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The Almaz Space Station Complex: A History, 1964 - 1992

Part 2: 1976 - 1992*

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During the Cold War, both the United States and the Soviet Union explored the possibility of using humans in space for military purposes. The only such project that was brought to fruition was a Soviet military space station program known as "Almaz." Between 1973 and 1976, the Soviets launched three Almaz stations, which were publicly known as Salyut-2, Salyut-3, and Salyut-5. Several crews visited the stations with varying degrees of success. A major element of the Almaz program was the large Transport-Supply Ship (TKS), a vehicle that was never used with Almaz, but eventually served as the basis for the core of the International Space Station. This article is an attempt to use recently published information from Russia to present a history of the Almaz program.

Keywords: Almaz, Military Space, Soviet Union, TKS, Salyut, Space Stations

(Part 1 ended with Section 11. Plans for the Future. *To aid continuity, Section 11 is taken as the opening section of Part 2.)*

11. Plans for the Future

Although the record with Almaz missions had been mixed, the Soviet military and government apparently had a lot of confidence in the project. On 19 January 1976, the Central Committee and the Council of Ministers issued a major decree (no. 46-13) entitled "On Future Work on the Creation of the 'Almaz' Complex" that stipulated several deadlines for future work in the project. For the next Almaz station, the decree noted:

- in 1977, end the first stage of flight-testing of the third Almaz station, OPS-3, using the Soyuz spaceship to deliver crews.

For the TKS and its Return Apparatus, the document set the following dates:

- in the first quarter of 1976, begin robot flights of the Return Apparatus;
- in 1976, begin two robot space flights of the TKS as a whole; and
- in 1978, begin five piloted flights of the TKS.

The decree also gave formal approval for Chelomey to begin work on a fundamentally modified version of the Almaz station:

- in the second quarter of 1976, end work on the "draft plan" of a modified Almaz space station with two docking ports, OPS-4, a station to be used for continuous piloted operations by using rotating crews; and
- in 1977, move to orbital testing of OPS-4; one of the docking ports would have a Return Apparatus attached to it.

Finally, the decree set a date for operational use of the complete complex:

- in 1980, declare the entire Almaz system (OPS, TKS, and VA) to be completely operational [99].

The decree's stipulations meant that for the first time, Chelomey would be flying both the Almaz OPS and the TKS simultaneously in orbit. As plans went in early 1976, the design bureau would fly Almaz OPS-3 in 1976, fly the advanced OPS-4 in 1977, begin piloted flights of the TKS in 1978, and the declare the whole system operational within two years. It was an ambitious schedule, and its success would depend on a combination of factors, including the success of the next Almaz, the results of testing of the TKS, and finally, but not least, the winds of political change in the upper echelons of the Soviet defense industry.

Cosmonauts continued to prepare for future Almaz missions. The practice was for backup crews from past missions to recycle into prime crew spots for the next flight. The Almaz training group, the Second Department of the First Directorate at the

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Cosmonaut Training Center was headed by Col. Yevgeniy V. Khrunov from June 1973 (who replaced Shonin, now transferred to the Apollo-Soyuz Test Project). Khrunov himself was replaced by Col.-Engineer Yuriy P. Artyukhin, fresh off his two week mission to Salyut-3, on 11 December 1974. After a major restructuring of the cosmonaut squad, the Almaz group was headed by Col. Viktor V. Gorbatko from 30 March 1976 [100].

12. The Third Almaz Station

12.1 The Launch of OPS-3/Salyut-5

As per the decree in January 1976, the third Almaz station was prepared on time and readied for launch the same year. OPS vehicle no. 0103 was successfully launched into orbit at 2104 hours Moscow Time on 22 June 1976 by a three-stage Proton-K booster. Initial orbital parameters were announced as 219 x 260 kilometers at 51.6° inclination [101]. Officially named Salyut-5, the station performed a series of orbital maneuvers that deposited it in a fairly standard "military" orbit of 260 x 270 kilometers, about 70 kilometers lower than those for the "civilian" DOS articles.

For tracking during the Almaz project, the Soviets used 12 Scientific-Measurement Points (NIP) spread across the Soviet landmass, one of which, NIP-16 at Yevpatoriya, was the site of the main Flight Control Center. During a standard 24 orbit day, the station flew over the Soviet Union for 17 orbits. During the remaining seven orbits, the Soviets used sea-based ships. During the Salyut-3 mission, they used the *Kosmonavt Yuriy Gagarin* and the *Kosmonavt Vladimir Komarov*. The more modern *Gagarin* was stationed in the north Atlantic near Newfoundland, while the *Komarov* remained off the coast of Cuba. For the Salyut-5 mission, the Soviets added the *Akademik Sergey Korolev*, but took off line the *Komarov* [102]. Additionally, the older *Morzhovets* and *Bezhitsa* also supplemented communications.

12.2 The Soyuz-21 Mission

About two weeks following the beginning of the station's mission, the first crew for the station was launched into orbit at 1508 hours 45 seconds Moscow Time on 6 July 1976 in the Soyuz-21 spacecraft. On board were Col. Boris V. Volynov and Lt.-Col.-Engineer Vitaly M. Zholobov, both of whom has served on the backup crew for the previous Almaz mission. Volynov was a member of the famous 1960 group of cosmonauts and had commanded the Soyuz-5 flight in early 1969. It was Zholobov's first flight into space after a wait of over 13 years as a cosmonaut. Initial orbital parameters for the Soyuz vehicle were announced as 193 x 253 kilometers at 51.6°. Originally, mission planners had expected to carry out a three-month mission, but sometime prior to launch, the State Commission decided to limit the flight to a more conservative 60 days [103]. After launch, the Chairman of the State Commission – presumably Strategic Missile Forces officer Col.-Gen. Grigor'yev – announced that the flight program of Soyuz-21 was "to fulfill the targets set for space science by the 25th [Communist Party] Congress...to benefit the national economy" [104]. He made no mention of any military work.

Despite the modifications to the *Igla* system, once they were in orbit, an alarm went off that indicated that one of the antennas of the system had not deployed. The system, however, continued to operate as planned, at least in the initial phases. The crew acquired clear visual contact with the station at a range of 350 meters. As Soyuz-21 closed in on Almaz, at a range of 270 meters, relative velocity between the objects abruptly increased beyond acceptable limits, i.e. more than two meters per second. At that point, the crew asked permission to switch over to manual control. Ground control replied that "The approach process is going normally...wait for switching off of the 'Zone of Braking' indicator light" [105]. The crew replied soon that the light had turned off, meaning that the spaceship was no longer increasing in velocity towards the station. At the same time, it was clear that lines of sight for the two vehicles were slowly diverging beyond acceptable limits. The crew had to take urgent action or else the ships would pass each other by. At a range of 70 meters, Volynov switched over to manual control and skillfully brought the Soyuz to the Almaz for a successful docking at 7 July at 1640 hours Moscow Time. The crew entered the station within five hours of docking.

Within a few days, Volynov and Zholobov settled down to a routine of photo-reconnaissance activities supplemented by some medical, technological, astrophysical, and Earth resources-oriented experiments. The primary goal of the mission was photo-reconnaissance, some of it coordinated with Operation Sever ("North"), a massive Soviet air and sea military exercise east of Siberia. Although the Soviets naturally refrained from making any commentary on any military experiments, Western analysts were quick to point out that the mission was primarily military in nature. By 19 July, the American trade journal *Aviation Week and Space Technology* was reporting that Salyut-5 was definitely a military reconnaissance platform and that the experiments conducted on board were little more than "window dressing" to hide the actual experiments program. Later, on 9 August, the same journal reported that voice communications and telemetry monitored during the mission indicated that the Soviets were trying to conceal voice exchanges between the station and the ground. Often, once the complex was over Soviet territory, normal voice communications would cease, and the crew would transmit data via "non-standard" frequencies or transmitters. At several points during the mission, TASS announced that the crew were conducting observations of the Soviet landmass. Presumably, these were of a military nature. For example, on 26 July, the cosmonauts took photos of the southern areas of the country, while five days later, TASS announced that the crew had began studying a vast amount of territory in the south and north of the Soviet Union – although the work was hindered by poor weather [106].

Despite the relative scarcity of information released about the mission, the two cosmonauts on 8 July gave a televised tour of part of the station. On 15 August, the crew held a question and answer session with children on a Young Pioneers tour of the Flight Control Center [107]. Many operations of controlling the station were performed under ground control to relieve the cosmonauts from the routine tasks. Communications with the crew was also kept to a minimum and reportedly only an emergency situation was reason enough to require informing the cosmonauts. Like previous space stations, the crew exercised for about two hours every day to maintain a healthy degree of muscle strength. Most of the exercise equipment was provided by the Air Force's State Scientific-Research Institute of Aviation and Space Medicine (GosNII AiKM). For the first time on a Soviet space mission, the crew also used a "mass meter" to measure their masses in space. In addition to the experiments listed in Table 12, the cosmonauts evidently also tested a mockup of a propellant transfer system, although very little information was released on the details.

Events on board the station were more or less normal through the first month, although both cosmonauts evidently felt an unpleasant odor during their first days on board. The odor was not strong enough to affect their work routine, but the crew worried whether the smell might be from a fuel leak [108]. Their mission took an abrupt turn on their 42nd day in orbit, on 17 August. As the crew were working, the station's alarm suddenly went off; simultaneously, all interior lights turned off and several onboard systems simply died. At the time, the station was passing over the night side of the Earth. In the darkness, with the loud shrill sound of the siren, the crew were totally confused. Within seconds, however, they first turned off the alarm, only to hear dead silence, i.e. it seemed that all of the station's systems had shut down. Volynov immediately transmitted an emergency message to ground control: "There's been an accident on board." Ground control tried to establish what had happened, but just then the station passed out of communications coverage. With no help from the ground, the crew were left on their own. They rejected the possibility that there had been some sort of decompression since there was no audible hiss nor was there any indication that air pressure was dropping. In slowly checking the station's systems, the crew discovered that not only had the station's life-support systems stopped functioning, but that the station had also lost complete attitude control and was drifting. Volynov moved to the station's main control panel while Zholobov moved to the station's periscope, and the two of them, through verbal cues, managed to restore normal attitude. Over a course of two tense hours after the first alarm, the crew managed to restore most of the station's systems back to normal, including the life-support system [109]. If the crew believed that the worst was over, however, they were in for a shock.

After the emergency, Zholobov's health began to deteriorate. He began to suffer from severe headaches, insomnia, nausea, and loss of appetite. Medicine from the first-aid kit was of no help; his condition continued to worsen day by day. At first, the crew decided not to report Zholobov's condition to the ground, hoping that it would improve, but during one routine contact, probably on 20 August, Zholobov himself mentioned his discomfort to ground physicians. Volynov added that his Flight Engineer was looking pale, weak, and "looked as if he was a very sick man" [110]. The following day, the newspaper *Izvestiya* reported that psychologists monitoring the mission had asked for music to be played to the crew to ease the effects of prolonged isolation. The newspaper reported that the cosmonauts had been suffering from "sensory deprivation" [111]. Medication was unable to treat Zholobov's condition, although on 23 August, the crew were said to have carried out observations with the ITS-5 telescope. Journalists who had been stationed at Yevpatoriya were apparently asked to leave by this time. Eventually, with no hope that Zholobov's health would improve, ground control was forced to make an urgent decision. On 23 August, Deputy Chairman of the State Commission,

TABLE 12: *Named Civilian Experiments Conducted on board Salyut-5.*

Name / Instrument	Activity
Amak-3	instrument to analyze blood samples to determine metabolic processes and immune responses and to study concentration of certain chemicals
Aquarium	study of the development of guppy fish and Danio rerio fish
Biokat	study of plant growth in three 'biofixators' with eggs of the danio fish, crepis plant seeds, mushroom spores
Chibis	vacuum suit worn to exert negative pressure on lower body
DRP-90	dynamometer
Fizika/Diffuzia	production of an alloy from 25% toluene and 75% dibenzyl with mixing by thermal convection
Fizika/Potok	study of capillary action of increased surface tension
Fizika/Sfera	study of the melting and hardening of molten metals in weightlessness (mixing of a bismuth-lead alloy with cadmium and tin, which was then cooled down)
Impul's-2	comparison of threshold of sensitivity of the vestibular apparatus to electrical irritants
ITS-5	infrared telescope from the Lebedev Institute of Physics for studying the Sun, the lunar surface, galactic sources, the vertical distribution of water vapor and ozone in the Earth's atmosphere
Kristall	study of the growth of monocrystals over periods lasting 24, 18 and 11 days
Kultivator	use of drosophila to study changes in the chromosome levels
Levkoy-3T	measurement of blood pressure in the brain by rheoencephalography
Pal'ma-3M	measurement of cosmonaut reaction times
Plotnost'	measurement of bone density
Polinom-2M	multi-functional instrument to check blood circulation, breathing patterns, body temperature and heart functions, used for coordination of the overall medical program
Priboy	experiment to test recycling of water
Reaktsiya	soldering (at 1,200°C) of stainless steel with a magnesium-nickel solder
Rezeda-5	study of breathing capacity
Terrarium	study of turtles in weightlessness
Tonus	measurement of muscular tone to identify muscle weakness
Veter	vacuum capacity instrument

Sources: Bert Dubbelaar, *The Salyut Project* (Moscow: Progress Publishers, 1986); I. B. Ushakov et al., eds. *Istoriya otechestvennoy kosmicheskoy meditsiny (po materialam voyenno-meditsinskikh uchrezhdeniy)*, Voronezh: VGU, 2001, pp. 56-57, 108; Christian Lardier, *L'Astronautique Soviétique* (Paris: Armand Colin, 1992)., pp. 205-206; Phillip S. Clark, *The Soviet Manned Space Program: An Illustrated history of the men, the missions, and the spacecraft* (New York: Orion Books, 1988), p. 72; *Soviet Space Programs: 1976-80 (With Supplementary Data Through 1983): Manned Space Programs and Space Life Sciences*, Prepared for the Committee on Commerce, Science, and Transportation, U.S. Senate, 98th Congress, 2nd Sess. (Washington, D.C.: U.S. Government Printing Office, October 1984), pp. 561-562.

former cosmonaut Maj.-Gen. German S. Titov – who at the time was a senior official in the military space forces – spoke personally to Volynov. The Soyuz-21 Commander reported that Zholobov's condition was rapidly worsening, and that he himself was beginning to suffer from headaches. Titov decided to immediately return the crew back home [112]. Volynov took over the responsibility of maintaining the station in a working mode, and transferred documents, exposed film, and the results of experiments to the Soyuz-21 ferry vehicle. In a statement that aroused strong suspicion among Western observers that the mission had been terminated early, the Soviet press announced at 1004 hours GMT on 24 August that the mission would end within 10 hours [113]. The quick notice of the landing seemed to have taken the reporters of Radio Moscow by surprise, making the normally major news story only a one line addition to the news broadcast [114].

The drama in the mission did not end with Zholobov's illness, and the undocking from the Almaz station proved to be one of the most nerve-racking for any Soviet crew. During separation of the Soyuz-21 ferry (at around 1800 hours Moscow Time) on 24 August, the latches on the docking node failed to open up completely and following an automatic firing of the Soyuz thrusters to move away from the station, the latches became jammed, leaving the Soyuz vehicle suspended but connected to the station. Ground controllers quickly relayed a series of emergency commands to the crew but only the first set was apparently received prior to loss of communication as the complex began to move out of range. Volynov attempt once more to detach the spacecraft but only managed to loosen the connection slightly. Volynov later remembered the look of horror on Zholobov's face. For an entire orbit, the two ships remained hanging with each other, unable to separate. It seems that a second series of commands after acquisition of communication allowed the two vehicles to successfully separate [115].

The actual landing was outside a nominal recovery window, around midnight local time. Soyuz-21's Descent Apparatus landed amid very strong gusty winds forcing an asymmetrical firing of the cushioning landing jets on the capsule. The capsule landed with a very strong impact – at 2132 hours 17 seconds Moscow Time – and bounced several times over a distance eight meters before coming to rest [116]. The landing point was about 200 kilometers southwest of Kokchetav in Kazakhstan, in the middle of the Karl Marx Collective Farm. The cosmonauts found themselves hanging in mid-air suspended by their seat straps. Volynov, with great difficulty, managed to open the hatch and leave the capsule. Unable to stand up without any help, he collapsed on the ground where he made a makeshift bed in the warm southern night. Zholobov was unable to follow because his helmet had jammed on to an obstruction within the capsule. Volynov, summoning all his strength, managed to crawl up to the hatch and help Zholobov, taking care not to short-circuit the electrical wiring on the Flight Engineer's suit. Still adjusting to the Earth's gravity, the two men were too weak to move very far from the capsule, and opted not to fire off a flare, fearing that they might set the field ablaze. Within 40 minutes of landing, however, rescuers arrived on the scene to pick up the crew and the capsule [117]. Total flight time for Volynov and Zholobov was 49 days 6 hours 23 minutes and 32 seconds.

