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

Part 1: 1964 - 1976*

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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

1. Introduction

In the late 1950s and early 1960s, the Soviet military explored many avenues to establish a permanent presence in space. A part of this strategy was to explore the possibility of using officers in Earth orbit who would carry out military functions. The Soviet military's eagerness to establish a permanent foothold in space was given a boost from plans of its primary rival, the U.S. Department of Defense (DoD). Through the immediate post-Sputnik era, there had been much talk of piloted military space projects funded by the DoD. One of the most visible projects had been the X-20 Dyna-Soar spaceplane project, approved in the aftermath of Sputnik, but cancelled by President Lyndon B. Johnson in December 1963. Some military strategists had shifted their thinking to a more permanent presence in space than afforded by the X-20A – in particular a military space station in Earth orbit capable of supporting multi-crewed long-duration missions. Preliminary work on such a vehicle, later named the Manned Orbiting Laboratory (MOL), began in late 1963 concurrent with the termination of the X-20A program. Johnson officially approved the program with an announcement on 25 August 1965 [1].

The underlying concept behind the U.S. Air Force's MOL was the use of a modified Gemini spacecraft named the Gemini-X (later referred to as the Gemini-B), which would be launched together with the Mission Test Module (later the Laboratory Module) as a single unit by a Titan IIIC launch vehicle. Once in orbit, astronauts would open a hatch in the heatshield of the Gemini-B vehicle and crawl into the Laboratory Module for a month-long mission. At the time that Johnson made his announcement, MOL's primary goal was overhead reconnaissance, primarily over the Soviet Union. Other tasks emerged later. These included satellite inspection, testing the accuracy of orbital bombardment systems, command and control over military operations during wartime, assessing the effects of month-long missions on humans, and electronic intelligence reconnaissance [2].

All this caused much anxiety in the USSR's Ministry of Defense. On 24 August 1965, the day before Johnson's announcement, the Central Committee and the Council of Ministers issued a joint decree calling for the expansion of military research in space [3]. By this time, the USSR had already begun the development of a specialized piloted vehicle exclusively for military purposes, the Soyuz-R, which was a small "space station" comprising two modified Soyuz spacecraft docked to each other. From 1963 to 1965, the Experimental-Design Bureau No. 1 (OKB-1) under the famous Chief Designer Sergey P. Korolev had tasked the design of Soyuz-R to its Branch No. 3 at Kuybyshev (now known as Samara) under the command of Branch chief Dmitriy I. Kozlov, one of Korolev's protégés. The appearance of MOL appears to have quashed Kozlov's

*Part 1 of 2 parts.

hopes since the Ministry of Defense's General Staff began looking for a more substantial military presence in space. They found a willing provider in OKB-52 General Designer Vladimir N. Chelomey, a rising star in the missile and space industry whose original expertise was in the development of naval cruise missiles. Chelomey shrewdly played into the hands of the Soviet military's own interest in crewed reconnaissance and their fear of MOL. It was also rumoured that Soviet leader Nikita S. Khrushchev had a "fixation" on U.S. aircraft carriers and wanted a Soviet system to keep track of them. Appraised of the MOL effort and appealing to Khrushchev's fears, Chelomey emerged with a mirror concept, a space station containing sophisticated reconnaissance equipment including powerful radars to track U.S. naval forces [4].

On 12 October 1964, just two days before Khrushchev's overthrow, Chelomey gathered all his deputies and proposed the creation of a new Earth orbital complex named Almaz ("Diamond"). The 20-ton station would be crewed by two to three military officers on a rotating basis and launched by the three-stage UR-500K booster, better known as the Proton. The station was intended for operation of about one to two years during which time cosmonauts would conduct experiments and scientific activities formulated by the Ministry of Defense, primarily consisting of photographic and visual reconnaissance [5]. With MOL clearly accelerating, Kozlov's modest Soyuz-R proposal was no match for Chelomey's Almaz. In early 1966, the Scientific-Technical Council of the Ministry of Defense's General Staff reviewed both projects on a competitive basis and decided to recommend Almaz for formal approval. All the technical documentation on Soyuz-R was turned over to Chelomey for use in planning and designing the Almaz complex [6]. The Ministry of General Machine Building (MOM), the ministry that oversaw most Soviet missile and space programs, approved formal work on Almaz with a decree on 27 October 1965 [7].

As projected in 1966-67, the Almaz complex comprised two elements, a space station proper called the Orbital Piloted Station (OPS) or "product 11F71," and a transport ferry called the Transport-Supply Ship (TKS) or "product 11F72," to bring crews back and forth between the Earth and the station. (See Table 1). Because the development of a large delivery ship such as the TKS would take some time, Chelomey decided on an alternative short-term solution: to use Kozlov's transport ship from the now abandoned Soyuz-R complex, a modified Soyuz spaceship named the 7K-TK. On 30 March 1966, Minister of General Machine Building Sergey A. Afanas'yev formally assigned the old Korolev Branch No. 3 under Kozlov to design and build this modified Soyuz to serve as a ferry vehicle for the Almaz complex. Kozlov, using the basic 7K-OK Soyuz vehicle as a baseline, quickly completed the "draft plan" for the 7K-TK the same year and began working on preparing the technical documentation for manufacture of the ship [8]. In a decree (no. 304) of the Military-Industrial Commission (VPK) dating from 28 December 1966 in which the Soviet government formalized all the contractors and subcontractors for the project and established deadlines for completion, the VPK delayed timelines for the development of 7K-TK transport ship. Eventually by 1967, Chelomey dropped Kozlov's transport ship from the Almaz plan, a decision partly motivated by a reluctance to cooperate with the old Korolev design bureau. The Almaz space station, the OPS, would now include its own large return capsule for the crew. At

TABLE 1: *Designations.*

Component	Production Index
Almaz (OPS + Return Apparatus)	11F71
TKS	11F72
TKS Return Apparatus	11F74
Almaz OPS	11F75
Almaz OPS Information Return Capsule	11F76
TKS FGB	11F77
Almaz-T	11F668

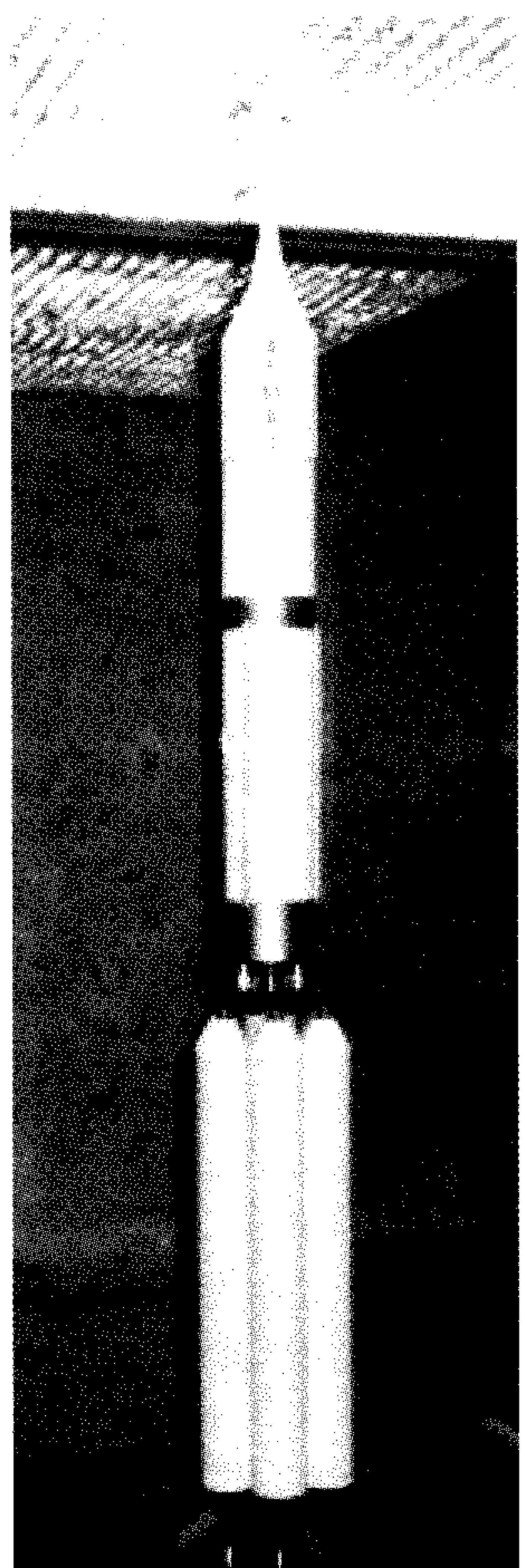

Fig. 1 This is a model of an unusual variant of the UR-500K Proton launcher with the Almaz station as a payload. Note the use of a launch escape tower, indicating that the station would have been launched with a crew on board. Actual flight versions of the Almaz were launched in the 1970s without the crew return capsule ("Return Apparatus") and thus did not have a launch escape tower.
(Copyright Dietrich Haeseler)

