbol'd (FRG) and V. Ockels. At that time, the Dutch astronaut was the backup for W. Merbol'd. Now, during preparation for Spacelab D-1's flight, W. Merbol'd served as a backup for V. Ockels.

The flight of Spacelab D-1 took place from October 30 to November 6, 1985. The space shuttle Challenger with Spacelab aboard entered nearly circular orbit at an altitude of 320 km and an inclination of 57°. On the whole, the flight was described as successful, especially as regards medical and biological investigations. Many equipment breakdowns occurred during manufacturing experiments, and the astronauts had to trouble-shoot. Equipment for galvanizing in zero gravity completely broke down. It was impossible to synchronize onboard and ground atomic frequency standards in the experiment on recording the effects of the theory of relativity. Equipment for experiments with microorganisms broke down due to improper operation.

9 AUGUST -- in the USSR, the next (16th) Raduga communications satellite was launched. In stationary orbit at a "stopping point" at 45°E, it was given the international registration mark "Statsionar-9." Along with Gorizont and Ekran stationary satellites, as well as Molniya-1 and Molniya-3 satellites, these satellites are being extensively used in television broadcasting systems operating in our country.

19 AUGUST -- in Japan, a 140-kg Planeta-A interplanetary station intended to study Halley's Comet from a flyby trajectory was launched on an Mi-3S-2 Japanese booster rocket. This station is similar in design to the Sakigake station launched in January, 1985, but carries more varied equipment: UV telescope, charged particle detector, and plasma research instruments. The Planeta-A should complete its flight near Halley's Comet on March 8, 1986 at a distance of about 200,000 km from the comet's nucleus.

22 AUGUST -- in the USSR, the next (65th) Molniya-1 communications satellite was launched into a highly elliptical orbit (with an apogee altitude of 40,638 km in the Northern Hemisphere). It is intended to ensure operation of the long-distance telephone, telegraph, and radio communications system, as well as transmission of USSR Central Television programs to points in the Orbita Network. With the launch of the first such satellites in 1965, our country became the first to operate a civil satellite communications system.

27 AUGUST -- the first Avsat satellite for the Australian National Civil Satellite Communications System was launched aboard the space shuttle into a stationary orbit at "stopping point" at 156°E (for more detail on this system, see the appendix to No. 11, 1985).

27 AUGUST -- the first Amersat satellite for the American Broadcasting Corporation's satellite network was launched aboard the space shuttle into stationary orbit at 122°E (for more detail about this system, see the appendix to No. 11, 1985).

11 SEPTEMBER -- the American unmanned interplanetary station ICE (formerly the ICEE-3) completed a flight around Comet

*Continued (cf. No. 10, 1985). Materials from various information agencies provide data on launches of certain artificial Earth satellites beginning with August, 1985. Manned space flights are discussed in separate appendices. Launches of Kosmos series satellites are announced regularly in the pages of the journal Priroda, to which we refer interested readers.

Giacobini-Zinner 7,800 km from its nucleus, passing through the tail of the comet, which at that time was 70 million km from Earth. It took 20 min to pass through the comet's tail, which corresponded to a tail width of about 24,000 km. Ice particles were detected among the particles with which collisions occurred at a rate of about one per second during the flight. The presence of extremely cold plasma with water and carbon dioxide ions was recorded. The station's magnetometer revealed no traces of a shock wave, which, according to theory, forms when solar wind interacts with a comet. Unexpected results include the electrical activity of the medium around the comet and turbulent motion of charged particles.

13 SEPTEMBER -- the launch of the Western European booster rocket Ariane, which was supposed to put into orbit the Western European Eutelsat satellite and the American Spacenet satellite, ended unsuccessfully. This circumstance sharpened competition between Western Europe (Ariane booster rocket) and the USA (space shuttle) to launch satellites from different countries.

28 SEPTEMBER -- on the American booster rocket Atlas Centaur, Intelsat 5a was put into stationary orbit for the global satellite communications system belonging to the international organization ITSO (for more detail about this system, see the appendix in No. 10, 1985).

3 OCTOBER -- in the USSR, the next (26th) Molniya-3 communications satellite was put into a highly elliptical orbit (apogee altitude, 40,065 km in the Northern Hemisphere). Like the Molniya-1 communications satellites, these are integral parts of a satellite communication system used for long-distance telephone, telegraph, and radio communications and for transmission of television programs in the Orbita System.

21 OCTOBER -- the 17th artificial Earth satellite was launched in the People's Republic of China.

23 OCTOBER -- in the USSR the next (66th) Molniya-1 communications satellite was launched into highly elliptical orbit (apogee altitude, 38,845 km in the Northern Hemisphere).

24 OCTOBER -- in the USSR, to further improve the Soviet meteorological satellite system, the Meteor-3 was launched into near-polar orbit at an altitude of 1,265 km. Aboard the satellite was a set of scanning television and radiometric equipment, as well as geophysical research instruments. Information from the Meteor-3 travels to the USSR's Hydrometeorological Center and the State Research Center for Study of Natural Resources, as well as to independent

information reception points of the State Committee for Hydrometeorology.

28 OCTOBER -- in the USSR the next (67th) Molniya-1 satellite was launched into highly elliptical orbit (with an apogee altitude of 39,145 km).

No.	Date	Astronauts (commander given first ²)	Space-craft ³	Flight length		
				D	Hr	Min
110 ⁴	9/17	V. V. Vasyutin (b. 1952) A. A. Volkov (b. 1948) (V. P. Savinykh) All Soviet	ST-14	64	21	52
112 ⁵	10/30	G. Hartsfield (3) S. Nigel (2) J. Butchley (2) G. Bluford (2) B. Dunbar (b. 1949) ⁶ All American R. Furrer (b. 1941) E. Messerschmidt (b. 1946) All West German V. Ockels (b. 1946) Dutch	Ch	7	00	45

1 Continuation (cf. No. 11, 1985).

2 Names of astronauts launched into space for the first time are printed in boldface (for the rest, the number of space flights is given in parentheses).

3 Spacecraft are identified as follows: ST = Soyuz-T; Ch = Challenger.

4 The primary expedition on the Salyut-7. V. P. Savinykh, crew member of the Soyuz T-13 spacecraft, was added after partial replacement of the primary expedition crew when V. A. Dzhanibekov returned to Earth together with Soyuz T-14 crew member G. M. Grechko (V. P. Savinykh's flight lasted 168 days 03 hr 51 min).

5 The flight of Spacelab under the West German program.

6 U.S. woman astronaut.