In their post-flight reports, the cosmonauts confirmed that there had been a strong odor of nitric acid in the station – perhaps the nitric acid from the engine's propellant tanks [118]. To confirm or refute the crew's contention, and to determine the reasons for the worsening state of the crew, two of the top institutions of space medicine in the country, the GosNII AiKM and the Institute of Biomedical Problems (IMBP) led an investigation commission coordinated with engineers from the TsKBM and the developers of the life-support systems. The commission investigated every possible avenue including the composition of the structural and fitting materials on the station, the nature of the preparatory technology at the launch site, the daily schedule of the cosmonauts, medical indicators, the types of medicine given to the crew, and the nature of the psychological support available to the crew during the flight [119]. Surprisingly, prior to the announcement of the final results of the commission, General Designer Valentin P. Glushko of NPO Energiya had informed top officials in the program that the reason the crew were in such poor shape was because the Almaz station carried toxic materials. Glushko was quoted as saying that "it is impossible to conduct any work on board the station" [120]. Perhaps protective of his own DOS program and fearful of losing control over all Soviet piloted operations, this may have been an attempt by Glushko to reclaim domination in the field. While the crew had indeed "subjectively sensed some strange odors" in the station which were unexplained, the investigative commission failed to find any toxic components in the blood and urine of the crew. A research institute from the Ministry of State Security (KGB), perhaps fearing sabotage, also failed to find any sign of any toxic materials in all the articles returned from Salyut-5. The final report of the commission (headed by Oleg G. Gazenko, the Director of IMBP) stated that the cause of the poor state of the crew was "overload and emotional stress" [121]. According to the report, during the mission, the cosmonauts did not get enough sleep, broke the physical training routine, and received insufficient psychological support from ground control. The commission's recommendations were to be adhered beginning the very next flight. It seems likely that the report did not reveal the whole story; on many other occasions, ground management had not hesitated to blame crews for shortened missions despite the lack of sufficient evidence. As for the near-catastrophic failure of the station in mid-August, no open sources are available to suggest possible causes. The cosmonauts themselves, both were reportedly in worse condition than earlier crews and had lost about 1.5 kilograms each during the flight. They spent the few days following landing completing their flight logs and recovering from their malaise. After about a week Volynov and Zholobov flew back to Zvezdnyy gorodok on 2 September and the next day received the usual awards of Hero of the Soviet Union.

12.3 The Soyuz-23 Mission

Ground controllers implemented at least one major orbital maneuver with Salyut-5 prior to the next launch of a Soyuz crew to the station. One of the primary goals of the mission was to set the record straight on whether the station could be used further for experiments. Indeed, the lingering doubts about the "toxic" atmosphere of the station prompted mission planners to prepare a special "laboratory" for the crew to carry to conduct air tests and trace chemical compounds in the station. They also carried gas masks to wear when entering Salyut-5 [122]. The fact that these precautions were taken indicates that although the official investigative commission had exonerated the air inside the station, there was still some suspicion about the internal atmosphere. One recent Russian source suggests that the atmosphere inside the station may have been automatically replaced – at least partially – after the early return of the Soyuz-21 crew [123]. The prime crew designated for the new flight were rookie cosmonauts Lt.-Col. Vyecheslav D. Zudov and Lt.-Col.-Engineer. Valeriy I. Rozhdestvenskiy. Both had joined the ranks of the cosmonaut team in 1965 and had spent a significant amount of time mastering all the systems on board the Almaz. Rozhdestvenskiy, a naval officer, had evidently been included on the crew to observe U.S. ships [124].

In early October 1976, the State Commission held an official meeting at the Kosmonavt Hotel at Tyura-Tam and formally approved the choice of Zudov and Rozhdestvenskiy. Chelomey was not present, and his First Deputy at the TsKBM, Gerbert A. Yefremov reported on the state of the station. Glushko approved the Soyuz vehicle ready for flight and Lt.-Gen. Vladimir A. Shatalov, the coordinator of cosmonaut training at the Cosmonaut Training Center delivered a report on the readiness of both the prime and backup crews. The planned duration of the mission has not been revealed, although Soyuz landing windows suggest a relatively short flight of about 17 to 24 days [125]. State Commission Chairman Col.-Gen. Grigor'yev wished the crew success and hoped that they would "breeze freely" [126].

The launch of Soyuz-23 occurred on time at 2038 hours 18 seconds Moscow Time on 14 October 1976. Zudov and Rozhdestvenskiy successfully entered a 194.2 x 249.9 kilometer orbit with an inclination of 51.63° [127]. According to later reports, during the ascent to orbit, the Soyuz launch vehicle deviated from its flight path nearly the full extent possible before a possible launch abort. As a result, the initial orbit for Soyuz-23 was much lower than planned [128]. By its 16th orbit, the ferry had maneuvered close to Salyut-5 and began its final approach regime. At 2158 hours Moscow Time on 15 October, the cosmonauts put Soyuz-23 in its automatic mode for docking when it was approximately seven kilometers from the station. At about 4.5 kilometers from its target, as *Igla* was bringing the Soyuz to Almaz, Rozhdestvenskiy reported to the ground that "There are very strong fluctuations." Zudov added as the vehicle closed into about four kilometers that there were "very strong lateral fluctuations" in the vehicle [129]. By about 1,600 meters range, the spacecraft began to turn as the amplitude of the oscillations increased. Curiously, the indicator lights on board the ship that communicated parameters for lateral drift suggested that the ship shouldn't be turning. By the time, the Soyuz was 500 meters from the station, with the Soyuz now continuing to turn and with approach velocity reducing too fast to carry out a docking, Zudov urgently commanded Rozhdestvenskiy to turn off the approach program, which he did. Transcripts of the communications suggest that the crew was less than pleased with the outcome. They waited for word from the ground while still in sight of the station:

> Zudov: What a pity! Indeed...what a pity! What should be do? [in a despairing voice] The object [i.e. Almaz] is [still] visible. You understand. The object is at the present moving to the left.
>
> Rozhdestvenskiy: You understand. The object is leaving.
>
> Zudov: But who is to blame for this!? All of us! [The station is] moving to the left. The [approach] velocity was not very great [heavy sigh] [130].

At this point, the vehicles were roughly 40 meters from each other. The crew evidently requested permission to try a second attempt at docking, confident that they could still pull it off since the Soyuz ship had slowed down its turning by this time. Ground control replied by asking the crew to shut down the remaining systems on *Igla*, remove their spacesuits, and try and get some rest, adding that there would be no repeat attempt. Given that telemetry showed that the attitude control propellant load was relatively low, they apparently believed that it would be impossible to attempt a second docking attempt. Due to the absence of solar panels on the Soyuz spacecraft, the crew were severely limited in the amount of power reserves available for a second docking attempt. The crew were later told to shut off all non-essential electrical systems including the radio to conserve power and prepare for a return to Earth [131]. Unfortunately for Zudov and Rozhdestvenskiy, their Soyuz craft had already passed the landing opportunity for the day and had to wait an additional day for the next pass over Kazakhstan to land, which was during night time local time. At the time, the Soviet press announced that the docking had been canceled due to a malfunction in the rendezvous and approach electronics system aboard the Soyuz. It was the very first time in the history of the Soviet space program that a failure had been announced while a mission had been in progress.

As the tension increased among ground controllers, many important dignitaries arrived at the Flight Control Center at Yevpatoriya. Among them were General Designers Chelomey and Glushko, top leaders in the Air Force and the Strategic Missile Forces, the head of the Ministry of General Machine Building (MOM) Sergey A. Afanas'yev, and Leonid V. Smirnov, the Chairman of the very powerful Military-Industrial Commission (VPK) [132]. Meanwhile, back at the Cosmonaut Training Center, the crews' families, who had assembled at Zudov's apartment to welcome the cosmonauts back home, were anxiously awaiting word about their safe return. Retrofire went as planned at 2002 hours Moscow Time on 16 October, and the Soyuz-23 Descent Apparatus entered the atmosphere over North Africa, the normal landing corridor for the Soyuz. Weather in the landing area was, however, not favorable. Shatalov had told the crew to stay in their seats after landing due to squall force winds and blizzard conditions at the targeted location. There was evidently little choice in the selection of a landing site due to the capsule's limited battery power, although rescuers could gain some consolation from the fact that the Descent Apparatus was effectively an all-terrain vehicle.

In the event, the capsule overshot the target landing site by 121 kilometers and drifted down under its parachute into squall force winds and fog, at temperatures of -22° C, and splashed down in sludge ice in Lake Tengiz at 2045 hours 13 seconds Moscow Time (long after dusk local time) [133]. The 32-kilometer wide Lake Tengiz is a salt lake in the middle of the spacecraft recovery zone about 140 kilometers west of Arkalyk in Kazakhstan, and has a surface area of about 1,590 square kilometers. The capsule landed in the partially frozen lake approximately eight kilometers from the northern shore. As the capsule cooled rapidly in the freezing water, the cosmonauts removed their pressure suits and put on their normal flight suits expecting a quick recovery. The cosmonauts were exhausted after removing their pressure suits in the small capsule and decided to eat some of the spacecraft's rations while awaiting recovery. Helicopters began searching for the spacecraft, but the capsule's light beacon was obscured as the helicopters descended in 50-70 meter thick fog. Only fifteen minutes following splashdown, the pyrotechnic cartridges of the reserve parachute hatch suddenly blew, violently moving the capsule into a nearly "upside-down" position. In this position, Zudov, still held by his seat straps, was suspended above Rozhdestvenskiy. The cartridges had evidently fired because the water had short-circuited two contacts. The parachute filled with water and sank to the bottom of the lake. Because the lake was rather shallow, the sunken parachute did not drag the capsule underwater with it. Communications with the crew also ceased at this time, and the bitter cold began to seep into the capsule [134].

Recovery teams tried using rubber rafts to reach the capsule but were obstructed by blocks of ice and icy sludge on the surface of the freezing lake shore, making it impossible for them to reach the spacecraft. In the heavy snow and thick fog, helicopters air-lifted amphibious vehicles to the lake, but they were unable to reach the capsule because of the bogs surrounding the lake. One helicopter, piloted by 34-year old Nikolay Kondrat'yev, flying over the lake in squall winds of up to 20 meters per second, managed to descend to about 4-5 meters above the black "smoking" waters, and with a powerful searchlight, was able to find the floating capsule. Based on received information that water, land, and air routes were effectively blocked, the recovery forces decided to wait until dawn for the helicopters to take in frogmen. Although there was no immediate threat facing the cosmonauts (since the capsule was theoretically sea-worthy), there was a concern over the amount of remaining power aboard the vehicle. Normally the vehicle's batteries were only needed for the short landing sequence of 40 minutes. The emergency situation forced the cosmonauts to shut down everything except a small interior light. Food rations were available for just such an emergency; air to breathe was available through the pressure equalization vent which was above the water line [135]. At some point, it appears that the ventilation holes of the spacecraft may have become immersed underwater, blocking the air route into the cabin. By their fourth hour after landing, the crew were apparently feeling the lack of oxygen and having problems moving at all [136]. Outside meanwhile, the snowstorm continued to prevent an immediate rescue.

Immediately after the landing, officials at the Flight Control Center at Yevpatoriya had received a report from the search and rescue service that the spacecraft had splashed down in Lake Tengiz, and that all-terrain vehicles had departed for the lake and would be arriving within an hour. A second report soon after described the terrible weather and the failure of the helicopters in picking up the capsule from the middle of the lake. A third report received at the control center around one o'clock in the morning Moscow Time indicated that all-terrain vehicles were unable to get through and that all rescue efforts would have to be suspended until dawn [137]. These reports were naturally worrying and the State Commission was seriously fearing that the crew were freezing to death inside the capsule.

Through the night, rescuers on the lake shore prepared for their mission the next day. They prepared two helicopters, one an Mi-8 capable of lifting up to 20 tons, and the second, an Mi-6, which would carry frogmen to the capsule. In preparation for the rescue, the cosmonauts put on their emergency water survival suits in case they had to exit the capsule through the top hatch. The crew also turned on the exterior light beacons again in order for the helicopters to find the spacecraft in the fog and snow. At the break of dawn, with Kondrat'yev at the controls, the Mi-6 took off and found the Soyuz capsule again, this time depositing a team of frogmen next to the capsule. Between squalls of snow, the frogmen attached flotation aids to it, as the Mi-6 returned back to shore. Kondrat'yev switched helicopters, and then took off in the Mi-8 back to the capsule, this time to bring it back to the shore. Once over the capsule, the Mi-8 crew dropped a halyard to the frogmen below, who, in the still turbulent waters, secured it to the spacecraft. Unfortunately, the helicopter was unable to completely lift the capsule out of the water. Instead, Kondrat'yev began dragging the ship through the water. At about five kilometers towards the shore, the capsule nearly sank, but Kondrat'yev kept his cool, and after a 45 minute trip, harrowing for both the helicopter crew and the Soyuz-23 crew, he managed to deposit the capsule on the shore of the lake [138]. Reportedly, the cosmonauts nearly suffocated during the journey to the shore [139]. The recovery was finally over about eleven hours following touchdown. It was around dawn at Yevpatoriya when Smirnov, Afanas'yev, Chelomey, and the others finally left the center. The Soviet press announced the crew's safe recovery at 0700 hours Moscow Time on 17 October 1976. After a series of initial checkups, the crew flew back to Zvezdnyy Gorodok on 26 October and were received with a large welcome ceremony attended by many important officials. Referring to Rozhdestvenskiy, Chelomey emoted, "...fate is fair to people – they found themselves in water, bitter and salty, and one of them is a sailor" [140]. Rozhdestvenskiy had headed a naval diving team during his pre-cosmonaut days, and was one of the few cosmonauts with a non-Air Force background. In addition to praise for the crew, Shatalov also commended the performance of the recovery forces. Helicopter pilot Kondrat'yev received the Order of the Red Star for his efforts.

Yet another commission was formed to investigate the accident, this time under the chair of Vsevolod A. Avduyevskiy, the First Deputy Director of the Central Scientific-Research Institute of Machine Building (TsNIIMash, formerly NII-88). Representatives from NPO Energiya, principally flight director (and former cosmonaut) Aleksey S. Yeliseyev firmly believed that the crew was at fault for discontinuing the docking procedure. He believed that the crew could have attempted a second docking attempt (for which they had trained for) on the 33rd orbit.

The problems had all stemmed from a failure in an antenna of the *Igla* system. Evidently, there were spurious and large "oscillations" in the signals of *Igla* which had led the approach engines of the spaceship to fire in a "self-oscillation" mode. The cumulative effect was a large amplitude in lateral drift [141]. A minute-by-minute reconstruction showed that the crew may have violated prior instructions, although their decisions were not unreasonable. At 2148 hours, Soyuz-23 had acquired "capture" of its target, and all systems were nominal. At 2150, the "lateral extinguishing zone" light had come on, indicating that all lateral movements should have stopped. However, the spacecraft continued to turn since the engines responsible for stopping lateral turns were not turned on. The crew, as they reported, felt the turns, but their information suggested that they should not be turning. Despite another two minutes in the same situation, the crew opted to continue the approach. They evidently realized that discontinuing the current approach would mean abandoning the mission since propellant levels were rather low. The ship had used excessive propellant during the preliminary approach between 7.0 and 5.7 kilometers range. The crew had had the possibility to switch off the approach at four points during the entire time, and in each case had violated prepared instructions, waiting until the last possible moment to do so. However, the mitigating circumstance was that the indicator lights on board the spacecraft suggested that the approach systems were functioning normally [142].

Clearly, the Soyuz's *Igla* system was displaying repeated signs of improper performance, sabotaging entire missions. During a post-mission meeting with Minister of General Machine Building Afanas'yev, the Chief Designer of *Igla*, Armen S. Mnatsakanyan, weakly defended his product but was unable to explain why such large fluctuations (such as seen on Soyuz-23) were not detected on the ground. The Minister wanted a guarantee that *Igla* would be reliable in the future. At the time, Mnatsakanyan's organization, the Scientific-Research Institute of Precision Instruments (the former NII-648) was developing a new approach, rendezvous, and docking system for Soyuz known as *Kurs* ("Course"). In answer to Afanas'yev's demand for reliability, Mnatsakanyan replied that, "Establishing standards for fluctuations on *Igla* would be useless – the future use of *Igla* would end similarly [to Soyuz-23]. We need to quickly introduce *Kurs*" [143]. Neither Afanas'yev nor General Designer Glushko were pleased with Mnatsakanyan's response. During subsequent ground tests, engineers were unable to confirm Mnatsakanyan's hypothesis that the excessive vibrations on *Igla* were due to a badly designed boom on which the *Igla*'s gyro-stabilization antenna was installed. An official Ministry report, dated 2 December 1976, stated that:

> Due to insufficient ground work and low levels of methodical measurements of primary parameters of the apparatus in all stages of its manufacture, testing, and operation which led to the unfulfilled program of the Soyuz-23 flight, a strong reprimand is issued to the Director and Chief Designer of NIITP [comrade] Mnatsakanyan and a warning is given that in case that active measures are not taken to correct the situation, he will be freed from his post [144].

Events behind the scenes were apparently moving too fast for Mnatsakanayan. On 10 December, the Ministry recalled the Chief Designer from Baykonur and ordered him to resign of "his own wishes." Mnatsakanayan refused. Finally, on 6 January 1977, the Ministry issued a formal order firing him from the post of Director and Chief Designer of the institute. Despite his best efforts to protest the decision, Mnatsakanyan never returned to his organization.