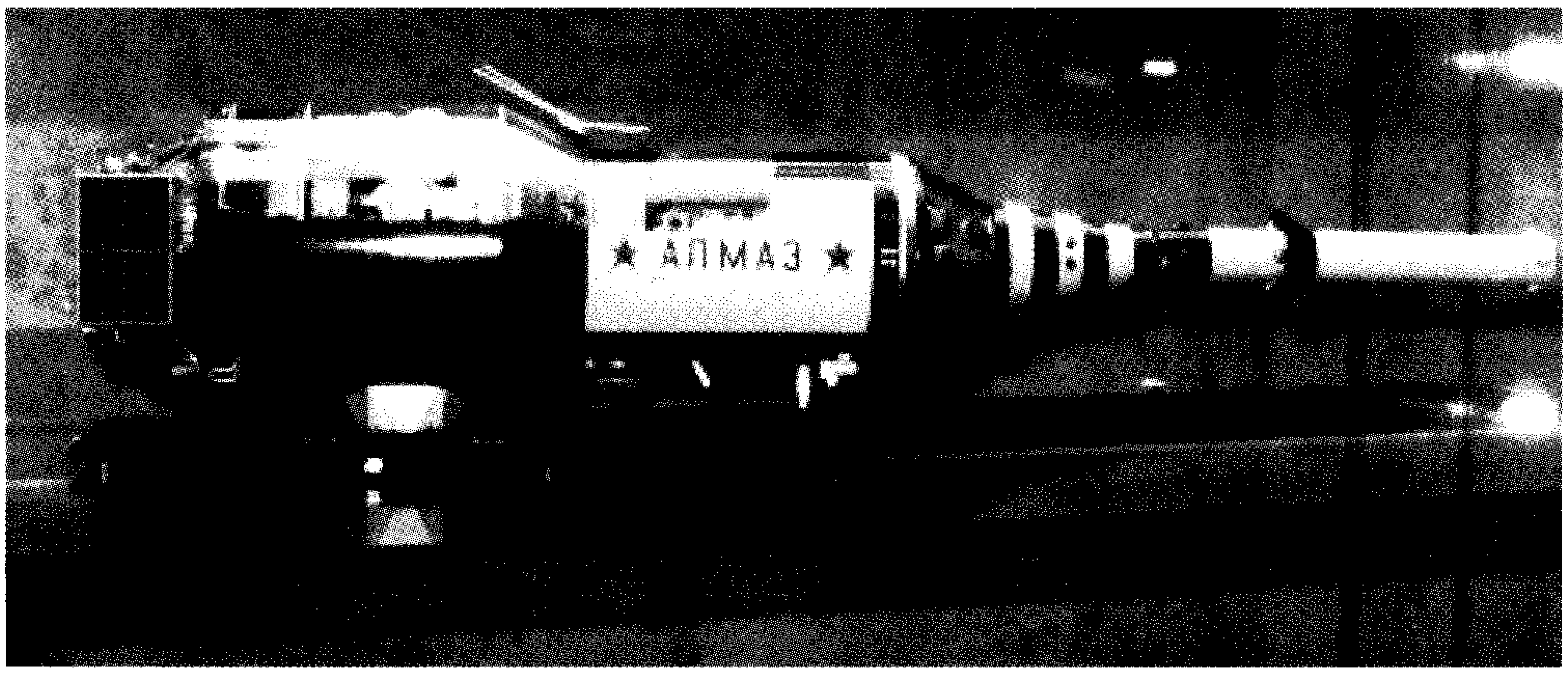

Fig. 2 This is a model of the original Almaz Orbital Piloted Station (OPS). On the right is the conical Return Apparatus (VA) with its launch escape tower. The middle area (with the word "Almaz" written in Cyrillic) is the living quarter of the station. The larger diameter section on the left contains the photo-reconnaissance camera system known as Agat-1. A Soyuz would dock on the left port of the station, with the crew entering the station into the large diameter area. (Copyright Dietrich Haeseler)

the same time, Chelomey continued to promote his old idea of a separate transport craft to deliver crews to the station at a later date. During this period, the Soviet government established an "interdepartmental" commission of 70 renown scientists, heads of design bureaus and research institutes from the aviation industry and the Ministry of Defense to evaluate the design of the Almaz complex. Their recommendation and high appraisal of the technical characteristics of the plan proved to be critical to the further progress of the project. The final details of the Almaz design were frozen by 21 June 1967 when Chelomey signed the "draft plan" for the spacecraft comprising over 100 volumes of technical documentation from 25 major design bureaus [9]. Less than two months later, on 14 August 1967, the Central Committee and the USSR Council of Ministers issued a joint resolution defining a final schedule and approving the "tactical-technical characteristics" of the Almaz complex [10]. The decree signaled the full commitment of the Soviet government to implementing the project. (For a list of the major government decisions in support of Almaz, see Table 2).

In the initial plan of development for Almaz, approved by the Ministry of Defense in Tactical-Technical Requirement (TTT) no. K-00535 in 1967, the program was divided into two stages. The first stage would involve autonomous piloted flight of the station with its own crew Return Apparatus. Operational lifetime of each station would be between one and three months. One three-person crew would be launched with each station into orbit and return to Earth in the Return Apparatus. The second stage would consist of joint flights of the station and the large TKS vehicle. Operational lifetime of each complex would be about one year, and would include three to four dockings of the TKS. In the second phase, crews would be launched on the TKS rather than with the station. Chelomey envisaged that the first stage would last three years, and the second stage about five to six years [11].

In a time of rapid growth for the Soviet space program, Almaz was not the only piloted military program. At least three other comparable programs were under development in the late 1960s. These included the Zenit Design Bureau's Spiral' small spaceplane interceptor, Kozlov's 7K-VI Zvezda project that would use a modified Soyuz spacecraft known as 7K-VI for rapid action reconnaissance missions, and later the Korolev design bureau's Soyuz-VI platform, which also used elements of the Soyuz spacecraft [12]. The strongest supporter of all these programs was the Soviet Air Force, which through the late 1960s supported what now seems like overtly ambitious plans to maintain a presence in space. For example, in a proposed 8-year plan tabled in September 1967, Air Force officials considered launching at least 20 Almaz stations and 50 Zvezda ships between 1968 and 1975. To support such a grandiose plan, officials believed they would need about 400 transport ships and as many as 400 cosmonauts [13]. Not surprisingly, these ambitious plans had to be curtailed to more realistic levels. By 1969, for a variety of reasons that had as much to do with internal political conflicts as with funding limitations, the Soviet military had one-by-one canceled or suspended work on all three projects. Almaz, the fourth one, was the only one that remained and then, only in a much more modest form.

What made all these programs unique was that unlike earlier space-based reconnaissance platforms such as Zenit in the USSR and CORONA in the U.S., they would have an actual human presence in

TABLE 2: *Government Decisions on the Almaz Space Station Program.*

Date	Description	Issuing Organ
1964		
12 Oct 1964	Almaz project proposed	OKB-52
1965		
27 Oct 1965	work on Almaz approved	MOM
1966		
28 Dec 1966	schedule for Almaz approved	VPK
1967		
21 Jun 1967	Almaz draft plan approved	
14 Aug 1967	Almaz schedule and requirements approved, full approval of project	TsK and SM
1970		
9 Feb 1970	DOS program approved, sidelined Almaz	TsK and SM no. 105-41
16 Jun 1970	Almaz and TKS schedule approved, testing to be done in two phases	TsK and SM no. 437-160
1972		
21 Apr 1972	DOS and Almaz programs coordinated for remainder of the 1970s	MOM
15 Jun 1972	Almaz schedule for missions in 1973 approved	MOM
27 Dec 1972	Almaz State Commission formed	TsK and SM
1973		
16 May 1973	Almaz schedule for missions in 1974 approved	VPK
31 May 1973	Almaz schedule for missions in 1974 approved	MOM
1976		
19 Jan 1976	revised Almaz and TKS schedule for missions in 1977-80 approved, fourth Almaz station with two docking ports approved	TsK and SM no. 46-13
1978		
27 Jun 1978	piloted Almaz program terminated, resources redirected to automated Almaz-T	TsK and SM no. 534-165
1981		
19 Feb 1981	remaining TKS vehicles redirected to DOS/Salyut program	TsK and SM
30 Jun 1981	TsKBM Fili Branch removed and attached to NPO Energiya	TsK and SM
19 Dec 1981	all work on Almaz program terminated to redirect resources to Energiya-Buran program	TsK and SM no. 1206-371
1982		
26 Aug 1982	Pion-K military observation program using TKS and DOS/Salyut approved	MOM
1986		
12 Apr 1986	automated Almaz-T program resumed	VPK no. 126

Abbreviations:

MOM = Ministry of General Machine Building **SM = Council of Ministers**
TsK = Central Committee of the Communist Party **VPK = Military-Industrial Commission**

Sources: Ivan Yevteyev, *Operezhaya vremya: ocherki*, (Moscow: Bioinformservis, 1999); S. A. Zhil'tsov, ed., *Gosudarstvennyy kosmicheskiy nauchno-proizvodstvennyy tsentr imeni M. V. Khrunicheva*, (Moscow: RUSSLIT, 1997); K. Lantratov, "First Module of the 77th Series" (in Russian), *Novosti kosmonavtiki*, no. 11, pp.60-63, 2000.

space. While debates over the efficacy of humans vs. robots for military applications in space continue to this day, in the early 1960s, the arguments on both sides of the issue were less than clear. In the early 1960s, automated reconnaissance systems had still not reached high levels of maturity. On the Soviet side, at least, a strong human military presence in space was a natural evolution in thought, especially considering that they had taken a strong early lead in the space race with the missions of Vostok and Voskhod. Early experiments on Vostok had also indicated that there might be a potential payoff with human observations of military targets. Although the USSR Ministry of Defense took an ambivalent position on the "humans-in-space" issue, the military lobby was at least willing to explore the possibility that military officers in orbit might be able to provide timely and useful information that automated satellites might not. Strategists believed that two factors might be advantageous in terms of human observation – a quick turnaround in terms of information retrieval, and the observation of mobile targets (such as aircraft carriers and aircraft).