12.4 The Soyuz-24 Mission

Through the end of the year, the Salyut-5 station was kept under control for another attempt to board the station. On 22 November, the Soviet media announced that during the automated part of the mission, the station had taken photographs of the Earth, that experiments had been conducted by the ITS-5 infrared spectrometer, and that radiation from the Earth and Moon had been studied. At least three orbital maneuvers were conducted during this period, preparing the way for the third visiting mission, tentatively scheduled for February 1977. Cosmonauts Col. Viktor V. Gorbatko and Lt.-Col.-Engineer Yuriy N. Glazkov were assigned as the prime crew. Gorbatko was another cosmonaut from the original 1960 group and had flown his first space mission, Soyuz-7, in 1969. He had also served as backup on Voskhod-2 and Soyuz-5, both missions involving EVA. Since 1969 he had continuously trained in the Almaz program. His Flight-Engineer Glazkov was a rookie cosmonaut selected in 1965 and had worked on his "Candidate of Technical Sciences" thesis on EVA activities. The fact that both cosmonauts had some background related to EVA spurred speculation in the West that such activities had been planned for the mission, but recent reports suggest that none of the Almaz mission plans included EVAs; spacesuits were, in fact, unavailable on board the station [145]. As Gorbatko later recalled, the main task of the crew was "to determine if the station had been poisoned or not" [146]. The crew carried special gas masks with them which they hid out of sight so as to preclude the press from taking photos of them. In addition to being trained for the mission originally meant for the Soyuz-23 crew, i.e. testing the atmosphere inside the Almaz, the new crew were also trained to perform the *Atmosfera* experiment to completely replace the existing air in the complex. Plans called for using the reserve of compressed air intended for the airlock to renew the atmosphere [147]. Special tools such as wrenches and screwdrivers were manufactured in accordance with specifications submitted by the cosmonauts themselves.

The Soyuz-24 spacecraft was successfully launched at 1910 hours Moscow Time on 7 February 1977 carrying cosmonauts Gorbatko and Glazkov into orbit. Initial parameters were 184.7 x 346.2 kilometers with a 51.65° inclination [148]. The crew conducted orbital maneuvers on the 4th, 5th, and 17th orbits before an automatic approach to about 80 meters of the station. At that point, there was yet another failure in the *Igla* system, prompting Gorbatko to take over manual control to complete the linkup successfully at 2038 hours GMT on 8 February [149]. Entry into the station was delayed for unspecified reasons and the crew had an unusual six hour sleep period prior scheduled at the time [150]. It was another 11 hours before the cosmonauts would make their way into Salyut-5. Ground control was anxious to hear reports from the crew concerning the safety of the station, and prearranged code words had been agreed upon to indicate particular situations. Gorbatko was the first one to enter the station, cautiously testing the air at various points throughout the entire length of the station. Very shortly, he was able to report that "Excellent, it's a big and good home," a coded message meaning that the atmosphere was normal and that there were no odors [151]. The results of the initial tests were then transmitted to Earth and ground control confirmed the initial analysis. The cosmonauts then took their breathing apparatus off and began reactivating the station. Soon after, on 9 February, Chelomey thanked the crew for their work and wished them a successful flight. Within two days, the cosmonauts had completed reactivating the station's basic systems, including replacing components on Salyut-5's computer [152].

Recent reports suggest that the crew had had a very intensive program during their planned 18-day flight, and that the demands made on the cosmonauts were comparable to those for crews who had flown much longer missions lasting as much as two months [153]. Gorbatko himself recalled many years later that:

> The station was built mainly for purposes of reconnaissance...the Almaz that I flew only had reconnaissance equipment on board. This consisted of a very big camera – the *Agat.* Apart from taking photographs with this camera, we also carried out instantaneous development. The highest speed we ever reached was around 30 minutes or even just under. In just under 30 minutes we managed to take the photographs, develop them, and send them back to Earth [154].

While military reconnaissance photography was no doubt a major objective of the mission, the crew also carried out several scientific and technological tasks, some of which were extensions of the activity performed by the earlier Soyuz-21 crew. On 16 February, the Soviet press announced that the crew had reached the halfway point of the mission, a practice similar to Soyuz-15 to preclude speculation on premature termination of the mission.

A major portion of the crew's work was taken up by repair and rehabilitation work on the station. Backup cosmonauts Berezovoy and Lisun worked in a ground-based simulator at TsPK to troubleshoot any problems encountered by the spaceborne cosmonauts [155]. On 21 February, the cosmonauts finally performed the major air-changing *Atmosfera* experiment in the station coordinated with a TV transmission to the Flight Control Center, part of which was later broadcast on Moscow TV. The original rationale for conducting the experiment was as a precautionary measure in case the air inside the station was found to be contaminated. When the cosmonauts verified that the atmosphere was clean, engineers delayed the experiment, but decided to go through with it as a technology demonstration exercise. The air replenishment equipment, developed by the Chelomey design bureau, was described as "a multifunctional combined system" that could supply compressed air to control the station's stabilization system and also account for leaks if necessary. The complete operation was fairly complex and required the use of torqueless nozzles to prevent the station from losing its attitude while the air was being vented into space [156]. During the experiment, air was slowly vented from one end of the station, releasing 100 kilograms of air from tanks in the Soyuz Living Compartment at the other end. Gorbatko manned the main station controls during the exercise, while Glazkov operated the controls for the air replacement exercise. The Soyuz-24 Commander later recalled that when the valves were opened to begin the operation, "there arose a terrible rumble. It gave the impression that the station was going to break open. The sound effect was much like we were inside a rolling metal barrel" [157]. After the exercise, an unidentified Soviet scientist was reported as saying that the air in the station was "quite satisfactory to the crew and the doctors, but all the same it was decided to test the system, which is important for prolonged expeditions" [158].

The rest of the mission was fairly uneventful although there was a minor scare at some point when the crew heard a loud noise, as if the station had been hit by some object. After checking for pressure leaks, the crew concluded that the station had probably been hit by a small particle, perhaps a small meteoroid, a speculation that was communicated to Chelomey on the ground [159]. Due to concern about expiration dates on food stuff on board the station, ground controllers forbid the crew to eat some of the food on the station. The crew's overall impression of the station was, however, positive, and Gorbatko, especially recalled that he was "very pleased" and that the "work was interesting" [160].

The crew conducted two orbital maneuvers on 23 and 24 February, the first one by the Soyuz-24 spacecraft itself. By that time, the cosmonauts had begun to pack the results of their stay in the Soyuz spacecraft and mothballing the station. Prior to disembarking from Salyut-5, Gorbatko and Glazkov packed the small reentry capsule at one end of the station with exposed film from the *Agat-1* camera. The crew finally undocked from the station at 0921 hours Moscow Time on 25 February and landed at 1236 hours the same day 36 kilometers northeast of Arkalyk in strong winds, snow, and temperatures around -17° C. The capsule evidently did not land in the intended recovery zone, and as such, rescue crews were unable to reach the crew immediately. After landing, the crew module tumbled over a couple of times before ending up on its side. The crew received minor injuries in the process and had to wait in a very uncomfortable position for a while, before opting to unstrap themselves and try and leave the capsule. Although they did manage to get out, they decided to crawl back in again due to the bitter cold. Rescue crews took over an hour to reach the crew. As a result of their experience, as well as those of the Soyuz-18-1 and Soyuz-23 crews, NPO Energiya introduced some changes in protective and survival gear for future cosmonauts [161].

Just one day following the crew's return, the small return capsule from Salyut-5 was automatically ejected and landed at 1228 hours Moscow Time on 26 February 1977 [162]. Rescuers safely recovered the capsule and brought it to Moscow, and at

Chelomey's personal request the detachable heatshield from the capsule was also found nearby and brought to the premises of the TsKBM for examination. Engineers were evidently very satisfied with its performance [163].

Gorbatko and Glazkov were formally welcomed back from their mission at Zvezdnyy gorodok on 5 March. Chelomey was one of the speakers and expressed deep gratitude to the crew, noting that the cosmonauts' work was a model for those who would prepare for further flights. Glushko spoke after Chelomey, and perhaps in a moment of reconciliation, enigmatically announced that he "understood and shared Vladimir Nikolayevich's elation – eyes have been opening to mysterious phenomena registered during recent flights." The lead designer of the Almaz station, Vladimir A. Polyachenko later recalled that this gathering was the end of the debate between Glushko and Chelomey over the utility of the Almaz space station [164]. The final speaker was State Commission Chairman Col.-Gen. Grigor'yev who stated that the first stage of the development of Almaz had been completed.

12.5 Soyuz-25 Cancelled

Although the "first stage" was over, there were in fact plans for an additional and final visit to the station in March 1977. Soon after the end of the Soyuz-24 flight, the State Commission asked backup cosmonauts Lt.-Col. Anatoliy N. Berezovoy and Lt.-Col.-Engineer Mikhail I. Lisun to prepare for the Soyuz-25 mission. Their backups were Lt.-Col. Vladimir S. Kozel'skiy and Lt.-Col.-Engineer Vladimir Ye. Preobrazhenskiy. The flight would be a short 15-day jaunt to the station to conduct some additional observational experiments. At a meeting of the State Commission sometime in March, General Designer Glushko told those present (including Berezovoy and Lisun) that he would require two months to build and test the extra 7K-T spaceship for the scheduled Soyuz-25 mission. An *additional* two months would be needed to test the vehicle at Tyura-Tam prior to declaring it safe for launch [165]. The extra four months of automated operation by Salyut-5, however, would require at least 250 kilograms of propellant to maintain proper attitude and orbital parameters [166]. This would leave the station 70 kilograms less propellant than would be required to conduct the 15-day Soyuz-25 mission. Since automatic propellant tankers were not available at the time, the Commission decided to cancel the forthcoming flight and keep the station in automated mode for the remainder of its orbital lifetime [167]. Controllers adjusted Salyut-5's orbit once during this period on 5 March, and once more possibly on 22 March.

On 30 March 1977, the State Commission hosted a final meeting attended by the leadership of the TsKBM, the TsPK, and all the cosmonauts who had trained for the Salyut-3 and Salyut-5 missions [168]. It was a final concluding session to review the results and events in the program, and perhaps to discuss a general course of action for the next Almaz. Salyut-5 meanwhile was said to be continuing "scientific research" in an automated mode, and controllers conducted at least two maneuvers on 14 and 15 April [169]. The station was finally deorbited successfully over the Pacific Ocean on 8 August 1977 after a 412 day mission during which the station had completed 6,630 orbits.

13. Chelomey's Cosmonauts

Through the missions of Salyut-3 and Salyut-5, only military officers had actually crewed the station. But they weren't the only ones to train for long duration missions on the Almaz station. Beginning the late 1960s, it was customary for the Korolev design bureau to train their own engineers for flights on board the Soyuz and Salyut. By the same token, Chelomey also took the initiative to train his own engineers for flights aboard the Almaz station. These civilians would fly as the "third person" on three-person crews, accompanying two military officers into orbit.

The Soviet Central Committee and the Council of Ministers had issued a document (no. 270-105) on 27 March 1967 entitled "On the Preparation of Cosmonaut-testers and Cosmonaut-researchers" which laid the foundation for future training of civilian cosmonauts. A subsequent order by the Ministry of General Machine Building on 22 April 1967 prompted Chelomey to organize a special training squad of engineers from his own design bureau. In late 1967, he sent a small group of engineers for medical screening to the Ministry of Health's Institute of Biomedical Problems (IMBP). Several men passed these tests, and in 1969, the Chelomey design bureau, i.e. the TsKBM, formed a "special contingent group" of trainee cosmonauts. These men were not "official" cosmonauts as they had not been approved by the State Interdepartmental Commission (GMVK) which certified all Soviet cosmonauts. During 1971-72, the special contingent group took part in ground-testing of what would be launched as Salyut-2 and also trained in mockups of the Almaz Return Apparatus. They tested different types of spacesuits, performed ergonomic research, and completed weightlessness flights on board specially equipped Tu-104 aircraft during which they simulated many different possible scenarios for the impending Salyut-2 mission.

Finally on 22 March 1972, two of the men, Eduard D. Sukhanov and Valeriy G. Makrushin, applied to the GMVK. Makrushin was approved and thus became the first "Chelomey cosmonaut" inducted into the cosmonaut team. Two further men, Aleksey A. Grechanik and Dmitriy A. Yuyukov, applied on 27 March 1973. Yuyukov passed and became the second member of the Chelomey team.

Further trainees continued to join the special contingent group through the 1970s, but Makrushin and Yuyukov were the only two "real" cosmonauts from the Chelomey design bureau. In 1974-75, the special contingent group, as well as Makrushin and Yuyukov, continued with theoretical preparations, training on the ground with Salyut-3, Salyut-5, and ground models of the Return Apparatus. Perhaps the most significant work of these group of men during this period was as members of "conditional crews" who trained on a ground-based model of the Almaz station (known as the *Analog*). From June to August 1974, and from June 1976 to February 1977, these crews worked in the *Analog* trouble-shooting various problems that the crews of Soyuz-14, Soyuz-21, and Soyuz-24 faced in orbit. Additionally, in September-October 1976, the team participated in the development of new spacesuits such as the *Sokol*, *Sokol-KV*, and *Orlan-D*. In 1978, they trained in the Black Sea, and in October of the same year, began theoretical training for flights of the large TKS vehicle. All the men from the special contingent group were sent to the GMVK in 1978. On 1 December of the same year, the GMVK formally selected Grechanik, Vladimir M. Gevorkyan, Valeriy A. Khatulev, and Valeriy A. Romanov as "real" cosmonauts. Gevorkyan and Khatulev were both from the Fili Branch of Chelomey's design bureau – which produced the main hull of the TKS – rather than the main center at Reutov. On 7 June 1979, the Ministry of General Machine Building formally appointed Makrushin as the Chief of the cosmonaut group from the Chelomey design bureau [170]. (See Table 13 for a chronology of the Chelomey cosmonaut team).

TABLE 13: *Selections for the Special Contingent Group from the TsKBM and its FILI Branch.*

16 October 1968	
V. G. Makrushin	on 22 March 1972, passed GMVK
E. D. Sukhanov	left in 1972
V. N. Yeremich	left in 1971
20 May 1969	
O. N. Berkovich	left in 1969
1969	
L. D. Smirichevskiy	left in 1971
25 February 1971	
A. A. Grechanik	on 1 December 1978, passed GMVK
D. A. Yuyukov	on 27 March 1973, passed GMVK
26 July 1973	
V. A. Romanov	on 1 December 1978, passed GMVK
Late 1977	
V. M. Gevorkyan	on 1 December 1978, passed GMVK
V. A. Khatulev	on 1 December 1978, passed GMVK, left in 1980
July 1979	
A. M. Chekh	left in 1982
31 October 1979	
B. N. Morozov	
14 April 1981	
S. V. Chelomey	left in 1983
S. A. Chuchin	
S. E. Kondrat'yev	
L. N. Tatarin	

NOTE: All the men remaining in the team, both those who had passed the GMVK and those who were part of the "special contingent group," ended training on 8 April 1987. Source for data: I. A. Marinin, S. Kh. Shamsutdinov, and A. V. Glushko, eds., *Sovetskiye i rossiyskiye kosmonavty xx vek: spravochnik*, (Moscow: Informatsionno-izdatel'skiy dom 'Novosti kosmonavtiki,' 2001), pp.312-313.

14. Testing of the Return Apparatus

Both the special contingent group from the Chelomey design bureau as well as the military officers from the Cosmonaut Training Center regularly trained through the 1970s on mockups of the Return Apparatus of the TKS ferry ship. Development of this vehicle had been painfully slow. Designers at the TsKBM (at Reutov) and its Branch No. 1 (at Fili) had completed the "draft plan" for the TKS as early as 1969 [171]. Work on the vehicle as a whole had, however, been delayed by the diversion of commitments to the concurrent DOS-Salyut program in the early 1970s. Chelomey's Branch No. 1, which was responsible for the main portion of the TKS, the Functional-Cargo Block (FGB), was busy through this period with development of the DOS. Original plans had been to manufacture six TKS vehicles at the Khrunichev Machine Building Plant. The factory, however, was overloaded with work on both Almaz and DOS, significantly delaying work on TKS.