The early version of the Almaz station's design and capabilities were quite similar to the American MOL. This was partly attributable to the ancestry of both complexes. The design of the Almaz Return Apparatus was derived from the LK-700 and LK-1 capsules which were themselves appropriated to a great degree from Gemini. Similarly, the MOL Gemini-B was simply an uprated Gemini. Chelomey clearly had access to information on MOL. During the 1960s, the Soviet government published a classified weekly journal entitled *Raketno-kosmicheskaya tekhnika* ("Rocket and Space Technology") containing abstracts of articles published in the open media in the West. In 1964 and 1965, the journal evidently published numerous articles on MOL [14]. While there is no clear evidence to suggest that Chelomey took the MOL plan wholesale, macro-level design decisions for Almaz were probably influenced a great deal by the American project. Chelomey may have also inherited from a second source. Through the early 1960s, Korolev's OKB-1 design bureau had been working on a variety of different large space station programs, all grouped under the rubric of the Heavy Orbital Station (TOS) or Zvezda. By 1964, as Korolev's focus had shifted to the N1-L3 lunar landing program, he had to make some tough choices about allocation of resources. Recent recollections from engineers from his design bureau suggest that at the time, Korolev gave an order to transfer all work on the TOS-Zvezda to Chelomey's organization. Although many of Korolev's engineers were opposed to this, Korolev explicitly had given the order to "Transfer everything there is without keeping anything back" [15]. While Korolev's engineers suggest that Chelomey used these plans to develop Almaz, the designs of the two complexes were quite different.

2. The Almaz Station

In the original draft plan of the Almaz space station, the complex comprised two major components:

- The 11F71 Orbital Piloted Station (OPS); and
- The 11F72 Transport-Supply Ship (TKS).

Cosmonauts would use the TKS to visit the station proper and to return to Earth with the results of scientific experiments. Both modules were of roughly equal size, and much larger than the standard Soyuz spacecraft in operation at the time. Both spacecraft would also be launched by three-stage versions of the UR-500 launch vehicle, known more commonly as the Proton-K or 8K82K.

The Almaz station, i.e. the OPS, was a space station weighing between 18.9 and 19.9 tons that comprised three main sections:

- The 11F74, the Return Apparatus (VA);
- The 11F75, the station proper; and
- The 11F76, the Information Return Capsule (KSI).

The 11F75 was shaped like a long cylinder with sections of two different diameters, a large-diameter (4.15 metres) portion and a small-diameter (2.9 metres) portion. It had a mass of about 15 tons and a length of 11.61 metres. Total internal volume afforded was about 47 m^3. The small diameter was in the forward portion of the station and would be enclosed during launch by a conical nose fairing. The large-diameter area was at the aft of the station, and ended in a spherical airlock with a *Konus* ("Cone") passive docking port along the main axis of the station for visiting spacecraft. There was a hatch between the airlock and the large-diameter area, allowing depressurization for spacewalks. Crews would conduct extra-vehicular activity via a large hatch in the upper portion of the spherical airlock.

There was a second smaller hatch at the lower end of the airlock which connected to a chamber containing a small drum-shaped capsule, the 11F76, which was capable of being ejected from the station and returning back to Earth with exposed film (up to two kilometres in length) with a total mass of up to 120 kilograms from the main observation system known as *Agat-1*. The capsule had a mass of about 360 kilograms and a diameter of 0.85 metres. The crew would use a special manipulator arm to transfer the film directly from the *Agat-1* observation complex to the 11F76. Once the capsule was packed with its payload, the crew would spin-stabilize the pod and then eject it from the station. The one-meter long capsule had its own solid-propellant propulsion system for reentry (one main engine and four attitude control engines), a parachute system, a jettisonable heatshield, and the actual recovery pod equipped with a radio beacon for recovery forces on the ground. Prior to reentry, the capsule would discard the engine system. The film had strict limitations on g-loads during reentry and landing, and as such, the Scientific-Research Institute for Resin Industry developed a special pressurized system to buffer the capsule upon hard landing. Sunlight was another problem due to possible overheating after landing, and a splashdown on water was actually considered more preferable due to thermal constraints. In case of a landing on ground, rescuers had only a few hours to recover the capsule before degradation of the film. Designers developed a special all-terrain beacon with a thermostat. In case of a landing outside the Soviet Union, the military demanded an automatic self-destruct system which was installed in the "heart" of the film cartridges. The explosive was so powerful that it would rip the film into the smallest possible fragments so as to make it impossible for others to

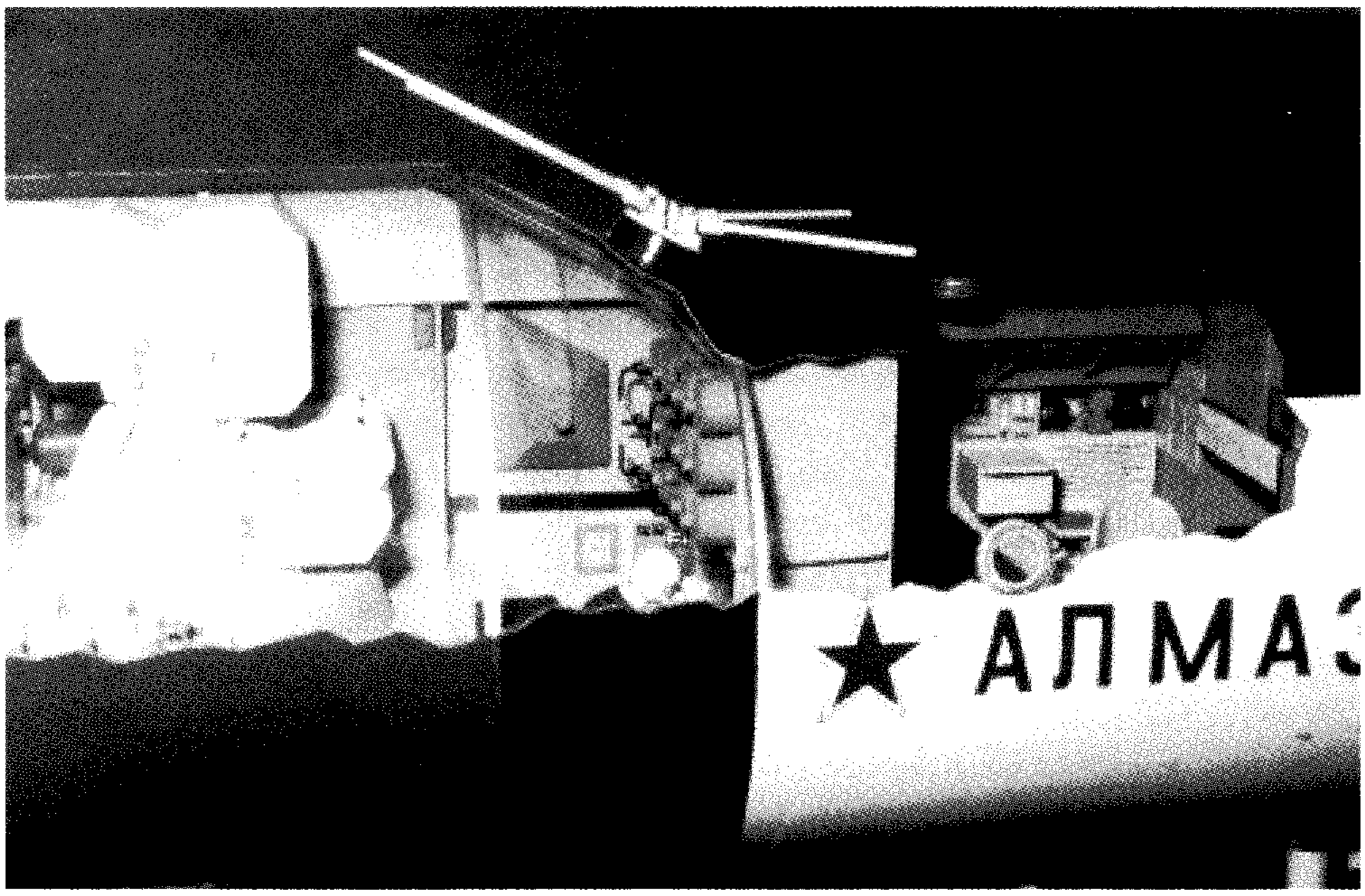

Fig. 3 This is a closeup of a model of the Almaz station. On the right is the living area of the station. The large white contraption on the left is the *Agat-1* photo-reconnaissance system. (Copyright Dietrich Haeseler).

reassemble the film. Initial plans were to launch the Almaz station with two or three capsules. Additional (as many as eight) capsules would be delivered by TKS vehicles in the future.

Several antennae as well as two main engines were positioned around the airlock on the end of the large-diameter portion for orbital corrections. Each RD-0225 (or 11D24) main engine with a thrust of 400 kilograms was developed by the Design Bureau of Chemical Automation (the former OKB-154) under Chief Designer Aleksandr D. Konopatov. These engines would be used for braking, maneuvering, and orbital corrections. Additional stabilization engines consisted of 16 microengines of 20 kilograms thrust, 12 engines of 1.2 kilograms thrust, and four with 40 kilograms thrust each. These stabilization engines were installed on the transfer compartment on the "nose section" of the station. Power for the station was provided by two large solar panels spread like wings to a span of 22.8 metres whose bases were attached to the spherical compartment. The panels would provide 3.12 kilowatts of power from a total exposed area of 52 m^2. The entire aft end of the station was surrounded by a cone-shaped shield made of vacuumed thermal insulation.

Cosmonauts would dock at the aft docking port, open the hatch into the spherical airlock, and crawl through a short tunnel into the large-diameter area. The tunnel was enclosed all around by a stubby instrument compartment containing spherical propellant tanks for the station's main engines, the engines themselves, pressurized gas tanks, and the small attitude control thrusters.

Going back towards the station, there was the large-diameter area which had a control console, a pilot's console that indicated the current coordinates of the station, and a panel to allow control over the station's orientation. Instruments were designed and installed as detachable modules to facilitate easy repair. The compartment also included athletic instrumentation (including a running track and a mass measuring instrument) and the toilet. The *Pechora-1* TV system and the onboard "information-search system" to monitor the station's various systems were also located in the main compartment.

The centerpiece of the large-diameter area was the *Agat-1* photo-reconnaissance complex (object 11V38), a large device that occupied a considerable portion of the aft part of the compartment. The Central Design Bureau (formerly the KB-10) of the Krasnogorsk Mechanical Plant (KMZ) was the subcontractor for the complex. The overall system included a large optical telescope with a variable focus length of up to 6.375 metres for detailed observation of targets in the equatorial regions of the Earth's surface as well as in the Earth's atmosphere. Russian sources have claimed that the telescope's resolution was less than three metres, but given the size of the mirror, it is more likely that the telescope was capable of distinguishing targets smaller than one meter. U.S. intelligence sources in early 1974, predicted that resolution would be as high as 30-45 centimetres [16]. The *Agat-1* telescope would be used with the wide-film ASA-34R camera (object 11V310) that was mounted on "top" of the telescope. The ASA-34R included as part of it the SA-34R topographic camera and the SA-33R stellar camera for geodesic observations. The cosmonauts would use *Agat-1* to photograph targets on the Earth, develop the film (50 x 50 centimeter frames) on the station, conduct an analysis, and send back the more strategically important ones directly to the Earth via a closed TV link known as *Avrora* ("Aurora"), all within about 30 minutes. The remaining photographs would arrive on Earth via the 11F76 recoverable capsule after being developed on board by the *Rakkord* system. Already in the late 1960s, designers were planning to install additional optical systems on future Almaz stations – especially ones for observations outside the visible spectrum. One idea was to install a synthetic aperture radar.

Of the total of 14 optical instruments on board the station, others included the OD-5 optical viewfinder which allowed the cosmonauts to "freeze" the movement of the Earth below, observe specific targets on the ocean, record their impressions on tape, and then transmit the recording when over a ground communications station. By using knowledge of the precise time of the observation, analysts on the ground could determine the exact coordinates of the target in order to carry out operational observation of the target using other systems. A different version, OD-4, was used on the first DOS-Salyut station in 1971. The Panorama-Survey Instrument, POU-11 (object 11V31) was for wide area coverage of the Earth's surface. The station also included the *Volga* (object 11V33) infrared instrument with a resolution of 100-120 metres, the *Yantar'-P* ("Amber-P") infrared instrument for detecting fires on Earth, and the AFA-M31S and KFK-100 remote sensing cameras. The *Volga* was considered the first Soviet infrared instrument deployed in space for observation. The station was also equipped with the *Sokol-1* ("Falcon-1") periscope for viewing areas around the station, and for observing cosmonauts during spacewalks.

Heading further to the aft of the station, the cosmonauts would enter the smaller diameter section which was the crew living compartment containing sleeping areas with deployable bunks, a dining table and chair, a food storage and preparation area, a medicine cabinet, and viewports for photography. For the first time on a Soviet piloted spacecraft, the life-support system included a device, known as *Priboy-101* ("Surf-101"), with the capability to recycle water from air humidity. Controls for the life-support system were also located in this aft area.

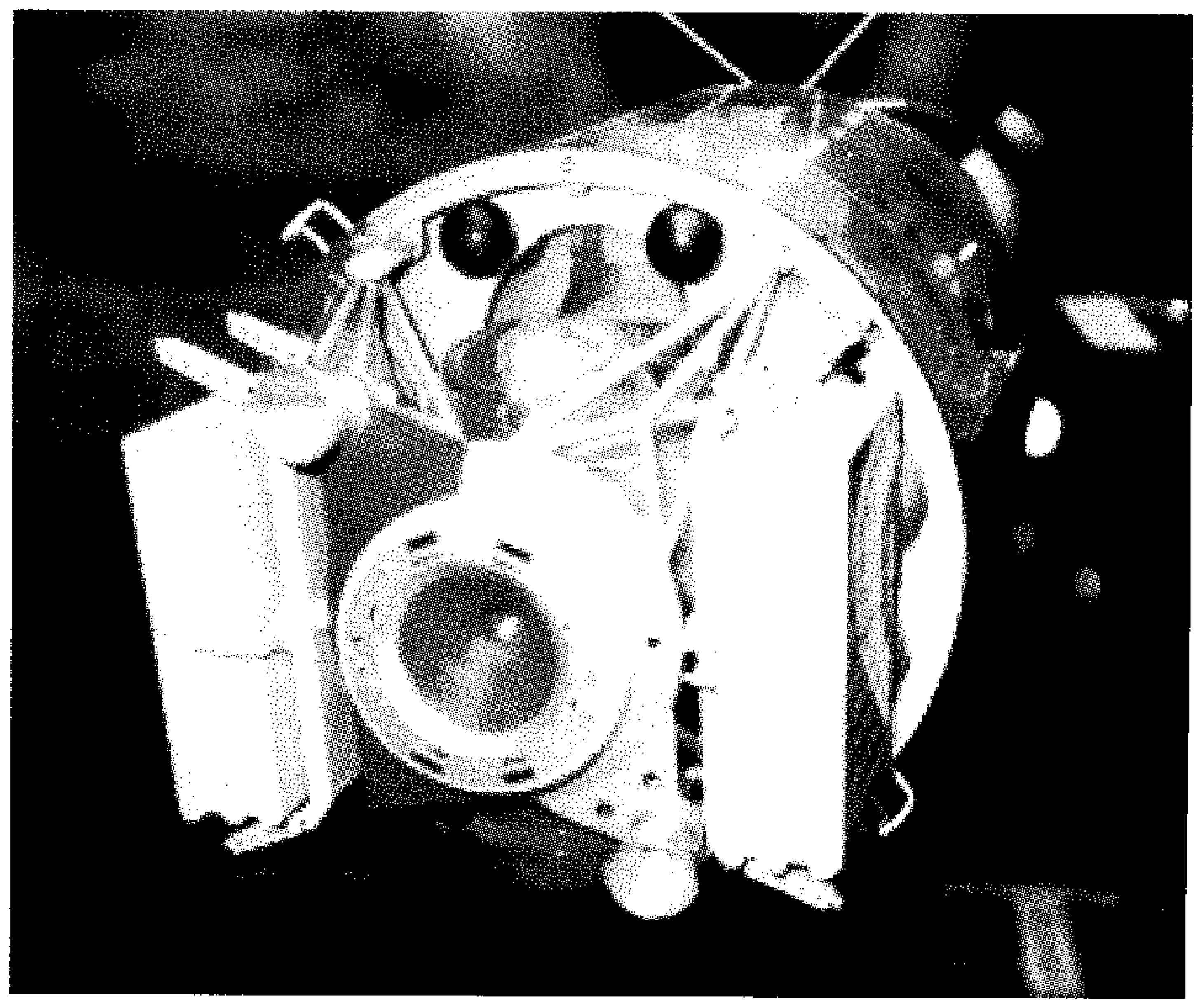

Fig. 4 This is a rear view of a model of the Almaz station. The circular object in the foreground is the main docking port. The vertical objects on each side are folded solar arrays which would unfurl once in orbit. Two nozzles of the main Almaz engine are visible on either side of the docking port. (Copyright Dietrich Haeseler)

Development of one of the most interesting components in the station was motivated by concerns among Soviet military officials that the United States might attack such an explicitly military space station in orbit. Under a contract, the Design Bureau of Precision Machine Building (the former OKB-16) under Chief Designer Aleksandr E. Nudel'man designed a 23-millimeter rapid-fire cannon for the station, known probably as *Shchit-1* ("Shield-1"). Nudel'man's previous claim to fame had been as the designer of several major anti-tank guns and missiles for the Soviet armed forces. Cosmonauts would be able to use a gunsight to turn the station and aim the cannon at a selected target. The Soviets evidently considered the weapon more of a defensive system rather an offensive one given the limited maneuvering capabilities of the Almaz station.

Since its primary mission was overhead reconnaissance, the station would have a low operational orbit (220 x 270 kilometres) and be oriented towards the Earth's surface for long periods. The search and observation of targets on the ground thus posed complex demands on the guidance system. As per original requirements, Chelomey's engineers designed a guidance system that would control the station continuously from the moment it separated from the launch vehicle to orbital decay many months later. What they emerged with was a "decentralized" system with subsystems for orientation, stabilization, movement control of the center of mass of the vehicle, navigation, and programmed control of the onboard instrumentation. The primary flight control system was based on an analog system since a digital device that was continuously operable for a year was not in existence in the USSR at the time. Instead, the All-Union Scientific-Research Institute for Electromechanics (formerly the NII-627) headed by Chief Designer Andronik G. Iosif'yan developed a new low power electro-mechanical stabilization system using a spherical flywheel (60 centimetres diameter) for three-axis stabilization and slow rotation of the station. A ring flywheel allowed the station to turn rapidly around its longitudinal axis. Unlike conventional orientation systems, there was almost no propellant consumption for the electro-mechanical system. Cosmonauts would be able to carry out rapid roll control at 1°/second to expand their field of view. Precision (of up to 10') would be achieved by a system which corrected the gyroscopic orientation system with a Doppler signal from a radar instrument which was part of the radar observation gear for the station. The gyroscopic orientation system was developed by the Scientific-Research Institute for Applied Mechanics (formerly the NII-944) under Chief Designer Viktor I. Kuznetsov, one of the original members of Korolev's old Council of Chief Designers from the 1940s. Although the system was very loud and caused much inconvenience to the crews, the flywheel system saved attitude control propellant consumption by about 10-15 grams per orbit. Almaz was the first station to use magnetically suspended flywheels (later called gyrodynes) for orientation.