It was only in December 1973, after the space station debacles of the previous year, that Chelomey managed to refocus some of his resources back to development of the TKS [172]. One senior designer at Chelomey's design bureau later blamed the delay on TKS to Chelomey's First Deputy Bugayskiy, who as head of the Fili Branch, was evidently more interested in work on the "civilian" DOS-Salyut project. It was only after Bugayskiy's dismissal in 1973 and replacement by Dmitriy A. Polukhin that TKS work could once again resume at a fast pace

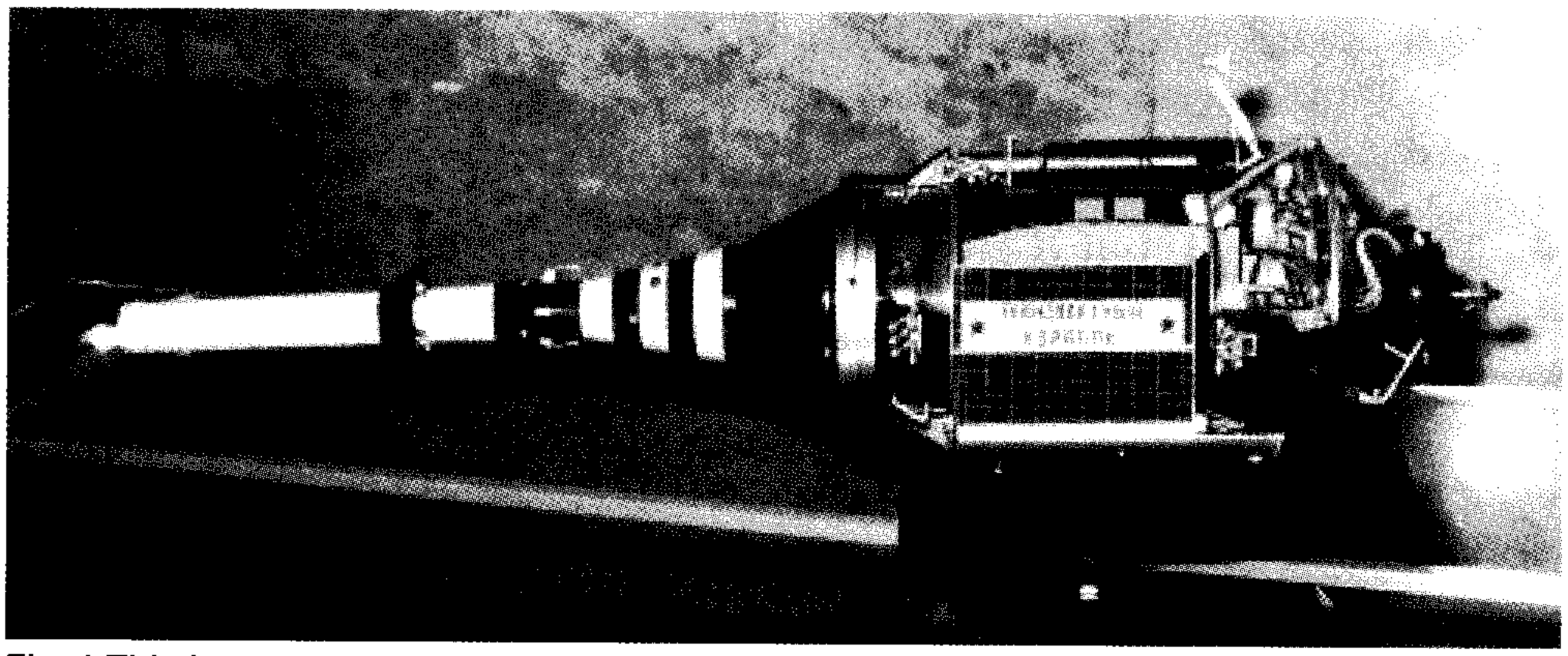

Fig. 1 This is a photo of model of the Transport-Supply Ship (TKS) of the Almaz complex. The tower-shaped structure on the left is the launch escape system. The cone-shaped object in the middle is the actual crew module ("Return Apparatus"). The main hull on the right-hand part of the photo is the service module ("Functional-Cargo Block"). The Cyrrilic letters on the sign say "Transport Ship." Note the docking pin on the right (aft) of the spacecraft. The TKS would dock to the Almaz space station at the aft section allowing the crew to move from one spacecraft to another. (Copyright Dietrich Haeseler)

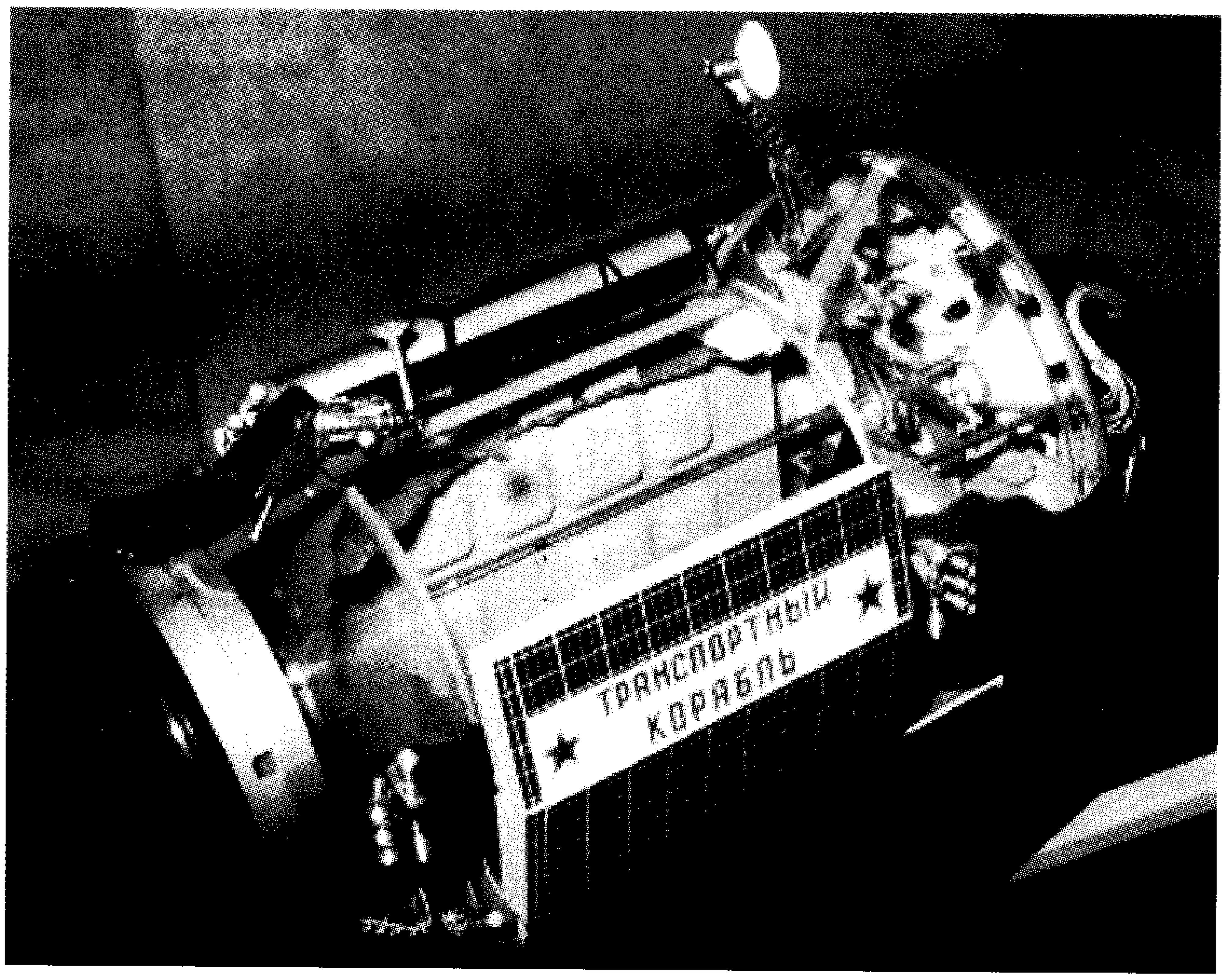

Fig. 2 This is a closeup of a model of the TKS. Note the various attitude control thruster modules distributed around the vehicle, including one at the top with a cover to prevent plume impingement on the spacecraft. The internal area of the FGB shows storage compartments for supplies. The Igla docking antenna is visible on the upper right hand side. (Copyright Dietrich Haeseler)

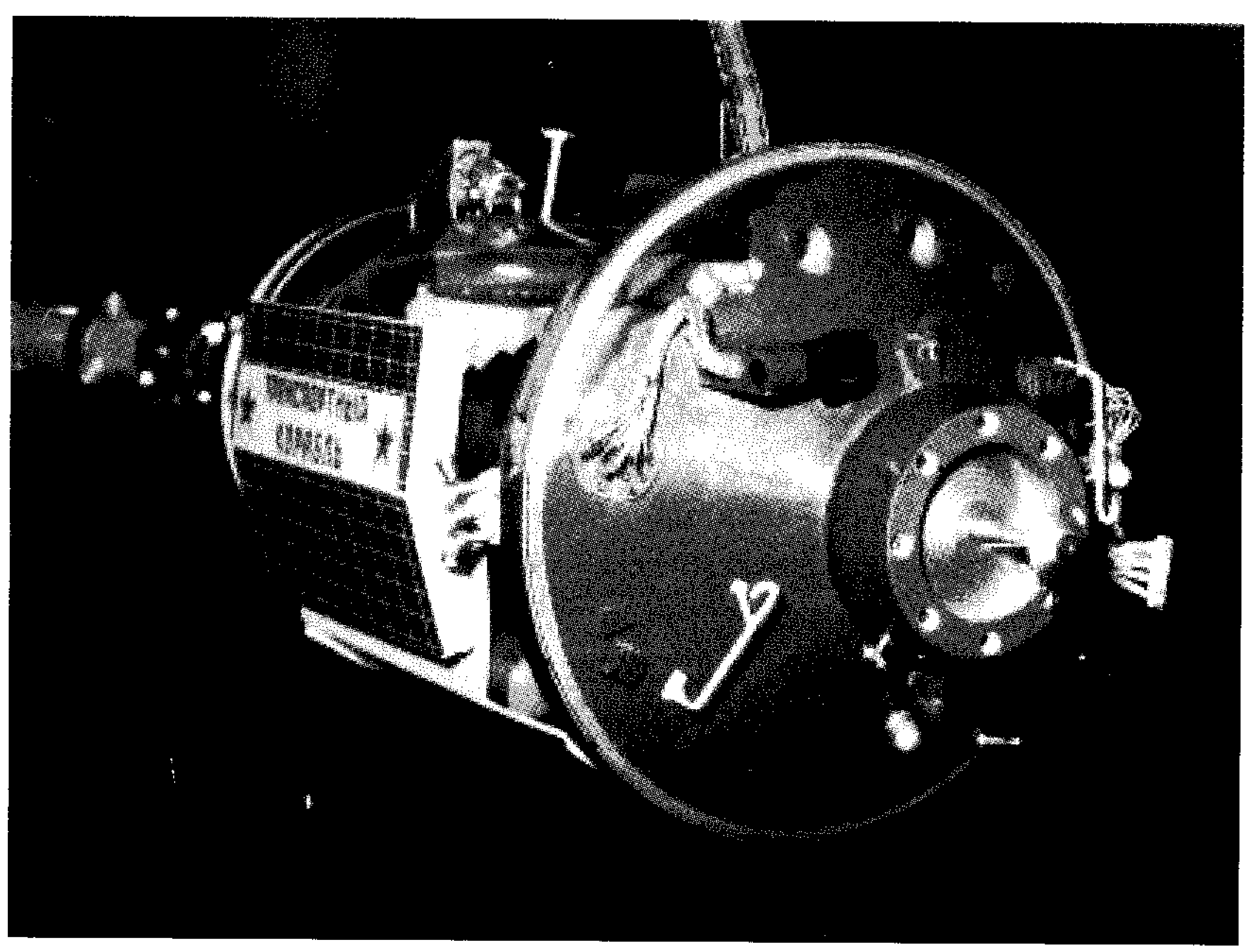

Fig. 3 This is a closeup of the aft of the TKS with a clear external shot of the docking equipment. Note the solar panels folded up against the spacecraft. These would be unfurled upon insertion into orbit. Note also the two portholes around the top of the aft end, which would allow cosmonauts to observe approach and docking directly without the use of periscopes (as in the Soyuz). (Copyright Dietrich Haeseler)

[173]. At this point, the first order of business was to human-rate the Return Apparatus of the TKS, a plan that included verifying the launch escape system – known in Russian as the Emergency Rescue System (SAS), and also checking all systems of the Return Apparatus as a whole. Between 1974 and 1977, Chelomey's engineers conducted five "launches" of the Return Apparatus and the SAS from site 51 at Tyura-Tam. The capsule was installed on a special firing table that simulated the remainder of the TKS. During these tests, the 86 ton thrust solid propellant engine lifted the Return Apparatus to an altitude of two kilometers, after which a three-level parachute system deployed (initial, braking, and three landing parachutes with a surface area of 1,770 m^2). During all five tests (three of capsule no. 005 and two of capsule no. 007), the Return Apparatuses landed safely about 1 to 1.5 kilometers from the launch pad [174].

The major decree in support of the Almaz program issued in January 1976 accelerated work on the TKS. According to the decree, Chelomey's design bureau would begin automated flights of the TKS Return Apparatus in early 1976, move to full-scale robot flights of the TKS later in the year, and then finally begin crewed missions in 1978. The tests of the Return Apparatus were crucial to any future work on the Almaz complex as a whole. The only organization in the Soviet Union which had developed a piloted vehicle capable of launch had been the old Korolev design bureau. For Chelomey, the future of his grand plans would depend on flight-rating these capsules for launch with cosmonauts.

In 1974, Chelomey decided to flight-test these crew capsules two at a time in order to speed up the development phase. His engineers proposed installing two Return Apparatuses under a long cylindrical payload fairing, linked to a mass model known as the Flight-Mass Article (LVI). The LVI fully reproduced the mass and dimensions of what on nominal missions would be the FGB portion of the TKS. The idea was to have one of the capsules, with its Emergency Rescue System, installed normally on "top" of the payload. The second capsule, without the rescue system, would be placed inside and facing down in the hull of the FGB mass model. Thus, the two Return Apparatuses were installed much like two cones with their bases attached. The total payload was known as the object 82LB72. According to the flight-plan, after launch on a Proton-K booster, the two Return Apparatuses would separate from the FGB mass model and then separate from each other. After a single orbit each, the capsules would reenter and land according to the normal program.

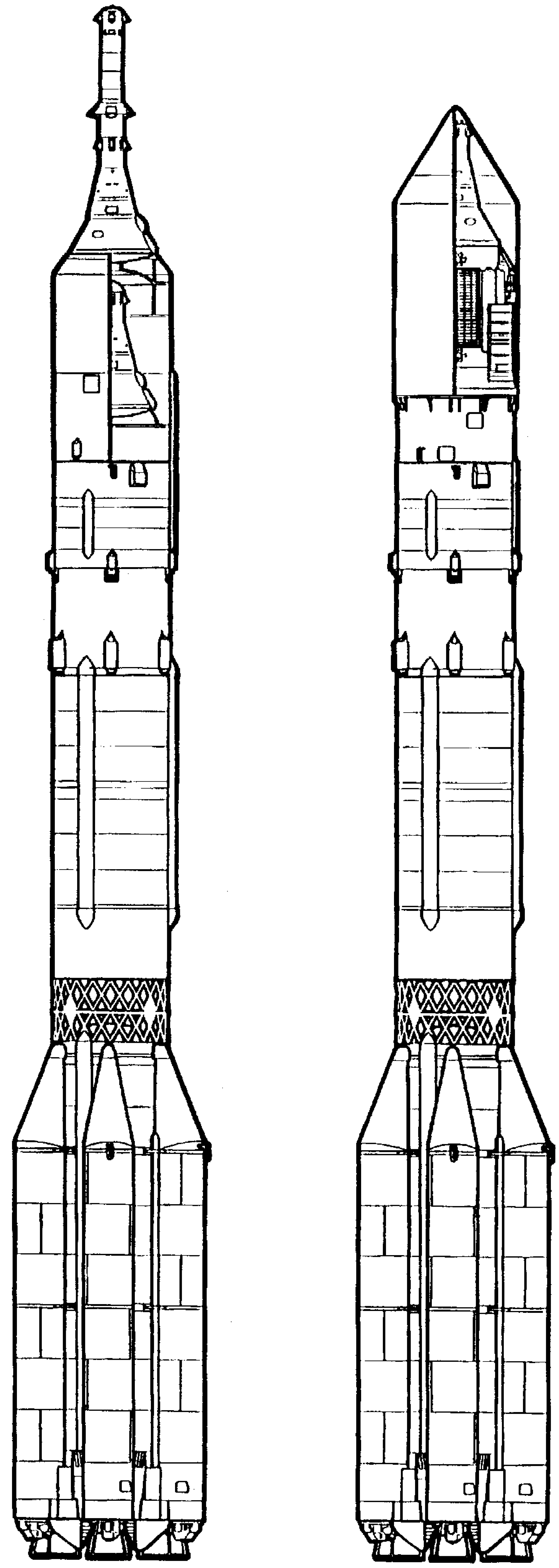

Fig. 4 This diagram shows two Proton configurations used during TKS-testing. The Proton on the left shows the the "dual-Kosmos" configuration used during several twin flights in the late 1970s to test the crew module ("Return Apparatus") of the TKS. These flights were known as the LVI ("Flight-Mass Article") series. Each Proton carried two crew modules. Note that sources differ on the actual configuration of the bottom crew module (here shown with the apex facing up). Some sources suggest that the apex of the bottom module faced downwards rather than up on the launch pad. The Proton on the right shows a standard TKS (complete with FGB and the crew module) on the launch pad.
(Copyright David Rickman)

Through 1975-76, Chelomey's engineers prepared the first flight-models of the LVI. The first two capsules intended for flight were no. 009A/1 (with a launch escape system) and no. 009/1 (without). On 10 December 1976, the whole complex was installed on a Proton-K booster at the launch pad at site 81P at Tyura-Tam. A major malfunction with the *Kaktus* gamma-ray altimeter at the base of the upper capsule threatened to disrupt preparations for launch, but engineers managed to quickly fix the problem in the bitter cold wind and snow that had suddenly descended on the launch site [175]. Cosmonaut Maj.-Gen. Pavel R. Popovich was on hand during launch preparations. He apparently asked to see the cosmonaut couches in the Return Apparatuses. For the LVI tests, engineers had installed only single couches in each capsule. Each couch carried a small explosive package to destroy the vehicle if it landed outside of the planned region. Space for the other two couches were taken up by measurement and telemetry instruments [176].

The Chairman of the State Commission for the LVI test-flights was Col.-Gen. Grigor'yev, who was serving in the same capacity for the Almaz space station missions. Apart from Popovich, other veteran cosmonauts such as Maj.-Gen. Aleksey A. Leonov and Col. Valeriy F. Bykovskiy were also on hand.

At 0430 hours Moscow Time on 15 December 1976, the LVI-1 (as the overall payload was known) lifted off on its Proton and after 170 seconds, the engine unit of the Emergency Rescue System separated as planned. After orbital insertion, the Return Apparatuses completed a single orbit as part of the whole LVI complex. At the end of the orbit, a command separated the top Return Apparatus from its power source and the remainder of the payload, i.e. the bottom Return Apparatus and the LVI. After two seconds, the bottom capsule then disengaged from its own power source and separated from the LVI. About 15 minutes prior to reentry, attitude control jets positioned the base of each capsule towards the direction of travel and turned on the reentry engines. After jettisoning some remaining instruments, both capsules performed simultaneous guided reentries. At an altitude of 10 kilometers, each Return Apparatus ejected its nosecone, began deployment of the parachute system, and turned on several recovery beacons. About 1 to 1.5 meters from the ground, the *Kaktus* system issued a command to ignite the soft-landing engines of each capsule. Both vehicles landed without any damage in their designated target points in Kazakhstan; there were no major anomalies during the flights. Publicly, the Soviets named capsule no. 009A as Kosmos-881 and capsule no. 009 as Kosmos-882 [177]. (See Table 14 for a list of all launches in the LVI program).

The second "dual-VA" test was in the summer of 1977. Chelomey had personally decided to refly both the Return Apparatuses from the previous launch. The two old capsules were redesignated no. 009A/P and no. 009/P. (The "P" stood for *povtorno* or "repeat"). At 0100 hours Moscow Time on 5 August 1977, another Proton-K booster lifted off on mission LVI-2. Unfortunately, at T+53.68 seconds, there was a failure in one of the engines of the launch vehicle's first stage, and the Emergency Rescue System went into operation. Even though only the "top" capsule was equipped for rescue, one source says that both capsules were recovered without harm, although this seems doubtful. Operation of the rescue system indicated that the escape system worked without problems [178].

The third launch took place at 0300 hours Moscow Time on 30 March 1978 with capsule nos. 009A/P2 and 009P/2. The first capsule had already flown on the previous two missions. The second capsule was flying for the second time, having flown in orbit

TABLE 14: *Launches of the Dual TKS Return Apparatus (VA).*

Mission	Name	VA No.	Launch Date	Launch Time (Moscow Time)	Launch Vehicle	Site	Orbit
LVI-1	Kosmos-881 Kosmos-882	009A/1 009/1	Dec 15 1976	0430	8K82K no. 289-02	81P	202 X 248 km @ 51.6° 199 X 232 km @ 51.6°
LVI-2	- -	009A/P 009/P	Aug 5 1977	0100	8K82K no. 293-01	81P	failed to reach orbit
LVI-3	Kosmos-997 Kosmos-998	009A/P2 009P/2	Mar 30 1978	0300	8K82K no. 292-01	81	205 X 230 km @ 51.6° 204 X 225 km @ 51.6°
LVI-4	Kosmos-1100 Kosmos-1101	0102A 0102	May 23 1979	0200	8K82K no. 300-02	81P	204 X 224 km @ 51.6° 200 X 235 km @ 51.6°

Sources: A. Vladimirov, "Table of Launches of the 'Proton' and 'Proton-K' RN" (in Russian), *Novosti kosmonavtiki*, no. 10, pp.25-30, 1998; S. Shamsutdinov, "Cosmonauts of 'Almaz' " (in Russian), *Novosti kosmonavtiki*, no. 12, pp.78-81, 2000.

and recovered after the Kosmos-929 flight in 1977-78 [See Below]. This mission, flight LVI-3, was more successful than its predecessor. Both Return Apparatuses flew successful missions and were recovered without problems about 50 kilometers from each other. Openly, the Soviets referred to the payloads as Kosmos-997 and Kosmos-998. Engineers conducted the fourth and final launch at 0200 Moscow Time on 23 May 1979 using capsule nos. 0102A and 0102. On this mission, the upper reentry vehicle completed two orbits instead of one. Both capsules successfully reentered, but due to problems in onboard electronics, they performed ballistic reentries. The landings for both, which were 90 minutes apart, were "non-standard" and both capsules were evidently destroyed [179]. The last two missions, LVI-4, were openly announced as Kosmos-1100 and Kosmos-1101.

At the time, Western observers were puzzled by these launches. One early theory, proposed as early as 1978, and bolstered by leaks from U.S. intelligence services, was that the "dual Kosmos" flights were tests of a small spaceplane [180]. Without any incontrovertible evidence, Western analysts continued to believe that the tests were in support of a reusable winged vehicle project [181]. It was only in 1991 that evidence from the Soviet Union suggested otherwise.

In total, during the LVI program, one of the Return Apparatuses was used three times: vehicle no. 009A (as its original designation was) was flown on LVI-1 as Kosmos-881, on LVI-2 as the "top" capsule during the launch failure in August 1977, and on LVI-3 as Kosmos-997 [182].

15. The First TKS Mission: Kosmos-929

Concurrent with tests of the crew return vehicle, by the late 1970s, Chelomey's design bureau also flew the entire TKS spacecraft on test runs. In early 1977, engineers prepared the first flight model of the TKS, vehicle no. 16101. It included a functional Return Apparatus, vehicle no. 009A/2. This spacecraft had originally been intended for ground training, but to hasten the flight-program, Chelomey's engineers modified it for flight. The first model originally intended for a mission, vehicle no. 16201, was instead consigned as a ground trainer.

The large TKS vehicle was successfully launched at 1200 hours Moscow Time on 17 July 1977 from site 81P at Tyura-Tam on top of a Proton-K booster. Initial orbital parameters were 221 x 298 kilometers at 51.6° inclination; the satellite was officially known as Kosmos-929 [183]. After reaching orbit, the Proton-K booster's third stage separated from the TKS and later reentered on 29 July.

Kosmos-929 changed its orbit at least three times during the first month in orbit to maintain a 89 minute period orbit. A simulated rendezvous and docking may have been carried out during this period with an imaginary target taking the place of the Almaz station [184]. On 16 August, the spacecraft was in a 194 x 228 kilometer orbit (as tracked by Western sensors), when the Return Apparatus separated for a landing sometime early the following day. After the separation and recovery of the crew capsule, ground controllers conducted an intensive series of at least eight orbital maneuvers until the end of the month as part of a testing program for the two main TKS engines. By the end of that phase, Kosmos-929 was in a 313 x 328 kilometer orbit at 51.6° inclination (as tracked by Western sensors), similar to orbits used by the Soyuz-T test flights in the Kosmos program. Between 16 and 20 August, telemetry which had been monitored on the Soyuz-type 166 MHz ended, probably related to Return Apparatus separation. The spacecraft performed at least three small maneuvers between 28

TABLE 15: *Launches of the Transport-Supply Ship (TKS).*

Mission	Name	Vehicle No.	Launch Date	Launch Time (Moscow Time)	Launch Vehicle	Launch Site	Orbit
TKS-1	Kosmos-929	16101	Jul 17 1977	1200	8K82K no. 293-02	81P	221 X 298 km @ 51.6°
-	-	16201	not launched	-	-	-	ground test article
TKS-2	Kosmos-1267	16301	Apr 25 1981	0501	8K82K no. 299-02	200L	200 X 278 km @ 51.6°
TKS-3	Kosmos-1443	16401	Mar 2 1983	1237:08	8K82K no. 309-02	200L	199 X 269 km @ 51.6°
TKS-M	Kosmos-1686	16501	Sep 27 1985	1141:42	8K82K no. 331-01	200L	178 X 320 km @ 51.6°

Sources: A. Vladimirov, "Table of Launches of the 'Proton' and 'Proton-K' RN" (in Russian), *Novosti kosmonavtiki*, no. 10, pp.25-30, 1998 . Note that the vehicle numbers refer to the FGB and not the Return Apparatus. The numbers for the Return Apparatuses were: for Kosmos-929 (VA no. 009A/2), Kosmos-1267 (VA no. 0103/3), and Kosmos-1443 (VA no. 0103/1). Also note that two further FGBs were flown as Kvant-1 (FGB no. 16601) and Polyus/Skif-DM (FGB no. 16701), both in 1987. Three others (FGB nos. 16801, 16901, and 17001) remained manufactured but unflown. Further modified FGBs have flown as Kvant-2 (no. 17101), Kristall (no. 17201), Spetr (no. 17301), Priroda (no. 17401), and the Zarya core (no. 17501) of the International Space Station.

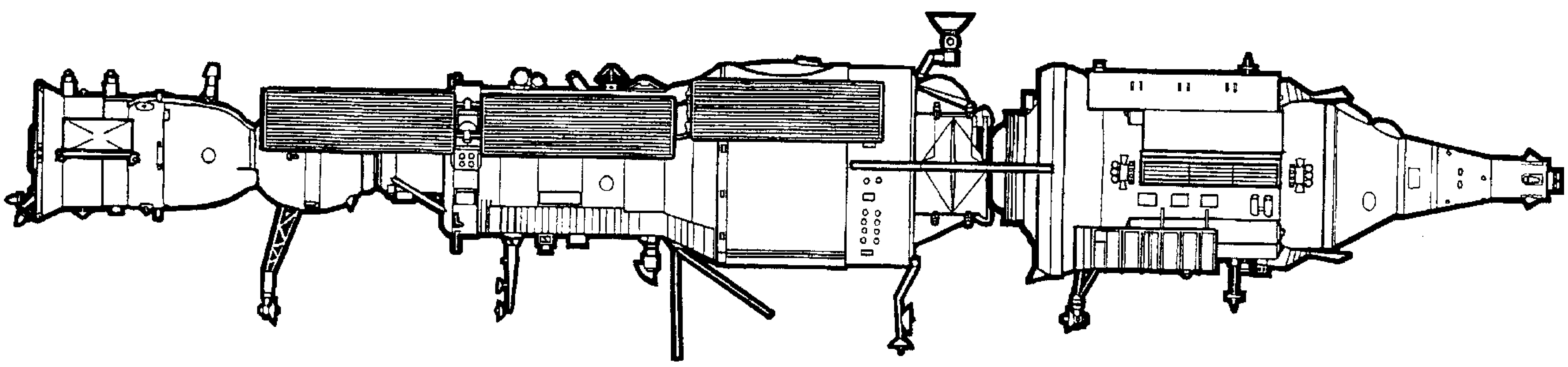

Fig. 5 This is a diagram of the proposed Almaz OPS-4 station which was never launched. The station was designed to have two docking ports, one to receive the TKS (as shown at the right) and one to receive a Soyuz ferry (as shown at the left). The Soyuz docking port was apparently hastily added after delays in "human-rating" the TKS. The long rectangular panel-like objects on the station proper are synthetic aperature radar antennas — which may or may not have been carried on OPS-4. The diagram gives a good sense of the comparative sizes of the TKS and the Almaz station, in comparison to the much smaller Soyuz. (Copyright David Rickman)

November and 19 December, reaching an orbit of 439 x 447 kilometers at 51.6° inclination (Western data), the highest orbit achieved during the lifetime of the TKS [185]. The mission finally ended on 2 February 1978 when the remaining FGB portion performed a final reentry burn that deposited the remains of the vehicle in the Pacific Ocean after 201 days in space. The Return Apparatus from Kosmos-929 was later reflown on the double-capsule missions – specifically as Kosmos-998 on LVI-3 in March 1978. (See Table 15 for a list of all TKS missions).

16. The End of Almaz

To any observer, the missions of Salyut-5, the dual-Return Apparatus LVI spacecraft, as well as the first full-scale flight of the TKS rightly would have indicated that Chelomey's goals of putting the entire Almaz complex into operation were approaching reality. The state of design and manufacture at the Chelomey design bureau and its associated Khrunichev Machine Building Plant in 1976-1977 was, in fact, quite impressive. By 1977, Chelomey was pressing on with plans to launch the fourth Almaz, vehicle no. 0104 (or OPS-4). The station, also known as Almaz-M, had a much longer lifetime and better characteristics than the earlier models. Although the first three Almaz stations were never meant to receive TKS spacecraft, this fourth one was designed and equipped with a stronger docking port, permitting receipt of the heavy TKS articles. Launch was planned for sometime in 1979 or 1980 [186]. In addition to the work on the Almaz OPS-4, at the time, the TsKBM had also begun preliminary work on the hulls of the similar OPS-5 and OPS-6.

Although OPS-4 used the same basic hull design as the previous Almaz stations, it incorporated some significant modifications including the following:

- the primary docking unit, G-3000, was replaced by a new docking system, the 11F77-5345-0 which was a passive system capable of receiving the TKS spacecraft;
- designers intended to modify the main engine unit of the station so as to allow for the possibility of propellant transfer from the TKS to the OPS;
- the station housed a new radar observation system known as *Mech-A* ("Sword-A") that would include the *Biryuza* ("Turquoise") system to transfer data to the Earth, the new *Aist* ("Stork") data transmission antenna, and an observation system to survey targets on the Earth;
- unlike the previous Almaz stations, OPS-4 did not house the large *Agat-1* reconnaissance system nor the *Pechora* TV system; instead, the station carried the ASA-34 topographic camera to ensure proper orientation for the film for the radar system; Almaz also carried some unspecified electronic intelligence (ELINT) equipment;
- designers eliminated some portions of the Almaz's thermal and life-support systems; this extra equipment would in the future be delivered to the Almaz by the TKS; the latter spacecraft was considered a "full partner" with Almaz and not just a delivery vehicle, since many of the station's systems would be maintained by TKS after docking;
- OPS-4 carried "space-to-space" cannons known as *Shchit-2* ("Shield-2") which were evidently improved variants of the older *Shchit-1* intended for the early Almaz stations;
- other less significant changes were made to the Almaz electrical system, telemetry system, TV systems, etc [187].

The Chelomey design bureau had begun issuing design documentation for OPS-4 in January 1975 to the Khrunichev Plant, and assembly of the station had begun by June of the same year. Designers evidently made some changes to the design of the station even while it was being assembled. Given the accumulated delays of the declaring the TKS safe for crewed launch, Chelomey's engineers decided "urgently" manufacture an Autonomous Docking Unit (AOS) equipped to receive Soyuz spacecraft. The AOS was installed at the forward end of the Almaz station, i.e. on the opposite end of the station from the docking port for receiving the TKS. In early conceptions of the Almaz, the station's own Return Apparatus would have been installed at the forward end of the station. During the Salyut-2, -3, and -5 missions, the forward end of the station had remained vacated and without a docking port. Crews in their Soyuz had docked at the port at the aft end of the station. For OPS-4, Chelomey planned to launch crews on the Soyuz ferry; the TKS would be launched without cosmonauts on board. The two would then link up separately and on opposite ends of the Almaz station [188].

Chelomey's engineers had also, by 1977, begun manufacture of station OPS-5 (i.e. vehicle no. 0105), also known as Zvezda ("Star"). This station would be equipped with two docking ports, *both* capable of receiving TKS spacecraft. With two TKS and one Almaz station, total mass of the complex in orbit would be on the order of 60 tons [189]. Testifying to Chelomey's clearly ambitious plans for a huge space station program, work had also begun by this time on a much larger space station, also known as Zvezda, with a core mass of 35 tons. Combined with two TKS vehicles, the total Zvezda complex would have a mass of 75 tons in Earth orbit. Among the new elements of the Zvezda station was the use, for the first time, of a relatively large recovery module on the station itself for returning crews to Earth. The complex would have rotating crews of four to five cosmonauts and serve as a continuously crewed military platform in low Earth orbit [190].

Since the 35-ton mass of the Zvezda core was well outside of the capacity of the three-stage Proton-K (or UR-500K) booster, Chelomey had already begun work around 1975 on a heavy satellite launch vehicle known as the UR-530, which was to incorporate stages and engines from both the UR-500K booster and the UR-100N (or SS-19) ballistic missile. Instead of the six RD-253 engines used on the Proton-K launcher, the UR-530 would use 24 RD-0233 engines taken from the UR-100N missile – each of the six tanks on the original Proton would have four of the new engines. The RD-0233 engines had a vacuum thrust of 53.1 tons. The new booster's second stage was similar to the Proton's except it would use larger propellant tanks and operate a guidance system derived from the UR-100N. Its lifting capability would be about 36 tons to a 200 kilometer orbit at 51.6° inclination. Evidently, one of its projected payloads was a version of the Almaz station for operation in a Sun-synchronous orbit. Development of the UR-530 never reached beyond a very preliminary stage. According to one source, the Soviet government never formally approved the proposal "for reasons beyond the control of [Chelomey]" [191]. All paper studies were terminated in 1977.

The worst was yet to come. In early 1978, work on OPS-4 was indefinitely postponed at the design bureau due to a lack of funds. The Ministry of General Machine Building had evidently issued a series of decrees establishing new timelines for the flight of the station, but the TsKBM had repeatedly disrupted these schedules [192]. By the end of the year, Chelomey had bigger problems than simply delays. On 27 June 1978, the Soviet government issued a decree (no. 534-165) that unequivocally discontinued further *piloted* flights in the Almaz program [193]. The reasons were complex and not singular. Three major reasons stand out.

First and perhaps most important, the Chief Directorate of Space Assets (GUKOS), the Ministry of Defense's operator for the Almaz missions, believed that human missions in orbit were less effective for photo-reconnaissance than automated satellites. In an official history of the Soviet/Russian military space forces, the authors note why the Ministry of Defense refused to continue further support for the Almaz complex:

> [Piloted stations] allow the receipt of unique information on the Earth and space. At the same time the expected...observational information was not received due to the impossibility of obtaining near to optimal parameters of the information (resolution, dimensions of closeups, etc.) from simultaneous use of all types of instruments. Due to the presence on the stations of the "human-machine" link, inadequate operational work and transfer of information was demonstrated. Moreover, the time necessary for servicing the station [and] maintaining the life support of cosmonauts considerably decreased the time required for work on special instruments. On the whole, the application of piloted stations for operational space observations from space proved to be unjustified [194].