The control system had various modes of operation, including precise orientation and stabilization, restoration of orientation from a disoriented position, and spinning the station into "storage" position. Cosmonauts could also manually orient the station when observing objects by putting the target in the cross-hairs of their optical sight with a turn of the control stick. As a result, the guidance system would allow *all* the optical instruments on board to inspect the selected target. Although analog computers were used on the overall station's guidance system, Chelomey's engineers designed a digital system based on two *Argon-16A* computers for the observation instrumentation, a first for a Soviet piloted space vehicle. The computer was developed by the All-Union Scientific-Research Institute for Digital Computer Technology. The two computers would be used to control the station's attitude and point the *Agat-1* system correctly. One would serve as the primary, the other as the backup. In practice, crews usually used both at the same time since there occasional processing errors [17].

In initial conceptions of the Almaz spacecraft, the station was equipped with a large crew return vehicle:

- The 11F74, the Return Apparatus (VA);

The idea was to launch crews on the Almaz station itself in the Return Apparatus. The crew would then spend an extended period in space, and then simply detach the VA and return to Earth.

The Return Apparatus was similar to the LK-1 and LK-700 lunar spacecraft. Apart from its shape, the Almaz Return Apparatus had two striking similarities to MOL's Gemini-B: the Soviet vehicle was designed to have a hatch in the center of the heatshield for transfer to and from the station proper; and the spacecraft was designed for reuse on subsequent stations.

The Return Apparatus comprised three sections: a conical crew capsule with a flat top shaped like the Apollo Command Module; a second longer cone with a sharper angle attached at the apex of the crew capsule; and a short thin cylinder at the very forward end containing a powerful deorbit engine. The length of the Return Apparatus was 3.64 metres and the base diameter was 2.79 metres.

On the Almaz station, the truncated spherical base of the Return Apparatus was fixed at the forward end of the station on the opposite end from the docking unit. The 4.9 ton module had three seats in its internal volume as well as control panels for operations during mission end. The longer cone section of the Return Apparatus was equipped with a set of attitude control thrusters for use prior to reentry, as well as the primary and backup parachutes. At launch the entire Almaz-Return Apparatus complex was topped off by a long thin escape tower equipped with two sets of solid propellant rocket engines for emergency situations during passage through the lower atmosphere. Once in orbit, the crew would vacate their seats and remove the center seat to open a hatch at the base of the Return Apparatus and crawl into the small-diameter area in the Almaz station. There were many engineers who believed that having a hatch in the middle of a heatshield, i.e. the most stressed part of a spacecraft, was akin to suicide, but Chelomey remained confident that this was a workable design. For return to Earth, the cosmonauts would secure themselves in the Return Apparatus, close the heatshield hatch, and undock from the station. After they fired the deorbit engine, the conical capsule would separate from the cylinder and brake into the Earth's atmosphere. The landing system comprised a set of three parachutes and solid-propellant landing engines to cushion impact. Independent flight was limited to about 30 hours. The Return Apparatus was capable of returning at least 360 kilograms of equipment, film, and other materials back to

Earth, and was designed to have a lifetime of five flights. Initially, crew size would be limited to three cosmonauts, while in the future, there were plans to expand the diameter of the Return Apparatus and increase crew size to five persons. The Return Apparatus' independent functioning time in orbit was as much as 31 hours. During independent flight, the spacecraft's control system would use a single *Argon-12* digital computer [18]. (For specifications of the Almaz station, see Table 3).

TABLE 3: *Almaz Parameters.*

Launch Mass	18.96 to 19.9 tons
Orbital Mass	17,800 tons
Internal Volume	47 m^3
Payload	5.0 tons
Solar Panel Area	52 m^2
Length	14.55 m
Main Body Diameter	4.15 m
Propellant Load	1.80 tons
Electrical Power	3.12 kW

Source: Nina Chugunova, "Chelomey's Cosmonauts: Why There Are No Crews From NPO Mashinostroyeniya In Outer Space" (in Russian), *Ogonek*, nos. 4-5, pp.24-29, January 16-30, 1993.

At some point in the late 1960s, Chelomey decided to delete the large Return Apparatus from the Almaz station. While there were advantages to having a unified crew vehicle incorporated into the station itself, the original reason for including a self-contained Return Apparatus was to avoid conducting complicated docking maneuvers with a independently sent crew return vehicle. In the mid-1960s, the Soviets had still to master complex operations such as rendezvous and docking in Earth orbit, but by 1969, the Soyuz spacecraft had performed several such procedures, instilling confidence in plans for regular docking operations with Almaz.

3. The Transport-Supply Ship

Although Chelomey opted to delete the Return Apparatus from the Almaz station proper, he incorporated the capsule as a part of the Transport-Supply Ship (TKS), the large ferry vehicle that was conceived as an integral part of the whole Almaz space station complex.

Like many of his other projects (such as ballistic missiles), Chelomey entrusted the work on developing the TKS to his Fili Branch headed by First Deputy General Designer Viktor N. Bugayskiy. There, under the latter's overall supervision, engineers completed the initial technical project for the TKS (or product 11F72) in 1969 [19]. On 16 June 1970, the Central Committee and the Council of Ministers issued a decree (no. 437-160) officially approving TKS development. As enumerated in the decree, the TKS would facilitate the following goals as part of the overall Almaz space station complex:

- The docking of 20 ton spaceships to each other (the TKS and the Almaz);
- The delivery and return of crews from the Almaz station;
- The delivery of supplies and equipment for carrying out functional work on the Almaz station;
- The delivery of life-support supplies for the crew;
- The raising of orbits of the station;
- The orientation and extended (up to 90 days) control of flight of the entire complex; and
- The possibility of autonomous descent from orbit [20].

In its design, the TKS served as a direct intermediary between early Chelomey designs such as the lunar LK-1 and LK-700 spacecraft from the 1960s and the Mir modules and Zarya module of the International Space Station in the 2000s. The spacecraft was composed of two major components:

- The 11F74 Return Apparatus (VA); and
- The 11F77 Functional Cargo Block (FGB).

The reusable Return Apparatus was almost identical to the one used on the original Almaz station for returning crews to the Earth.

The Functional Cargo Block (FGB) was a large and roughly cylindrical structure connected to the base of the Return Apparatus (VA), i.e. the crew would use the hatch in the middle of the base of the Return Apparatus to move between the FGB and the VA. At the base of the FGB, the cylindrical shape expanded into a skirt with a maximum base diameter of 4.15 metres. The spacecraft was completed by a terminal cone fixed at the flat base of the cylindrical skirt with the apex facing aft. The main body diameter of the FGB was 2.9 metres wide, the same as that for the smaller section in the Almaz space station. The docking assembly of the TKS was located at the aft end of the spacecraft past the larger diameter area. After rendezvous with the Almaz station, the crew would, in spacesuits, be right next to the docking assembly and observe operations through a viewport. The docking assembly, although it used the *Igla-1R* ("Needle-1R") system for rendezvous and docking, was significantly different from that used on the 7K-T Soyuz; time from the moment of soft docking to hard docking would be 3-4 minutes as compared to the 18-20 minutes on the Soyuz-DOS combination.

Mounted on the outside of the FGB were the primary propulsion system assemblies, attitude control engines and sensors, and two large solar panels fixed like wings to either side. The two main TKS engines, designated KRD-442 (or 11D442), were placed on the forward end of the FGB module 180° apart and slightly canted away from the spacecraft with shields to prevent impingement of exhaust on the vehicle. The engines had 447 kilograms thrust each and were produced by the Design Bureau of Chemical Machine Building, the former Isayev OKB-2 design bureau, headed by Vladislav N. Bogomolov after 1971. Propellants were nitrogen tetroxide and unsymmetrical dimethyl hydrazine. The engines had a capacity to fire 100 times and had a working lifetime of 2,600 seconds. The FGB carried 3,822 kilograms of propellant for orbital corrections. The main engine unit on board the TKS had sufficient propellant for completing all dynamic operations related to autonomous flight, docking, and correcting the orbit of the Almaz complex as a whole.

The FGB's attitude control engines were placed in four clusters, two each 180° apart on each end of the module. Each cluster had five 40 kilogram thrust engines with three pointing on the Y (left-right) axis and the other two pointed opposing each other on the Z (up-down) axis. These engines were also produced by the old Isayev design bureau. Other instruments on the exterior of the FGB included eight cylindrical main propellant tanks covered by at least two rectangular thermal radiators. As in the Almaz station, the docking assembly of the TKS was situated in the aft section of the FGB at the apex of the terminal cone. The two DOS-type solar arrays totaling about 40 m^2 area produced three kilowatts of electricity; an additional smaller solar array covered the propellant tanks.

On the launch pad, the TKS was positioned with the crew on their backs. A very powerful Emergency Rescue System (SAS) crowned the spacecraft. The 3.5 meter long system comprised a long cylindrical tower with two sets of four solid-rocket jets for different phases of the recovery operation during launch. Unlike the Soyuz spacecraft, during launch escape, the SAS would only detach the Return Apparatus from the TKS. The system would subject the crew to loads of up 15 g's and lift the capsule to an altitude of about 1 to 1.5 kilometres from the pad.