An additional factor was also the cancellation of the American MOL program nearly a decade before, a point explicitly admitted by officials of the former Soviet defense industry in 1999 [195]. The Ministry of Defense's refusal to continue with Almaz was not without dissent. The Chairman of the Almaz State Commission, Col.-Gen. Grigor'yev – who was also the First Deputy Commander-in-Chief of the Soviet Strategic Missile Forces – apparently tried unsuccessfully to lobby for further flights of Almaz [196].

Second, there was the issue of cost. By 1977, the Soviets were operating two independent space station programs simultaneously – the Almaz program under the TsKBM and the DOS program under NPO Energiya. Officials in the Defense Department of the Central Committee, the Military-Industrial Commission, and the Ministry of Defense all believed that it was inefficient to operate two independent programs. Many believed that program resources, such as ground communications systems would not be able to ensure simultaneous work on two piloted programs. Most important, there was a consensus that money would not be available to continue with two such expensive projects [197]. Moreover, the Soviet government had just initiated development of the massive Energiya-Buran program, which no doubt siphoned off resources from many other programs of the period.

The third and not the least important reason was political. Chelomey had the misfortune of having an enemy in the upper echelons of power who was perhaps the most important personage in the Soviet defense industry, Dmitriy F. Ustinov. Since Chelomey's entry into the missile and space programs, Ustinov had continually opposed numerous project proposals from Chelomey [198]. As Khrushchev's son Sergey recalled many years later, "[Chelomey] hated Usitinov, who felt exactly the same about him" [199]. Chelomey had been partially protected by the patronage of USSR Minister of Defense Andrey A. Grechko, but in early 1976, fate took a cruel twist for Chelomey, when his patron succumbed to a heart attack. It was Ustinov who took over the vacant post of USSR Minister of Defense, and for the first time became a full member of the powerful Politburo. Although no longer the official head of the Soviet space program, Ustinov had accumulated a great deal of power and influence by this time. In the space program, Valentin P. Glushko, the new head of NPO Energiya was now Ustinov's favorite. Soon after Grechko's death, Ustinov had Glushko promoted to a full member of the Central Committee in 1976, an honor previously not even granted to powerful designers such as Korolev and Yangel'. One of Glushko's first moves was evidently "to deny Chelomey the contract for his orbital station [Almaz]" [200]. Ultimately, it may have been a war of ambitions rather than any technological or policy reason that finally ended the piloted Almaz program after only a handful of missions.

As a result of termination of work on the piloted portion of Almaz, further work on the program was reoriented to an automated station in orbit – known as Almaz-T (or "product 11F668") – with the capacity to receive crews who would repair and replace systems. The Ministry of Defense permitted development of a robotic Almaz, evidently based on the possibility of carrying out year-round reconnaissance using a suite of relatively heavy surveillance equipment with a mass of 4 to 6 tons – including a synthetic aperture radar, as well as TV and infrared observation equipment [201]. As a result, using equipment from the already manufactured models of the original Almaz station (OPS-4, OPS-5, and OPS-6), Chelomey's engineers began construction of at least two new Almaz-T spacecraft. The primary instrument on the Almaz-T was the *Mech-K* radar complex equipped with high resolution instruments for observing American naval targets [202].

17. TKS Training Continues

The 1978 decision curtailed piloted missions on board the Almaz space station. But it had not stipulated the same for the heavy TKS spacecraft. As such, Chelomey continued further ground-testing of the vehicle in the belief, not shared by many of his colleagues, that he would be able to use the TKS for the repair and maintenance missions to the large Almaz-T military radar platform.

On 17 August 1979, a full-scale trainer of the TKS's Return Apparatus was delivered to the Cosmonaut Training Center in anticipation of continuing cosmonaut training for flights on board the TKS. At the time, a relatively large group of cosmonauts, comprising both veterans and rookies, was formed to train for these missions. The group included veterans Artyukhin, Glazkov, Rozhdestvenskiy, Sarafanov, Shonin and rookies Berezovoy, Kozel'skiy, Lisun, Preobrazhenskiy, Stepanov, Vasyutin, as well as others from the "Chelomey cosmonaut group" [203]. The Training Center formed the first "conditional" crews for TKS soon after:

- G. S. Shonin/Yu. N. Glazkov/V. G. Makrushin
- A. N. Berezovoy/Yu. P. Artyukhin/V. A. Romanov
- G. V. Sarafanov/V. Ye. Preobrazhenskiy/D. A. Yuyukov
- V. S. Kozel'skiy/V. I. Rozhdestvenskiy/A. A. Grechanik.

After further changes, the final crews by late 1979 were:

- crew 1: Yu. N. Glazkov/V. G. Makrushin/E. N. Stepanov
- crew 2: G. V. Sarafanov/V. A. Romanov/V. Ye. Preobrazhenskiy
- crew 3: Yu. P. Artyukhin/D. A. Yuyukov/A. N. Berezovoy [204].

Between 20 and 28 November 1979, Sarafanov's crew participated in an 8-day "interdepartmental" simulation of an actual flight program using a TKS model (Return Apparatus no. 004 docked to FGB no. M11F77) at the premises of the Air Force's NII-30 institute at Chkalov. The long program was geared specifically in preparation for the first piloted launch and flight of the TKS [205]. Training Center Deputy Director, veteran cosmonaut Maj.-Gen. Aleksey A. Leonov reportedly posed for pictures with the crew after their "mission" was over, and young girls were present to give flowers to the crew to wish them good luck on their actual space mission [206]. The Chelomey design bureau also conducted numerous ground tests of the Return Apparatus. For example, on 15 August 1978, the design bureau successfully conducted a test to rehearse an unplanned depressurization of the Return Apparatus. Performing this rather dangerous test was Sergey V. Chelomey, a trainee cosmonaut in the "special contingent group" who was also the designer's son [207]. As late as 1981, various crews, including one comprising Zudov, Glazkov, and Chelomey continued to train in various conditions in preparation for TKS flights.

18. The Second TKS Mission: Kosmos-1267

Concurrent with cosmonaut training for TKS, Chelomey's engineers prepared several full-scale TKS vehicles for flight. All of these spacecraft were, however, vehicles in need of a mission. By this point, the original piloted Almaz program was over. The first launch of the robot Almaz-T was still in the future. As a substitute, Ministry of General Machine Building officials decided to test-fly the second full-scale TKS vehicle in conjunction with Salyut-6, the "civilian" DOS space station already in orbit. This arrangement, i.e. to test out the remaining TKS vehicles as part of the DOS program, was formalized in an official decree of the Central Committee and the Council of Ministers issued on 19 February 1981 [208]. Thus, the next TKS, the second to fly into orbit, was redirected for a mission to Salyut-6. This TKS vehicle was a full-scale operational version with three crew couches; heavy lead plates were fixed on the seats to simulate the mass of a crew. Protective plastic screens were also put on the main control panels in the Return Apparatus. Pre-launch testing included having a trainee cosmonaut – in this case Chelomey's son, Sergey – sit in the main couch of the TKS and perform tests of all the systems via radio communications with the control center. Evidently, the temperature had dropped by this time and the younger Chelomey found himself in very chilling conditions, made worse by the now ice-cold lead plates installed on each couch to simulate the weight of a crew. He later recalled:

> The actual job shouldn't have taken more than 10 or 15 minutes, but we had to stop every time American spy satellites [probably ELINT satellites] with recording gear were flying over the place. It's a good thing that after a while it occurred to somebody to bring me an army overcoat. I put it under me. I had the job done within an hour, but I chilled my back. I was not immediately aware of it: the ache soon disappeared, but the consequences made themselves felt a year later [209].

Evidently he had suffered some long-term injury because of the experience, and after 1983 stopped going to the annual medical checkups for the "trainee cosmonauts."

The second TKS was launched successfully into orbit at 0501 hours Moscow Time on 25 April 1981 into an initial orbit of 200 x 278 kilometers at a 51.6° inclination. Named Kosmos-1267 upon entering orbit, the spacecraft was launched into an orbital path 10° to the east of Salyut-6. This offset made the eventual docking slower and more controlled that the usual Progress or Soyuz dockings. The vehicle performed an intensive series of maneuvers over the following three weeks, with the spacecraft ending up in an orbit somewhat similar to that of the Almaz stations. The low orbit served as a test of the vehicle's atmospheric drag characteristics [210]. During the same period, the Soyuz-T-4 crew of Col. Vladimir V. Kovalenok and Viktor P. Savinykh remained busy on board Salyut-6. Kosmos-1267 was not expected to dock with the space station until the cosmonauts had ended their mission. One of the more interesting speculations on the TKS vehicle appeared in the West around this time in the trade publication *Aviation Week and Space Technology*, which reported that Kosmos-1267 was "equipped with firing ports to eject 1-meter-long miniature vehicles guided by infrared sensors" for anti-satellite missions [211]. It appears that covert imaging of the externally mounted cylindrical propellant tanks on the TKS by U.S. satellites and/or ground sensors may have prompted such a curious and unfounded allegation.

On 24 May 1981, the Return Apparatus (capsule no. 0103/3) detached from the main vehicle and successfully reentered and landed on Soviet territory. At the time, the Soviet press did not announce either the separation or the landing. There was evidently a bizarre postscript to the landing. A journalist later wrote that "[t]he machine operators who were first to reach [the capsule] decided to help themselves to certain parts [radioactive materials?] intending to use them to stun fish. As a result they were severely burned and it was only by miracle that their sight was saved" [212].

After the landing, the TKS, now constituted just by the FGB section, began to slowly climb up towards the orbit of Salyut-6, which was in an orbit more akin to those of the 'civilian' DOS vehicles. Before the Soyuz T-4 crew left Salyut-6 on 26 May, they suited up in the airlock and opened the forward hatch to attach a device into the forward docking port drogue in preparation for the Kosmos-1267 docking [213]. The cosmonauts attached this adapter to allow the TKS to dock with the DOS-type vehicle. The Salyut-6 station, when it had been originally built in the mid-1970s, had not been designed to receive heavy vehicles such as the TKS. Beginning in 1978, engineers at Chelomey's Fili Branch in cooperation with engineers at NPO Energiya had redesigned the TKS docking system as a pin-cone docking assembly to allow "self-oriented" dockings with future DOS stations *after* Salyut-6. In contrast to the Soyuz-DOS docking system, the self-oriented docking system was completely automatic, i.e. the system completed all docking operations from first contact to closing the junction locks (coupling, shock-absorption with elimination of all relative velocity, aligning the ships relative to each other along all three axes, and final tightening), all without any manual intervention. The TKS hatch had a diameter of 89 centimeters for internal crew transfer [214].

After a series of extensive maneuvers, Kosmos-1267 finally docked with the forward port of the Salyut-6 station at 0952 hours Moscow Time on 19 June 1981. The total mass of the combined complex was about 34 tons and was the largest spaceship in orbit assembled by the Soviets to date. There was no "hard" mechanical docking, only "soft" docking of the two craft, since Salyut-6 had not been equipped to handle the TKS docking mechanism. Over the following weeks, engineers conducted tests of the robustness of the docking system of the two large vehicles, as well as experiments related to testing the thermal characteristics of the complex. The BST-1M submillimeter telescope, installed on board Salyut-6, was also used during this period for atmospheric research; the TKS vehicle's engines carried out orientation of the complex during its program. The FGB engine was fired several times in June, July, and October for a series of experiments that tested the structural integrity of the complex. Orbital changes in October 1981 were the last such firings, and controllers allowed the Kosmos-1267/Salyut-6 complex to naturally decay over the following months. The main engine of Salyut-6 was used on 28 July 1982 to lower the perigee by about 100 kilometers. The following day, the FGB engine was used for a final de-orbit maneuver that deposited the remains of the huge complex in the Pacific Ocean [215].

19. The End for Chelomey

The end of the piloted portion of the Almaz program in 1978 was the first blow to Chelomey's ambitions in space. If he had any hope that he would be able to salvage what was left of his Almaz program, he was in for a series of big shocks in 1981. With his patron former Minister of Defense Grechko no longer alive, and his lifelong enemy Ustinov in Grechko's old post, Chelomey saw his fortunes dim with a speed that was unprecedented. First, on 30 June 1981, his Fili Branch (now known as the Salyut Design Bureau) – which had produced all his ICBMs, the Proton booster, and the FGB portion of the TKS – was detached from his main design bureau and attached formally to Glushko's giant NPO Energiya conglomerate [216]. In one stroke, he lost control of his main livelihood for the past twenty years. This was just the beginning.

In September 1980, Chelomey's engineers had finished assembly at the Khrunichev Machine Building Plant of the first large robot radar platform, the Almaz-T. Events were proceeding for a launch early the following year, but the final order for transporting the vehicle to Tyura-Tam was "strangely delayed" until late November. Only in February 1981 did workers at the Baykonur Cosmodrome begin final pre-launch testing, in preparation for a launch in July [217]. Although all members of the State Commission had signed the final launch document, just three days prior to the slated launch, Ustinov issued an order prohibiting the launch [218]. The order had evidently followed a violent argument between the Minister of Defense and Chelomey. One senior Soviet scientist later recalled that, "[t]he thirst to humiliate and punish Chelomey, his former adversary in rocket and space wars, was so overwhelming for Ustinov that he even signed an order to demolish extremely expensive hardware that had been accumulated for final integration in this ill-fated orbital radar station [Almaz-T]" [219]. The General Designer's engineers, however, contrary to orders, temporarily mothballed the station, in the hope that they might still carry out the launch. But on 19 December 1981, the Central Committee and the Council of Ministers issued a document (no. 1206-371) entitled "On Termination of Work on the 'Almaz' Automatic Station" that finally ended *all* remaining work on the Almaz program. The decree also effectively ended Chelomey's career as a missile designer: a supplement to the document specified that Chelomey's design bureau, the TsKBM, be "banned" from further involvement in the Soviet ballistic missile and space program. His organization would now only be involved in its original design theme, the development of naval cruise missiles [220]. Personal rivalry may have been a key reason for terminating all work on Almaz, but there was another more practical rationale. In an official history of the Soviet military space forces, the authors noted the following:

> The results of research showed that the complexity and high cost of manufacturing and operating the 'Almaz-T' station would not allow...the constant functioning in orbit of a group of two stations that was necessary to carry out uninterrupted observation, although the presence on board the station of radar apparatus gave a new capacity for round-the-clock and year-round observation [221].

At the time, the Soviet military space forces already had begun operation of the second generation of Yantar' photo-reconnaissance and Tselina ELINT satellites, that were far cheaper and easier to operate. Additionally, in 1982, the main developer of Soviet optical photo-reconnaissance satellites, the Central Specialized Design Bureau (TsSKB) based in Kuybushev, proposed their own smaller radar observation platform which was given preliminary approval by six ministries in August of the same year. There clearly was no need for the huge Almaz-T. Ustinov clearly had a role to play in this decision, but it was not without careful analysis by the military.

20. The Third TKS Mission: Kosmos-1443

The main portion of the TKS, the so-called Functional-Cargo Block (FGB) had been manufactured and designed by Chelomey's old Fili Branch. This large design office, having been wrested from Chelomey in June 1981, now worked for NPO Energiya. Thus, even though the Almaz project was over for the time being, the Fili Branch (now called KB Salyut) continued with work on the TKS on new orders from Energiya General Designer Valentin P. Glushko. Through 1982, engineers from KB Salyut prepared to launch the third full-scale TKS vehicle. At the same time, cosmonauts who had trained for TKS missions did not lose all hope. Through 1982, several of Chelomey's old "special contingent group" continued training with the TKS Return Apparatus. Tests included simulating water-landings and evacuations during emergency landings. By mid-1982, the cosmonauts had completed the full volume of tests related to the TKS in preparation for a piloted flight. It was at this point that the government decided that although TKS test-flights would continue, there would not be any piloted launches of the spacecraft at any point in the future. Thus, there was no reason to train cosmonauts in the Return Apparatus for launches or landings. Two nearly complete TKS vehicles remained on the ground and these would be used as cargo supply modules for Glushko's Salyut-7 space station [222].

In September 1982, the State Commission finalized plans for the third TKS mission. The plan was to launch the vehicle in March 1983 for a docking with Salyut-7 the following month. In April, the Soyuz T-8 crew – at that time planned as Lt.-Col. Vladimir G. Titov, Gennadiy M. Strekalov, and Irina R. Pronina (she was later replaced by Aleksandr A. Serebrov) – would begin a three-month residency on board the complex, thus becoming the first cosmonauts to work in the TKS vehicle in space.

The third TKS, vehicle no. 16401, was prepared for launch in the first few months of 1983. Since there were no further plans to launch crews on board these vehicles, the spacecraft did not have an Emergency Rescue System tower on top of its launch stack. Without the whole system, engineers were able to increase the cargo load on board the vehicle to as much as three tons. Designers had also removed the crew seats from the Return Apparatus (vehicle no. 0103/1) and replaced them with 500 kilograms of cargo for the Salyut-7 crew [223]. The TKS was launched at 1237 hours 8 seconds Moscow Time on 2 March 1983 into an initial orbit of 199 x 269 kilometers at 51.6° inclination. The vehicle was 13.6 meters in length and had a total wingspan over the solar panels of 16 meters; the two solar panels generated three kilowatts of power. The spacecraft, named Kosmos-1443 upon entering orbit, was launched into an orbit shifted 1.25° longitudinally away from the Salyut-7's orbit and began a relatively slow approach to the station. Unlike Kosmos-1267 however, the vehicle did not spend about a month in independent flight. The spacecraft performed at least five orbital maneuvers by 9 March, and docked with the forward port of Salyut-7 station at 1220 hours Moscow Time the following day. Unlike Salyut-6, Salyut-7 was equipped to handle "hard" dockings with the TKS and allow internal crew transfer [224]. The 40 ton complex was in a 325 X 345 kilometer orbit (as announced) at the time, and was a total of 28 meters in length [225]. As soon as the TKS was docked to the station, it took over all attitude and altitude control of the entire complex.

Kosmos-1443 delivered a total of 2,780 kilograms of cargo spread over 600 items, including new gallium arsenide solar arrays for Salyut-7 that were to be installed during EVAs by the Soyuz-T-8 crew. Other items on board the TKS included propellant (one ton), new replacement memory units for the *Delta* autonomous navigation system, water, air regeneration canisters, air filters, exercise and medical equipment, movies, film, a guitar, flash bulbs, clothing, spare parts and food including fruits, onion, garlic, and mustard. The spacecraft was equipped with a rail in the internal space of the FGB which could be extended into the Salyut-7 on which bags of supplies could be conveniently moved by cosmonauts [226].

On 5 and 11 April, the TKS conducted its first main engine firings linked to the core station, lowering the orbit to 293 x 305 kilometers (Western data). These maneuvers were in preparation for the visit by the Soyuz-T-8 crew – an attempt which failed to produce any results when the cosmonauts were unable to dock with the station due to a antenna failure in the *Igla* system on 21 April. The complex performed further maneuvers in late April as the State Commission reconfigured plans for a repeat attempt to visit the space station. Instead of the original three-month mission planned for Soyuz-T-8, mission managers rescheduled that flight for the Soyuz-T-9 opportunity. The latter crew were then to be replaced by the Soyuz-T-10 crew in September. The flight of Kosmos-1443 would end prior to that with an automated landing of the Return Apparatus just before the beginning of the Soyuz-T-10 mission.

The Soyuz-T-9 spacecraft was launched on 27 June with cosmonauts Col. Vladimir. A. Lyakhov and Aleksandr P. Aleksandrov who successfully docked to the aft port of Salyut-7 at 1346 hours Moscow Time the day after. The combined mass of Salyut-7, Kosmos-1443 and Soyuz-T-9 was about 47 tons; orbital parameters were 325 x 337 kilometers (Western data). On 30 June at 1249 hours Moscow Time, Lyakhov and Aleksandrov opened the hatch between Kosmos-1443 and Salyut-7, subsequently becoming the first individuals to work in the TKS in orbit.

Remote sensing photography was a major part of their experiments program. No doubt the large amounts of film delivered by Kosmos-1443 aided their program immeasurably. The Soviet media announced at the time that in one week, Lyakhov and Aleksandrov took as many photographs as the prior Salyut-7 crew had taken during their entire 211 day flight. Most of the film was used on Salyut-7's MKF-6M and KATE-140 cameras. On 3 July, the Soviet press published the first external illustration of the TKS in the newspaper *Pravda*. It reported that the craft was a cargo vehicle for bringing 2.5 times as much supplies and equipment to Salyut stations as the standard Progress tankers could. The return module of the TKS was said to be capable of returning up to 500 kilograms of results back to Earth. The spacecraft was also said to be capable of serving as a space tug, an extension of the core station to increase its internal volume by as much as 50%, and as an autonomous free-flying vehicle for carrying out materials processing and astronomy experiments. Kosmos-1443 was announced as the freighter version of the TKS, not an "interorbital tug" variant – implying such a version of the TKS was also in planning [227]. By 7 July, the cosmonauts had finished emptying the TKS's Return Apparatus of its contents but were still transferring other materials from the FGB to the Salyut-7 station.

On 4 August, Lyakhov and Aleksandrov began loading the TKS with the results of experiments and waste from their own stay on board Salyut-7. The cosmonauts transferred about 317 kilograms of film, materials samples from 45 experiments including the results of the *Elektrotopograf* test, used air regenerators, and the failed *Delta* memory unit into the Return Apparatus. Total payload was about 350 kilograms. As Kosmos-1443 was being prepared for cast-off, the crew reported that controlling the Salyut-7 station from the TKS had been quite difficult. Despite the troubles, Kosmos-1443 had conducted more than 100 attitude and orbital changes to the complex during the period it was docked. Kosmos-1443 undocked from Salyut-7/Soyuz T-9 at 1704 hours Moscow Time on 14 August 1983, approximately five months after launch. The vehicle lowered its orbit slightly on 18 August as a prelude to the separation of the FGB and the Return Apparatus on 23 August. The crew return vehicle landed safely with its precious and large cargo at 1402 hours Moscow Time on 23 August, about 100 kilometers southeast of Arkalyk in Kazakhstan. The remaining FGB section of the TKS remained in orbit for the ensuing month, conducting an orbital maneuver on 16 September. This led to a final main engine burn on 18 September that positioned the vehicle for a controlled and destructive reentry over the Pacific Ocean far from inhabited areas [228].

The Return Apparatus from Kosmos-1443 had an interesting future. Following recovery, it was brought to Moscow for examination of its vital systems. It was then deposited in a small museum at the

Khrunichev Machine Building Plant, where it was shown to Westerners for the first time in December 1989. Soviet officials at the time described the three ton vehicle as "the first shuttle"; its thermal protection system, which had been repainted dark green, appeared to be perfect condition [229]. Just four years later, in December 1993, the capsule was auctioned off at Sotheby's in New York City by its owners NPO Mashinostroyeniya (the successor organization to Chelomey's TsKBM). An anonymous buyer – with the intention of returning it to Russia some day – purchased the vehicle for $48,875 [230]. The capsule, on loan from the Perot Foundation, is now on display at the National Air and Space Museum in Washington, D.C.

21. The Fourth TKS Mission: Kosmos-1686/Pion

By 1983, there were no further cosmonauts training for either TKS or Almaz missions. The training group was disbanded. Yet, even after the closure of the Almaz station program, and canceling plans for piloted flights on board the TKS, cosmonauts continued to hope for a reprieve. The Khrunichev Machine Building Plant still had one more remaining TKS vehicle left, spacecraft no. 16401, which was undergoing ground electrical tests in 1982. At the time, some designers at KB Salyut proposed reconfiguring this vehicle into a specialized military module named TKS-M for work in conjunction with the Salyut-7 station. Minister of General Machine Building Afanas'yev signed an order on 26 August 1982 supporting this proposal. Given that the future of the TKS program was dim, he believed that a military connection might be the only way to get the remaining spacecraft into orbit. The idea at the time was to install a special optical complex named *Pion-K* ("Peony-K") on the TKS. *Pion-K*, which would use an electronic laser telescope built by the Kazan' Optical-Mechanical Association (KOMO). *Pion-K* (as well as other military instruments), would be installed on a special module known as the 74P which would replace the standard Return Apparatus (capsule no. 0103/8) on the TKS. According to the initial order, the TKS-M would be launched into orbit by 30 March 1985 to be received by the fourth main expedition on Salyut-7 [231].

In the initial design phase of the TKS-M, engineers at KB Salyut debated over whether to make the spacecraft simply a "delivery" module or to design it as an independent transport vehicle. Eventually, by 1983, designers settled on the former, after calculations showed that a delivery module design would increase the effective payload of the spacecraft up to five tons. During this same period, KB Salyut was also in the process of designing a family of four augmentation modules for the future Mir complex. The Ministry of General Machine Building had approved the design and construction of these modules on 23 June 1981. The first of these, an experimental version known as 37KE, would be launched to Salyut-7 [232]. Although the design of these modules were conceptually derived from the old TKS, they had a fundamentally different look, and used a special Functional-Service Block (FSB) instead of the FGB. In December 1983, however, the design bureau decided to switch to a different design for these Mir modules; they adopted a design quite similar in conception to the TKS-M, i.e. with an FGB mounted with specialized instrument modules in place of the old Return Apparatus. The new Mir modules would be known as 77K. This approach, formalized by a Ministry order in June 1984, effectively laid the foundation for the design and construction of the future Mir modules, later known as Kvant-2 (77KSD), Kristall (77KST), Spektr (77KSO), and Priroda (77KSI). Similarly, the core of the International Space Station, Zarya (77KSM), is based on the "77K" design. Thus, the TKS-M was effectively the design origin of all the Mir modules and the core of the International Space Station.

The TKS-M was equipped with 4,322 kilograms of cargo comprising more than 80 different items and 1,550 kilograms of propellant to maintain orbit and attitude with the Salyut-7 complex. The module was also capable of adding about 1.1 kW of power to Salyut systems. The TKS carried about 1,225 kilograms worth of scientific experiments for more than 200 experiments. The main part of this package was the *Pion-K* telescope designed by the Foton Central Design Bureau (TsKB Foton) of the KOMO. TsKB Foton's Chief Designer at the time was German R. Pekki. *Pion-K*'s main mission was to carry out high-resolution observations. It would also be used as part of the *Oktant* program designed to support research for both anti-ballistic missile systems and identifying satellites in orbit. Experiments with enigmatic names such as *Poverkhnost'* ("Surface") for Earth observations, *Zebra* for ocean observations, and *Obolochka* ("Cover") for observations of aircraft, were also part of the military program. The package also included the MRSF-IK mass-radio-spectrometer – designed by the Vavilov State Optical Institute – for infrared observations. In addition, the TKS-M had a large suite of "civilian" instrumentation, including the *Ozon* ("Ozone") radiometer, the *Faza*

("Phase") spectrometer, the *Sevan* to study cosmic rays, the *Kanonus* instrument, the *Nega* ("Comfort") instrument for recording gamma-rays and neutrons, and the ITS-7 to study the Sun and stars in the infrared wavelengths. The spacecraft also carried a beam construction experiment known as *Mayak* ("Lighthouse") for external deployment outside of the station complex and three materials processing devices: *Korund* ("Corundum"), *Kristallizator* ("Crystallizer"), and *Magma-F*. Overall, the TKS-M had a length of 9.7 meters and a maximum diameter of 4.1 meters. Total mass was approximately 19 tons [233].

Plans for *Pion-K* raised hopes among many of the Almaz "old-timers" that they would finally get their chance to fly in space. Since it was a dedicated military experiment, many of the old military cosmonaut rookies believed that their chance had finally come to fly. A retired cosmonaut, Air Force Col.-Engineer Gennadiy M. Kolesnikov, was head of the department at the Cosmonaut Training Center in charge of directing preparations for the *Pion-K* mission. Kolesnikov, part of the 1965 intake, had resigned from the cosmonaut team in December 1967 due to ill-health. One of the most academically trained cosmonauts, he had more than 20 inventions to his credit, and later (in 1989) defended his Doctor of Military Science dissertation on "Methodological Organization and Directing Space Operational-Strategic Military Reconnaissance with Cosmonaut Participation." At Kolesnikov's urging, in early 1982, the Cosmonaut Training Center established a group comprising such Almaz veterans as Glazkov, Rozhdestvenskiy, Sarafanov and military officer rookies who had now been waiting two decades to fly as part of the Almaz program: Khludeyev, Lisun, and Stepanov. The group was later joined by rookie Fefelov. Kolesnikov also included himself in the training group despite the fact that he had no official status as a cosmonaut [234]. In May 1983, the *Pion-K* training group, who named themselves "TKS-165" were already studying Salyut-7 and Soyuz T systems. They did test runs on board a Tu-154MLK aircraft to learn to operate the *Pion-K* complex in simulated zero gravity. Despite all this work, the military cosmonauts were to be disappointed. In September 1985, when the Cosmonaut Training Center formed the next crew for Salyut-7, none of the TKS-165 men were included for "a variety of reasons" [235]. Kolesnikov himself had evidently failed to pass a medical commission. In 1985, the team eventually just stopped training and left operation of the *Pion-K* to "other" cosmonauts who were part of the mainstream Salyut and Mir programs. The dispersal of the *Pion-K* training team effectively signaled the end of cosmonaut training for Almaz-related missions. Between 1966 and 1985, dozens of men had trained for the project, but only a handful had ever made it to space.

The TKS-M mission itself was delayed for several reasons. First of all, the *Pion-K* telescope complex was delivered late. Second, ground controllers lost contact with Salyut-7 in February 1985. After the "repair crew" of Soyuz T-13 brought the station back to a usable condition, the State Commission decided to use the TKS-M for the next mission, Soyuz T-14, in late 1985. The plan at the time was to operate the TKS as a part of the Salyut-7 complex for a total of 100 days, from 2 October 1985 to 10 January 1986. The major determining factor for the length of the mission was the lifetime of the systems on board the TKS which would expire by 30 December 1985. Before the return of the Soyuz T-14 crew, controllers planned to undock the TKS-M from Salyut-7 and carry out autonomous flight for an unspecified period [236].

The Soyuz T-13 crew were followed by the Soyuz T-14 crew, who were launched to the Salyut-7 Station on 17 September 1985. Cosmonauts Lt.-Col. Vladimir V. Vasyutin, Viktor P. Savinykh, and Lt.-Col. Aleksandr A. Volkov remained on board the Salyut-7 station after 26 September, to finally begin the *Pion-K* program, for which they had trained for. Notably, for the first time since a "military" Salyut mission in the late 1970s, one of the crew members apart from the Commander was a military officer (Volkov).

TKS-M was launched at 1141 hours 42 seconds Moscow Time on 27 September 1985 from site 200 at Tyura-Tam on top of an uprated three-stage Proton-K booster. Initial orbital parameters were 320 x 178 kilometers at 51.6° inclination. The vehicle, publicly designated Kosmos-1686, successfully docked at the forward port of the Salyut-7 space station at 1316 hours Moscow Time on 2 October. The Soviet media released some generic information about the spacecraft at the time, noting that the vehicle carried "food, gas regenerators, new scientific apparatus and individual assemblies and parts" [237]. Only one photo taken in the interior of the module was released.

On 5 October, the crew opened the hatch into the TKS-M and began switching on systems on board the cargo ship and began their experiments program. The crew were, however, not able to complete the *Pion-K* experiment program due to Commander Vasyutin's illness which forced the crew to return to Earth prematurely on 21 November.

Savinykh later recalled that "...much work was left unfinished, and it was therefore with regret that we closed the hatch of the scientific module before our return" [238]. As a result of the early return, ground controllers decided not to undock Kosmos-1686 from Salyut-7 in January 1986 as they had planned to do earlier. Instead, the State Commission redirected their efforts to plan the following Soviet piloted flight, a mission to the Mir space station. In order to complete the remainder of the *Pion-K* program, officials incorporated an ambitious visit of the next crew to the Salyut-7/Kosmos-1686 complex during their residency at Mir.

The Soyuz-T-15 crew of Col. Leonid D. Kizim and Vladimir A. Solov'yev began their stay aboard Mir on 15 March 1986. The trip from Mir to Salyut-7 was planned for May 1986, at a time when the Soviet media had reported that Kosmos-1686 had been automatically conducting atmospheric observations and cosmic ray studies [239]. On 5 May, the crew undocked from the Mir space station to begin their trip to the Salyut-7/Kosmos-1686 complex. The latter was 4.15 minutes and 3,000 kilometers ahead of Mir at the time. Ground controllers used the TKS-M engines to correctly orient Salyut-7 during the approach. After four orbital maneuvers over a period of a day, the crew finally manually docked to Salyut-7's aft port at 2058 hours Moscow Time on 6 May. At the time, the Soviet press reported that the Soyuz T-15 crew had taken 500 kilograms of materials from Mir to Salyut.

The Soyuz-T-15 cosmonauts carried out many of the military experiments left undone by the previous crew. During their short stay on Salyut-7, there was a noticeable lack of information on their experiments program. Kizim, in a TV interview on 7 April 1986 during his mission, unequivocally denied that his crew was carrying out military experiments, disingenuously omitting mention of Salyut-7, and referring only to his flight to Mir:

> The program for our work on board the Mir scientific station does not contain any experiments for military purposes. As for the statements by U.S. officials, it seems to us that they are being made in order to justify their own plans for transferring the arms race to space [240].

The Soyuz-T-15 crew remained on board the complex for approximately 50 days during which they performed two major EVAs (on 28 May and 31 May) to deploy the *Mayak* girders. At 1858 hours Moscow Time on 25 June, the crew undocked from the Salyut-7/Kosmos-1686 complex. They carried 400 kilograms of equipment back to Mir with them. They were the last visitors to the station. They redocked with the Mir space station the following day, and ended their spaceflight with a return to Earth on 16 July 1986.

On 16 August 1986, TASS reported that Salyut-7's "work in the manned regime was fulfilled" and six days later, the complex was moved to a 492 x 474 kilometer storage orbit using the TKS-M engines. NPO Energiya Chief Designer Yuriy P. Semenov, in an article in *Pravda*, noted two weeks later that "It is possible that after several years, an inspection expedition may be sent up to the complex to rendezvous with it" but he gave no more specifics [241]. In the immediate future, following the Soyuz T-15 mission, ground controllers continued testing various TKS-M systems. Its engines maintained gravitational orientation of the whole complex. At the time, controllers expected the station to remain in orbit for about three to five years. There were even plans to send a crew on the Buran space shuttle to visit the complex. One plan involved returning the TKS-M and Salyut-7 spacecraft to Earth in Buran's payload bay. In December 1989, however, due to a failure in Kosmos-1686' s orientation system and loss of control of the whole complex, controllers had to reconfigure their future plans. The situation was made all the more urgent because of higher than anticipated solar activity which meant that the linked vehicles were decaying from orbit much faster than anticipated earlier. Finally, at 0947 hours Moscow Time on 7 February 1991, the Salyut-7/Kosmos-1686 complex reentered the Earth's atmosphere out of control over South America and burned up, thus destroying the last "original" TKS vehicle [242].