Following a nominal and orbital insertion, the crew would open the hatch at the base of the VA, crawl through a short cylindrical tunnel into the main body of the FGB where most of the cargo would be stowed. Cargo would include the small 11F76 recoverable capsules for film recovery. The interior of the original FGB has not been described in detail, but there was clearly a significant amount of storage space, with two cosmonaut seats mounted on a girder frame between two master tracks. These tracks ran the entire length of the FGB, and were designed facilitate easier movement of cargo to and from the TKS to the Almaz. Once the crew had completed basic orbital checkout, they would move to the aft end of the FGB and begin rendezvous and docking operations with the Almaz using a control panel at the FGB aft station. Portholes surrounding the docking probe would assist in visually locating the target, thus bypassing the use of the complex system of periscopes and TV cameras on the Soyuz, where direct two-way contact with the target was not possible at all times. After docking, the crew would equalize pressure between the vehicles, open the hatch, and float into the station proper.

Overall, the TKS had a mass of 21.6 tons at launch and 17.5 tons in orbit, and afforded as much internal space as the Almaz space station – in the case of TKS, 49.88 m^3. The length of the TKS, i.e. the FGB plus VA was on the order of 13 metres. It was both a qualitative and quantitative leap in abilities over the modest Soyuz ferry spacecraft [21]. (See Table 4 for a summary of TKS parameters).

The prime contractor and systems integrator for the whole Almaz complex was the Chelomey design bureau, known since 1966 as the Central Design Bureau of Machine Building (TsKBM). The TsKBM also had the responsibility for designing the Almaz station (i.e. the OPS), the 11F76 film return capsule, and the large Return Apparatus of the TKS. Chelomey subcontracted the design of the FGB portion of the TKS to his Fili Branch in Moscow. (See Table 5 and 6 for a list of contractors and subcontractors for the Almaz program).

4. A Change of Plans

In late 1969, in the aftermath of the loss of the Moon race, the Soviet government was in a state of near-panic to find a way to repair the public face of the Soviet space program. Leading officials, including Dmitriy F. Ustinov, the Secretary of the Central Committee for Defense and Space, in consultation with some leading engineers from the Central Design Bureau of Experimental Machine Building (TsKBEM), the old Korolev design bureau now headed by Vasiliy P. Mishin, decided to put together a plan to quickly design, build, and launch the world's first space station into orbit. The most likely option would have been to accelerate Chelomey's Almaz program. By

TABLE 4: *TKS Parameters.*

	TKS	VA	FGB
Launch Mass	21,620 tons	7,200 tons	14,420 tons
Orbital Mass	17,510 tons	4,250 tons	13,260 tons
Reentry Mass	-	4,250 tons	-
Landing Mass	-	3,800 tons	-
Internal Volume	45 m^3	8.37 m^3	36.03 m^3
Total Useful Payload	12,600 tons	2,235 tons	10,365 tons
Length	11.83 m	3.64 m	8.19 m
Autonomous Flight Time	7 days	31 hours	same as TKS
Propellant Mass	3,822 tons	-	-
Electrical Power	2.4 kW	-	-
Solar Panel Area	40 m^2	-	-
Solar Panel Wingspan	13.7 m	-	-

Sources: Nina Chugunova, "Chelomey's Cosmonauts: Why There Are No Crews From NPO Mashinostroyeniya In Outer Space" (in Russian), *Ogonek*, nos. 4-5, pp.24-29, January 16-30, 1993; Vladimir Polyachenko, "The 'Pep' of Almaz" (in Russian), *Kryl'ya rodiny*, no. 2, pp.30-32, 1992.

TABLE 5: *Prime Contractors for the Major Almaz Components.*

Vehicle	Description	Contractor	Chief Designer
Almaz	entire complex	OKB-52	V. N. Chelomey
Almaz OPS	space station	OKB-52	V. N. Chelomey
Return Apparatus	crew return vehicle	OKB-52	V. N. Chelomey
KSI	film return capsule	OKB-52	V. N. Chelomey
TKS FGB	TKS service module	OKB-52 Branch No. 1	V. N. Bugayskiy
Proton-K	launch vehicle	OKB-52 Branch No. 1	V. N. Bugayskiy

late 1969, work on the actual hull of the Almaz station and certain service systems was on schedule although there were major delays in some of the internal instrumentation. The schedule had been repeatedly disrupted due to problems with clients in the Ministry of Defense. Because of the need for very high requirements for the actual military hardware on board the station (in terms of reliability, lifetime, etc.), Chelomey's engineers were unable to meet the prescribed deadlines. There were also conflicts with the military in sharing instrumentation on the station which also delayed the delivery of onboard systems. Despite the problems, as of 1970, Chelomey's engineers had built the hulls of eight test-stand units and two flight-worthy vehicles. At the same time, ground testing of the control system, solar panels, and some of the station's other components was underway [22].

The delays in the Almaz program proved to be critical when it came time to "select" a space station program to "save" the Soviet space program. Despite Chelomey's best efforts, he did not expect a first launch prior to early 1972 or late 1971 at best [23]. In this situation, TsKBEM engineers proposed a most unlikely solution: they suggested transferring several models of Chelomey's Almaz station to the TsKBEM where Mishin's engineers could refit the station with tried and tested systems transferred from the Soyuz spacecraft. After a set of torturous negotiations, the Soviet Central Committee and Council of Ministers officially approved the plan in a decree (no. 105-41) issued on 9 February 1970 [24]. In March 1970, designers from the Mishin design bureau for the first time met with Chelomey at the latter's offices in Reutov to discuss the handover of several Almaz hulls to Mishin. The meeting was long and did not go very well; the proud Chelomey evidently gave Mishin's men an earful. It was only after personal intervention by Minister of General Machine Building Afanas'yev that the matter was resolved. Chelomey capitulated and handed over four already-built hulls of the Almaz station to the TsKBEM [25]. Ultimately, the hulls of eight station hulls, associated equipment and documentation were transferred to the DOS program. So began the Long-Duration Orbital Station (DOS) program, later known to the world as *Salyut* ("Salute").

5. Early Crewing

The first cosmonaut training group for the Almaz station was established as early as 2 September 1966 – although crew training proved to be of a very preliminary nature through 1967. Seven cosmonauts were included in the training group: Pavel I. Belyayev, Lev S. Demin, Vasiliy G. Lazarev, Aleksandr N. Matinchenko, Georgiy S. Shonin, Lev V. Vorob'yev, and Dmitriy A. Zaikin [26]. Veteran Belyayev was appointed the commander of the team on 7 September 1966 and served in that position until 18 January 1967 when he was transferred to work on the L1 circumlunar project.

The composition of the Almaz training group changed through the late 1960s with the intake of new rookie military cosmonauts who were enlisted in the group after finishing their general cosmonaut training program. In early 1969, after a reorganization of the Cosmonaut Training Center (TsPK), the Second Department of the First Directorate was established with two training groups, one for the military 7K-VI Soyuz spaceship and the second for Almaz. Veteran cosmonaut Pavel R. Popovich was appointed chief of the Second Department on 21 March 1969, later replaced by Shonin on 10 February 1970. By August 1970, once the 7K-VI project was terminated, all cosmonauts training for that

TABLE 6: *Contractors for Subsystems of the Almaz Complex.*

Name of System	Description	Contractor	Chief Designer
	control system	OKB-52	V. N. Chelomey
	stabilization system	NII-627	A. G. Iosif'yan
	gyroscope system	NII-944	V. I. Kuznetsov
	computer system	VNII Digital Computer Technology	
	Almaz main propulsion	OKB-154	A. D. Konopatov
	Almaz attitude control	TMKB Soyuz	V. G. Stepanov
	TKS main propulsion	OKB-2	A. M. Isayev
	TKS attitude control	OKB-2	A. M. Isayev
	Almaz and TKS life-support systems	OKB-124	G. I. Voronin
Agat-1	imaging system	TsKB of Krasnogorsk Mechanical Plant	Yu. B. Ryabushkin
ASA-34R	cameras	TsKB of Krasnogorsk Mechanical Plant	A. K. Men'kov
Volga	infrared instrument	State Institute of Applied Optics	D. Sh. Galiakberov
OD-5	optical visor	Leningrad Optical-Mechanical Assocation	B. Ye. Taranov
Sokol-1	external periscope	TsKB Foton of Kazan' Optical-Mechanical Plant	
Yantar'-P	infrared instrument	TsKB Arsenal	S. P. Parnyakov
Rakkord	film development system	GosNII Khimfotoproyekt	

program were transferred to the Almaz program [27]. (See Table 7 for a chronology of cosmonaut training for Almaz).

In 1970, the first "conditional" crews were formed to test out the Return Apparatus of the Almaz complex on the ground. These crews were:

- A. P. Fedorov/L. S. Demin/V. Ye. Preobrazhenskiy
- O. A. Yakovlev/V. M. Zholobov/E. N. Stepanov
- V. D. Zudov/Yu. N. Glazkov/M. I. Lisun.

Through 1970, these three crews conducted tests of the Return Apparatus in periods of brief weightlessness in parabolic flights on board specially equipped Tu-104LL aircraft from the Chkalov airfield. A special mockup of the pilot's cabin of the Return Apparatus was installed in the aircraft with a central seat for the commander and an instrument control panel. The three crews rehearsed various stages of mission, both in standard and "emergency" modes. The cosmonauts also tested out the critical transfer of crews from the Return Apparatus via the hatch in the heat shield out to the cabin of the aircraft – at this point, there were no mockups of the FGB available for training. The crews did not have spacesuits, and thus trained in regular in-flight suits. Usually, the teams carried out two flights per day, with five parabolas per flight [28].