22. The Almaz-T Program

22.1 The Almaz-T1 Mission

At the time that the order to terminate the Almaz program was issued in December 1981, three models of the Almaz-T (Almaz-T1, -T2, and -T3) as well as the abandoned OPS-4 station (called Almaz-M) remained in storage [243]. Ustinov had ordered in 1981 that all Almaz equipment be destroyed. But with the help of Minister of General Machine Building Sergey A. Afanas'yev, Chelomey had illegally preserved the flight-ready Almaz-T1 vehicle at a secret location at Tyura-Tam. Chelomey's assistants discouraged unwelcome visitors to the area by a huge sign that read "DANGER – RADIATION" [244]. Chelomey had little hope that any of these spacecraft would ever make it to orbit while his nemesis Ustinov was still in power.

Fate, however, took a strange turn when both Chelomey and Ustinov died within two weeks of each other in December 1984. Gerbert A. Yefremov, one of Chelomey's most able proteges, succeeded him as Chief Designer of NPO Mashinostroyeniya (as the TsKBM had been renamed in 1983). One of Yefremov's first acts as head was to go directly to new USSR Minister of Defense Sergey L. Sokolov for permission to refurbish the Almaz-T for a launch. He also enlisted the help of General Staff Chief Marshal Akhromeyev who had the final say on such military space projects. Rumor has it that one of the late Ustinov's former aides – Gen. Igor' V. Illarionov – who now served in the same position to Sokolov, refused for three months to allow Yefremov to see the Minister of Defense [245]. Eventually, the military acquiesced, and on 12 April 1986, the Military-Industrial Commission (VPK) issued a decree (no. 126) that formally permitted NPO Mashinostroyeniya to resume work on the robot Almaz-T [246]. Thus, after nearly five years in storage, Yefremov's engineers unearthed their precious spacecraft and prepared it for a space mission.

There was a major redirection in the Almaz-T program in 1985-86. Originally, the stations had been ordered by the Soviet "military space forces," i.e. the Chief Directorate of Space Assets (GUKOS), for observational reconnaissance of American naval assets and troop movements. But if Yefremov had managed to rekindle some interest from the military in his platform, it proved to be insufficient. In an official history of the space forces, the authors note that the military were not interested in using the Almaz-T "because of the results of ground testing that had given preference to new directions in the use of optical-electronic [i.e. digital] aperture space apparatus being developed at the time" [247]. Instead, the Ministry of Defense handed the program over to the USSR Academy of Sciences, who together with the Ministry of General Machine Building proposed launching the remaining Almaz-T vehicles for civilian purposes, particular for remote sensing.

Almaz-T1 had been built using the familiar hull of the original Almaz station. By eliminating all of the life-support systems on board the station, engineers were able to include a large amount of automatic gear inside the spacecraft, including a powerful high-resolution side-looking radar and optical cameras. The Moscow-based NPO Vega-M (the former NII-17) designed and built the actual radar. The same organization had also developed space-based remote sensing and observation systems for such spacecraft as Meteor, Mars, Venera, and Okean [248]. Few details of the instruments on board Almaz-T1 have been revealed. Originally, the Almaz-T series were equipped to received visiting repair crews at a docking port. The docking devices were evidently removed after Almaz-T1 was brought out of storage; the government had yet to decide whether to mount such maintenance missions [249]. The spacecraft was launched at 1100 hours Moscow Time on 29 November 1986, but the Proton-K second stage malfunctioned due to high frequency vibrations. The 18.5 ton payload never reached orbit and was destroyed [250]. (See Table 16 for a list of all Almaz-T launches).

22.2 The Almaz-T2 Mission/Kosmos-1870

After the failure in late 1986, Yefremov's engineers redirected their effort to the second Almaz-T vehicle. By early 1987, the government had decided emphatically to eliminate any possibility of piloted repair flights to the Almaz-T. Future vehicles would not carry any docking ports [251]. Preparations for the launch of Almaz-T2 were marred by a month-long delay due to a disagreement between State Commission Chairman Lt.-Gen. Aleksandr S. Matrenin and his deputy Anatoliy P. Zavalishin over readiness of the vehicle – the former believed that vehicle was not ready even though the complete stack had been approved for launch by ground crews. Some engineers claimed that high level officials in the military and government were still opposed to the launch. Eventually, Zavalishin obtained permission from the Central Committee to orbit the spacecraft [252].

Almaz-T1 was launched successfully at 1200 hours Moscow Time on 25 July 1987. Initial orbital parameters were 282 x 168 kilometers at 71.9° inclination. The vehicle, publicly known as Kosmos-1870, had about 1,350 kilograms of propellant on board and had a planned lifetime of at least two years. The main instrument on board was the 3.0 GHz synthetic aperture radar (SAR). The instrument had a peak pulse power of 190 watts and an optimal resolution of up to 25 meters [253]. The instrument relied on optical processing. Corrections to the orbit were required every 10 to 12 days to prevent orbital decay. In September 1988, the spacecraft moved into a 270 kilometer orbit and switched to a 24-day orbital correction cycle. After more than two years of evidently successful orbital operations, the spacecraft made a controlled reentry on 29 July 1989.

TABLE 16: *Launches of the Automated Almaz-T Platform.*

Mission	Name	Vehicle No.	Launch Date	Launch Time (Moscow Time)	Launch Vehicle	Launch Site	Orbit
Almaz-T1	-	303-01	Nov 29 1986	1100	8K82K no. 338-01	200P	failed to reach orbit
Almaz-T2	Kosmos-1870	304-01	Jul 25 1987	1200:00	8K82K no. 347-01	200P	168 X 282 km @ 71.9°
Almaz-T3	Almaz-1	305-01	Mar 31 1991	1812:00	8K82K no. 365-01	200P	170.2 X 279.6 km @ 72.7°
-	Almaz-1B	306-01	not launched				

Source: A. Vladimirov, "Table of Launches of the 'Proton' and 'Proton-K' RN" (in Russian), *Novosti kosmonavtiki*, no. 10, pp.25-30, 1998.

Kosmos-1870 successfully demonstrated the ability to detect oil pollution and to monitor ice movements. The radar reportedly provided an average of 30 meters resolution and all-weather coverage from the slotted wave antenna [254]. The Soviet press did not report extensively on the flight, although in 1990, the media announced that Kosmos-1870 was the prototype of a new series of radar remote sensing stations in the interests of the national economy [255].

22.3 The Almaz-T3 Mission/The First 'Open' Almaz

The third Almaz-T station had a similar design as its two predecessors, but provided improved capability. The spacecraft was about 15 meters in length and 4.15 meters in diameter. Like the crewed Almaz station, the vehicle had two large solar panels, but unlike the older spacecraft, the arrays were fixed to the larger diameter section and were each L-shaped. The total exposure area was 86 m^2 and the output was an average of 2.4 kilowatts (10 kilowatts maximum for 20 minutes at a time). The vehicle was three-axis stabilized, and the interior was pressurized by nitrogen (90 m^3 of space). Internal temperatures varied between 5 to 35°C. A three-meter diameter six rpm reaction wheel controlled the station's attitude. The spacecraft carried 4 to 6.5 tons of payload. The primary instrument on board was an all-weather/day-night 3.1 GHz synthetic aperture radar (SAR) that used two 1.5 x 15 meter slotted waveguide antennae with horizontal polarization. Peak power was 190 watts (80 watts average). The radar had a 39 kilometer beam width in two 350 kilometer swaths. During missions, it recorded in 20 to 230 kilometer lengths. The instrument was evidently a significant improvement on the one carried on Kosmos-1870, doubling resolution to less than 15 meters and providing the capability to transmit data digitally via a Luch satellite in geostationary orbit. The third Almaz-T also carried a 2-channel microwave radiometer with a 600 kilometer swath and spatial resolution of 10 to 30 kilometers. The spacecraft also had a backup 30 meter resolution synthetic aperture radar of the type carried on Kosmos-1870 [256]. Scientists had considering installing instruments for magnetic field mapping but opted not to use them for the flight-vehicle. NPO Mashinostroyeniya evidently also approach the French about contributing experimentation to the platform, but they declined due to the short time available [257].

Uncharacteristically, the Soviet media announced the third Almaz-T mission in advance of its planned launch, originally set for November 1990. In late 1990, the press reported that the launch had been moved to 15 January 1991 [258]. There was a further delay to allow for additional testing of an antenna that would transmit data to the Luch relay satellite [259]. The remote sensing platform was eventually launched at 1812 hours Moscow Time on 31 March 1991 into an initial orbit of 170.2 x 279.6 kilometers inclined at 72.7°. In orbit mass was 18.55 tons. The platform's two solar panels deployed 12 minutes after liftoff over the Kamchatka peninsula, while the two folded radar panels unfurled on the third orbit. Once in orbit, the Soviet media referred to the spacecraft as Almaz-1 – nearly twenty years after the first launch of an Almaz spacecraft. Maj.-Gen. Aleksey A. Shumilin, then the Deputy Commander of the Baykonur Cosmodrome called the Almaz flight, "the most significant unmanned Soviet space mission of 1991" [260].

On 4 April, the main Almaz engines fired to reach its operational orbit at 275 kilometers. A minimum 30-month operational lifetime was planned, with orbits to be adjusted every 24 days. Problems however began to prevent such a schedule. In January 1992, the Russian media reported that one of the two synthetic aperture radar antennas had failed, thus reducing the capability of the spacecraft in half. In order to compensate for the problem, engineers at the NPO Mashinostroyeniya altered the vehicle's orbit periodically to allow coverage of target territory

[261]. At the time, controllers were processing about 6 to 8 frames per week. The observation program for the spacecraft was prepared by the USSR State Committee on Hydrometeorology, the State Geodesy Committee, the Ministry of Nature Management, and the USSR Academy of Sciences. Despite the failure of the one antenna, scientists appear to have received good data through the mission. Almaz-1 was also used for rescue purposes. The vehicle took part in the rescue of the *Mikhail Somov* ship which was trapped near Antarctic under polar night conditions. For a month-and-a-half, the spacecraft was the only source of information on ice movement. Almaz-1 also "supplied information on Earth areas in which ecological and natural disasters had occurred, recording death-dealing oil spots spread off the coast of exotic bays or taking a look from above water into the crater of Pinatubo Volcano (Phillipines) which erupted suddenly" [262].

Increased solar activity led to high levels of propellant consumption just to maintain operational orbits. The rapid propellant consumption eventually shortened the expected duration of the mission. On 17 October 1992, a little over 18 months following the launch, controllers commanded Almaz-1 towards a controlled reentry into the Earth's atmosphere [263].

The U.S.-based Space Commerce Corporation acquired marketing data for the Almaz-1 mission under a joint agreement with Glavkosmos and NPO Mashinostroyeniya. The Almaz Foreign Trade Firm was also set up to market data with Space Commerce. Hughes STX later signed an agreement with NPO Mashinostroyeniya for distribution, processing, and analysis of Almaz radar data. By December 1992, the cost for a single 40 x 40 kilometer image was about $800 [264]. Only a few hundred customers had officially purchased images from the Almaz-1 mission by the time of its reentry. A scholarly examination of the effectiveness of Almaz versus the ERS-1 (ESA) and Landsat-TM satellites (by US and Russian researchers) suggests a favorable capability for the Almaz platform. The authors found that although Almaz and ERS-1 systems were considerably less efficient than those of Landsat-TM, when classifying vegetable types, the former spacecraft nevertheless provide systematic all-weather observations of other components of the tundra ecosystem during polar night. The article suggests that joint use of the ERS-1 and Almaz would have made a very effective pair in data classification [265].

23. The Future of Almaz

Originally, NPO Mashinostroyeniya had intended to launch a second Almaz-1-type spacecraft, to be publicly known as Almaz-1B, sometime in 1993. This mission would have been followed by the more ambitious flights of Almaz-2 and Almaz-3 in 1995 and 1996 respectively [266]. All these missions were eventually delayed, and at the time of writing, it is quite likely that none of them will ever be launched into orbit given the dire economic situation of NPO Mashinostroyeniya, which claimed in 1993 that it was short of $50 million of funding.

Almaz-1B would have carried three synthetic aperture radars (RSA-3, RSA-10, and RSA-70) and a large suite of sensors, including the RBO-3 side-viewing radar, a 4-channel optical stereo imager (with a resolution of 2.5 to 4 meters), two MSU-E scanners, the MSU-SK visible/infrared scanning radiometer, a sea/surface radiometer, and the *Balkan-2* lidar. The radars would have had a resolution of between 5 and 40 meters. By late 1994, NPO Mashinostroyeniya planned to launch Almaz-1B in late 1997. The organization had set up a joint-stock Russian-American company known as SAR (Sokol Almaz Radar) to implement the Almaz-1B project. The stocks were divided between NPO Mashinostroyeniya (47%), the state-run Rosvooruzheniye (4%), and the American Sokol Group, Inc. (49%). Evidently, by December 1994, the company had already invested $120 million in the $370 million project [267].

Almaz-2 and Almaz-3 would have been launched on uprated Proton-K boosters known as the Proton-KM into 600 kilometer orbits inclined at 73°. The vehicles would supposedly have had aft rendezvous and docking systems to allow for refueling by Progress-M vehicles or maintenance by piloted Soyuz TM spacecraft. Each of these vehicles would have had a payload mass of 6.5 tons and an average power output of 3.8 kilowatts. The primary instrument would have been a synthetic aperture radar with three bands (23 centimeters for vegetation and soil moisture, 9.6 centimeters to avoid storm interference, and 5.6 centimeters for ice and waves), augmented by multispectral imaging sensors [268].

NPO Mashinostroyeniya's fortunes, however, dimmed through the 1990s. By May 1994, the organization had 6,000 employees, down from about 8,000 in 1991. Within four months, the organization was in a severe financial crisis, planning to lay off thousands of employees. The design bureau had already switched from a 5-day work week to a 4-day work week to compensate for a lower workload [269]. Like most Russian defense companies, the design bureau has had to turn to commercial opportunities in the face of reduced orders from the state. Through 1998 and 1999, state orders (mostly for naval cruise missiles) amounted to only 33% and 12-13% of their work respectively. In this climate, the company has all but declared the Almaz program dead. In new plans unveiled by NPO Mashinostroyeniya at the MAKS-99 exhibition in Moscow in 1999, the organization clearly demonstrated that it was moving its strategy to more smaller platforms for remote sensing (such as Kondor-3) as well as small communications satellites (such as Ruslan-MM) and small satellite launchers (such as Strela) [270]. Almaz, begun in 1964 was no longer a part of their future plans. Chelomey's long-term dream was finally over.

24. Conclusions

The Almaz space station program spanned a total of 28 years, from proposal of the original Almaz plan in 1964 to reentry of Almaz-1 in 1992. Perhaps the most important result of the entire program, at least from a strategic military perspective, was that a human presence in space does not afford any significant advantages in reconnaissance activities. In fact, the Soviets found that human surveillance is more costly, less efficient, and not as timely as robotic reconnaissance. Thus, the most important contribution of the Almaz space station program was perhaps its failure to contribute significantly to military operations. The implications prompted the Soviets to rely wholly on robotic systems - a path taken by the Americans without actually flying any piloted military space stations in orbit.

Although the Almaz program underwent some severe and dramatic changes, it has left behind an enduring legacy that is perhaps more prominent than any of Korolev's old spacecraft. The original Almaz space station flew three times in 1973-1977 and was visited by three crews. The station was used as the basis to develop and produce the nine DOS 'civilian' Salyut space stations, flown and crewed as Salyut(-1) to Salyut-7 between 1971 and 1986. The DOS stations then served as the basis for the Mir core station and then eventually the Zvezda module for the International Space Station.

The Transport-Supply Ship (TKS) portion of the Almaz station has had an even more enduring career. After the flight of Kosmos-1686 in 1985, KB Salyut (on contract from NPO Energiya) used the TKS-M vehicle to design and build the Mir modules that were later known as Kvant-2, Spektr, Priroda, and Kristall. The original Kvant module (retrospectively known as Kvant-1) was itself also a derivative of the TKS. Eventually, the service module of the TKS, known as the Functional-Cargo Block (FGB), was used as the basis for the core of the International Space Station, known as Zarya. The FGB was also used the 'service module' for the Polyus/Skif-DM space weapons payload for the first launch of the giant Energiya launch vehicle [271].

The Return Apparatus from the Almaz complex was used for the last time on Kosmos-1443 in 1983; there are no further plans to use this large crew return capsule.

What is perhaps most ironic is that NPO Mashinostroyeniya, i.e. the descendant of the former Chelomey design bureau, is not involved in any of the current work on Almaz follow-on efforts. This is mostly because Chelomey had farmed out work on the TKS to his Branch No. 1 located at Fili. This branch had also been a key developer in converting the Almaz station into its 'civilian' DOS version. Thus, it was the Branch No. 1, taken away from Chelomey in June 1981, that gained the most out of the Almaz program in the long run. The Branch No. 1, now known as the Salyut Design Bureau (KB Salyut), also developed the Proton-K launch vehicle for Chelomey. On 7 June 1993, KB Salyut combined with the giant M. V. Khrunichev Machine Building Plant to become a single enterprise, known by the long-winded name, the State Space Scientific-Production Center Named After M. V. Khrunichev (GKNPTs Khrunichev) [272]. Khrunichev, using KB Salyut's history in developing the Proton, the DOS station, and the TKS, continues to dominate the Russian space market, and has become one of the most powerful space development organizations in modern day Russia. Without doubt, Almaz, born as a Cold War military space project, has bequeathed a legacy that will remain viable and vibrant for many more years to come in the new post-Cold War era.

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