6. Ground Testing

Since the February 1970 decision to move ahead with DOS in place of Almaz, Chelomey continued to doggedly and quietly pursue work on his coveted Almaz space station, methodically coordinating his efforts with his primary clients, the Ministry of Defense. Although the focus of activities at the massive M. V. Khrunichev Machine Building Plant (ZIKh) in 1970-72 was on the DOS effort, representatives from Chelomey's Design Bureau, the TsKBM, continued work on their own space station hulls. Engineers tested an updated version of the Almaz control system on a complex test rig. Tests of the Almaz power system included firings of the fly-wheel micro-liquid-propellant rocket engines at a test stand near Moscow. Various hulls were remanufactured for Almaz, including those for stress, vibration, heat testing. A special orbital block simulator was also built at the Air Force's State Scientific-Research Institute of Aviation and Space Medicine (GosNII AiKM) where testers spent 36 days in a "flight regime" which ended on 11 January 1972. After their "mission," they reported back that "the configuration of the work and living compartments is comfortable," that "the air is good and odorless" and that they had "soon become used to the hum and vibrations caused by the instruments" [29]. Crews whose missions had been sidelined because of DOS, resumed their training in station components in hydrolabs and on board Tu-104 aircraft.

7. The Soyuz Ferry

The TKS was considered the primary crew delivery vehicle for the Almaz station, but it was clear by the late 1960s that Almaz would need an interim ferry vehicle before the advent of the TKS. In the June 1970 government decree approving work on the TKS, a two-stage plan was approved for crew delivery to Almaz. In the first stage, crews would fly to the station using the Soyuz spacecraft. In the sec-

TABLE 7: *Major Milestones in Cosmonaut Training for the Almaz Program.*

Date	Description
1966	
2 Sep 1966	first Almaz cosmonaut training group formed
7 Sep 1966	Belyayev appointed commander of Almaz training group
1969	
1969	Special Contingent Group of trainee cosmonauts formed at TsKBM
21 Mar 1969	Popovich appointed commander of Almaz training group
1970	
10 Feb 1970	Shonin appointed commander of Almaz training group
1971	
Nov 1971	five conditional crews formed for Almaz
1972	
22 Mar 1972	TsKBM engineer Makrushin joins Almaz training group
11 Sep 1972	four flight-crews formed for Almaz
1973	
27 Mar 1973	TsKBM engineer Yuyukov joins Almaz training group
Jun 1973	Khrunov appointed commander of Almaz training group
1974	
11 Dec 1974	Artyukhin appointed commander of Almaz training group
1976	
30 Mar 1976	Gorbatko appointed commander of Almaz training group
1978	
1 Dec 1978	TsKBM engineers Gevorkyan, Grechanik, Khatulev, and Romanov join Almaz training group
1979	
7 Jun 1979	Makrushin appointed commander of Almaz TsKBM training group
Aug 1979	new TKS crews formed
1981	
1981	TKS cosmonaut training ceased
1982	
early 1982	Pion-K training begins
1985	
1985	Pion-K training ceases
1987	
8 Apr 1987	TsKBM Almaz/TKS training group officially dissolved

Source: S. Shamsutdinov, "Cosmonauts of 'Almaz' ", (in Russian), *Novosti kosmonavtiki,* no. 12, pp.78-81, 2000.

ond stage, crews would arrive using Chelomey's own much larger TKS [30]. Eventually, the Soyuz spacecraft served as an integral component of all Almaz missions. All crews to Almaz were delivered in a version of the Soyuz known as the 7K-T, which was nearly identical to the version used for the "civilian" DOS/Salyut missions. The original Soyuz vehicle, the 7K-OK, had been designed in such a way as to prevent internal passage from one vehicle to another. By late 1969, the TsKBEM had begun redesigning the 7K-OK Soyuz into the "new" 7K-T Soyuz specifically for the DOS program. In early 1970, the Department No. 231 at the design bureau issued the "draft plan" for the ferry vehicle under the overall leadership of Deputy Chief Designers Konstantin D. Bushuyev and Pavel V. Tsybin. The 7K-T ship had an active docking unit with a rod compatible with a cone on the passive docking node on the DOS ship. Manufacture of the new docking mechanism with its 0.8 meter diameter hatch was carried out at the Azov Machine Building Plant.

Unlike the basic Soyuz, the 7K-T had a simplified life-support system since it did not need to ensure autonomous flight for very long. The systems related to the *Igla* rendezvous system were transferred to the Living Compartment (or "orbital module") at the forward end of the ship, and one of the command radio-links was removed completely, allowing the elimination of the torroidal compartment around the engine unit at the rear of the original Soyuz. The 7K-T transport ship had a launch mass of 6,700 kilograms, i.e. about 50 kilograms in excess of its predecessors; its Descent Apparatus (or "reentry module") weighed 2,800 kilograms. As a whole, the ship was 6.98 metres in length. The vehicle would be capable of carrying three cosmonauts without pressure suits and return only 20 kilograms of scientific results back from the station, suggesting that the Soviets were pushing the upper limits of what they could squeeze out of the Soyuz booster-spacecraft system at the time. The new Soyuz was rated for 60 days of flight time of which three days could be autonomous [31].

In 1971, crews used the 7K-T Soyuz twice. On the first time, during the Soyuz-10 mission, the cosmonauts were unable to board the first Salyut space station. On the second time, during the Soyuz-11 flight, the cosmonauts completed a record breaking space mission only to lose their lives during reentry when a failed seal let air out of their Descent Apparatus. After a through investigation of the accident, TsKBEM (i.e. the old Korolev design bureau) completed a serious redesign of many of the 7K-T Soyuz's systems in preparation for future ferry flights to space stations [32]. In addition to redesigning the module separation systems and the life-support systems, designers introduced the use of pressurized space suits (the *Sokol-K1*) during all critical mission events (launch, reentry, docking, and undocking) on future Soyuz missions. Because of the bulk of each spacesuit, crew size had to be consequently reduced from three to two. The TsKBEM flew a qualification flight for the "new" Soyuz as Kosmos-496 in June 1972.

In 1971, Chelomy signed an agreement with TsKBEM Chief Designer Vasiliy P. Mishin to use variants of the 7K-T Soyuz spacecraft to deliver and recover crews from the Almaz space station. Work on this version of the Soyuz began the same year and by early 1972, TsKBEM Department No. 037 had completed redesign of the 7K-T to support piloted missions to Almaz [33]. The "new" vehicle had the production index 11F615A9, to distinguish it from the DOS version known as 11F615A8. The differences between the two had to do mostly with docking gear rather than any fundamental differences in design.

Engineers incorporated additional changes to the 7K-T Soyuz ferry in 1972-73. Anticipating that a ferry vehicle would not need to fly independently for more than two days, TsKBEM designers deleted the two heavy solar panels from the spacecraft, making the ship rely completely on its modest internal chemical batteries. These batteries could be recharged once docked to a space station using power generated from either the DOS or Almaz. The mass of this second iteration of the 7K-T Soyuz ferry was about 6,800 kilograms, up from the original 6,700 kilograms.

8. New Crews

With the switch to the Soyuz as a delivery vehicle for crews to Almaz, the Cosmonaut Training Center enlisted four cosmonauts with experience in Soyuz operations into the Almaz group in 1971. They were Yuriy P. Artyukhin, Viktor V. Gorbatko, Yevgeniy V. Khrunov, and Boris V. Volynov. All but Artyukhin were space veterans, having flown Soyuz missions in 1969. By late 1971, the Almaz group had a total of 28 cosmonauts in it, probably the biggest it was ever to get in its history.

In November 1971, the Cosmonaut Training Center formed five new "conditional" crews to study the Soyuz spacecraft, specifically to train for the critical docking procedures between Almaz and Soyuz. These crews were:

- P. R. Popovich/L. S. Demin
- B. V. Volynov/Ye. N. Khludeyev
- V. V. Gorbatkov/V. M. Zholobov
- A. P. Fedorov/Yu. P. Artyukhin
- G. V. Sarafanov/E. N. Stepanov.

In April 1972, Artyukhin moved to Popovich's crew, while Demin began training with Fedorov. Fedorov was soon dropped from training due to poor health, and he was replaced by Sarafanov. Zholobov also moved to Volynov's crew, replacing Khludeyev. The crews were reduced in number to three. Thus, by May 1972, the crews were:

- P. R. Popovich/Yu. P. Artyukhin
- B. V. Volynov/V. M. Zholobov
- G. V. Sarafanov/L. S. Demin.

In September 1972, the TsKBM began ground-testing of the first model of the Almaz station equipped with thermal and life-support systems. Two "conditional" crews performed this testing on station no. 04-11F71 at the premises of the GosNII AiKM from September 1972 to February 1973. They were:

- Yu. N. Glazkov/Ye. N. Khludeyev
- M. I. Lisun/V. Ye. Preobrazhenskiy.

They had one "backup" cosmonaut, N. N. Fefelov.

Finally, on 11 September 1972, the Cosmonaut Training Center named four crews for direct training for flights on board the Almaz space station complex. These crews were formed on the basis of experience with the "conditional" crews, and were:

- crew 1: P. R. Popovich/Yu. P. Artyukhin
- crew 2: B. V. Volynov/V. M. Zholobov
- crew 3: G. V. Sarafanov/L. S. Demin
- crew 4: V. D. Zudov/V. I. Rozhdestvenskiy.

All four of these crews, formed at the time, would go on to make space missions by 1976. In December 1972, the crews began working on a special trainer of the orbital station at the Cosmonaut Training Center named *Irtysh*, construction of which had began as early as April 1968 [34].

9. The First Almaz Station

9.1 Preparations

For Chief Designer Mishin, Korolev's successor, the DOS program had always represented an unnecessary diversion from what he considered the main thematic directions of work at the design bureau: large-scale space stations such as the Multi-role Orbital Complex (MOK), and the N1-L3 lunar landing project. DOS had essentially been hoisted upon him at a most inconvenient juncture. That the TsKBEM had managed to fulfill the original order within the given period of one year was partly because Mishin had been forced to redirect much of the resources at the design bureau to the DOS program. Despite his reluctant management of the project, the Chief Designer was eager to shift the focus back to his two pet projects, the MOK and the L3M, an advanced lunar landing project. Both had received encouraging shows of support with official decisions in February and May 1972 respectively. It was now time to make sure that DOS did not hinder their implementation.

At the same time, Chelomey had every reason to resent the DOS space station program, an effort which had been essentially appropriated from his own coveted Almaz project. Having seen the latter sidelined by DOS, Chelomey was in the unlikely position of being of the same mind as Mishin on this matter, i.e. that the small space station program, specifically DOS and Almaz, needed to go back to Chelomey. With this in mind, Mishin and Chelomey cosigned a letter on 3 February 1972 to Minister of General Machine Building Sergey A. Afanas'yev, the "head" of the space and missile industry, asking that work on the DOS/Salyut program be limited to the development four stations. They recommended that all "scientific" research and work in support of the "national economy" from the DOS/Salyut stations be transferred to future Almaz stations, which would fly after the first four DOS vehicles [35]. Apparently due to a lack of response, Mishin and Chelomey repeated their appeal to the Minister in a second letter dated 14 April 1972. This time, they added that initially, the Almaz space station would be serviced by the 7K-T Soyuz, replaced later by the advanced 7K-S Soyuz [36]. Despite significant opposition from within Mishin's design bureau against this unlikely alliance between Mishin and Chelomey, Minister Afanas'yev, under "pressured circumstances" agreed to ratify the proposal, giving it his signature on 21 April 1972. The Mishin-Chelomey agreement in April 1972 meant that Almaz was less of a competitor than a complement to DOS now. After the first four DOS stations, Almaz would remain as the only Soviet space station, until the advent of the much larger Multi-role Orbital Complex. In the interim, new flight models of both stations would, by coincidence or not, be ready to fly by late 1972. In April 1972, Chelomey's most optimistic projection for a launch date for Almaz was early December 1972 [37].

On 15 June 1972, a decree of the Ministry of General Machine Building specified a specific schedule for immediate operations in the Almaz program. The Khrunichev Plant was to complete assembly of the first flight model of the Almaz station and began preliminary testing by 30 June, leading to delivery to the testing station at the Baykonur Cosmodrome by November of the same year [38]. If all went well, launch would take place in late 1972 or early 1973, i.e. at about the same time as Mishin's DOS-3. The concurrent and timely preparations were colored to a great deal by activity in the United States. NASA was at the time wrapping up final preparations for the launch of its first space station, Skylab, which was scheduled for launch in April 1973. If all went well, it would host three crews during the year, with missions lasting 28, 56, and 56 days respectively. Having taken the lead with space stations with Salyut, Soviet space officials, especially Ustinov, were particularly sensitive to the possibility that Skylab would completely overshadow the achievements in the Salyut program. It was absolutely imperative that the Soviet Union have a space station in orbit before Skylab. It appears that Ustinov wanted to fly *both* DOS and Almaz in 1973 – although not simultaneously [39].

In September and October of 1972, however, significant delays crept into the Almaz schedule. As evidenced by a plethora of letters from Chelomey to various subcontractors, a number of design organizations had failed to deliver their sub-components to TsKBM on time. These included ground trainers, power sources, timing devices (*Kashtan*), the on board computer (*Argon-12*), sextants, photo-equipment (*Agat-1*), astro-measurement devices, the vacuum cleaner, etc. The delays were such that on 16 October, Chelomey appealed directly to the Defense Department of the Central Committee, enumerating in detail the various organizations, their instruments, and their violations of delivery schedules [40]. Schedule was particularly important at the time because of the urgency of launching a space station into orbit prior to Skylab. This sense of urgency is underlined by a memo issued on 23 November 1972 by Georgiy A. Tyulin, first deputy "space" Minister, to Chelomey:

> 30 April 1973 has been named as the launch [date] for the Skylab orbital station, [therefore] take all measures to launch the Orbital piloted station [i.e. Almaz] no later than March 1973 [41].

Delays in the delivery of subsystems meant that the first flight-model of the Almaz station, vehicle no. 0101, was not even ready to be delivered until late December 1972. The station was declared ready for transport from Moscow to Tyura-Tam only on 25 December and eventually arrived on site six days later [42]. As ground preparations began to accelerate, on 27 December 1972 the Soviet Central Committee and Council of Ministers named a "State Commission," an *ad hoc* body of officials from the industry, military, and design bureaus to oversee the first flight. Unlike almost all other Soviet State Commissions for the Soviet piloted program, this one was headed not by a civilian, but by a top-ranking military official, Col.-Gen. Mikhail G. Grigor'yev, at the time the First Deputy Commander-in-Chief of the Strategic Missile Forces. Grigor'yev had served as the first Commander of the Plesetsk launch site between January 1957 and 1962. He had been appointed to his current post in November 1968 [43]. Chelomey served as the "technical director" of the State Commission. To confuse matters, a second State Commission participated in the Almaz program, one whose only job as to oversee the parts where the Soyuz delivery vehicle was in independent flight. Once the Soyuz crew had docked with the Almaz station, this State Commission would hand over to Grigor'yev's team [44].

Delays in the delivery of subsystems were not the only problems threatening to disrupt Tyulin's schedule. A second major problem was the availability of a reliable Soyuz crew delivery vehicle. At State Commission meetings on 29 January, 4 February, and 2 March 1973, the primary issue of contention was the lack of a flight-ready Soyuz. On 3 February, there had been a major failure in the parachute system during a ground-test of the Soyuz. As a result, First Deputy Minister Tyulin, without consulting with the Almaz State Commission, planned three additional drop tests of the Soyuz on 15 March, 5 April, and 25 April. Both Grigor'yev and Chelomey were clearly upset by this course of events, since they knew that the flight-model of Almaz could not be fueled for launch until the results of these tests were in, i.e. an Almaz launch before May was out of question. Frustrated by the actions of Tyulin and Mishin, in early March, Grigor'yev and Chelomey sent off a letter to the Central Committee (i.e. probably directly to "space program" curator Ivan D. Serbin) complaining about the general pace of work on Soyuz. They asked that Mishin and parachute designer Nikolay A. Lobanov put as much effort as possible into ensuring that a safe Soyuz ship be ready so that the first Almaz could be launched in March [45]. Problems with the Soyuz, however, continued well into the early April. Eventually, Grigor'yev and Chelomey opted to move ahead with the Almaz launch despite the uncertainty over the ferry craft. The fact that Mishin's DOS was also undergoing ground testing at the launch site simultaneously was the source of some difficulty due to stretched resources. Both stations used the same pressure chamber and fueling stations. In fact, there was a great degree of cross-pollination between the two programs, partly because TsKBEM engineers had to be involved in the Almaz effort since they were responsible for the Soyuz spacecraft [46].

9.2 The Launch of OPS-1/Salyut-2

Four two-man crews were on standby for two consecutive missions to the Almaz station, the first comprising cosmonauts Popovich and Artyukhin lasting 15 days, and the second made up of Sarafanov and Demin. Launch day for the Almaz station was 3 April 1973, a little over a month prior to the Skylab launch. There were several scares prior to launch. At some point, after the booster stack had been installed on the pad, ground controllers discovered an unexpected "inductive capacitance" between the two guidance systems of the booster and the payload. After a busy night of investigation, pad engineers were able to explain the phenomenon as a natural process [47]. During the actual countdown, at T-15 minutes prior to launch, there was a sudden alarm: propellant was apparently leaking from the Proton rocket's filling system. The danger of a terrible explosion was on everyone's mind. Chelomey, in a moment of fearlessness, announced that he wanted to go directly to the pad. After an inspection of the situation, he returned to the blockhouse and recommended that the launch proceed. State Commission Chairman Grigor'yev concurred, and at exactly 1200 hours Moscow Time on 3 April 1973, the first Almaz station lifted off into the sky, eventually entering an initial orbit of 214.8 x 259.1 kilometres at 51.6° inclination. A full thirteen years after proposing his first space project, Chelomey had finally launched a piloted spacecraft into orbit around the Earth. It was also the first piloted military spacecraft in orbit. (See Table 8 for a list of all major launches and events in the Almaz program). (See Table 9 for a list of all launches of the Almaz space station itself).

Chelomey might have been forgiven for believing that his beloved space station would be named Almaz by the Soviet press. But highly-placed space officials, possibly including Ustinov, were adamantly opposed to this. Some have claimed this was because they "were dead against the presence of a second figure in the Soviet space program" [48]. Others believe it was to hide the fact that Almaz was a purely military space station [49]. Chelomey, apparently feeling humiliated, was explicitly ordered to have the name Salyut-2 painted on the station. The shrewd General Designer told his engineers to paint the offending name on the outside fairing of the station; once the fairing jettisoned in the upper reaches of the atmosphere, they revealed the station with Almaz clearly written on it. The Soviet press, of course, referred to it as Salyut-2. There were immediate indications from Moscow that crews would soon be on board the station. Veteran cosmonaut Col. Yevgeniy V. Khrunov announced the day after launch that cosmonauts were preparing for new missions, while on 6 April, a reporter from the London *Evening News* noted that a Soyuz spacecraft was ready for launch [50]. In fact, launch of the first crew, on Soyuz-12, had been planned for 13 April, but had to be delayed to 8 May due to continuing problems with the Soyuz parachute system. Chelomey evidently decided to proceed with the launch of the station because the payload and booster had already been fueled by the time of the decision to delay the launch of crew. The State Commission instead drew up a plan to perform a longer-lasting automated flight for Almaz prior to a crew's arrival [51]. At best, it would be over a month into the flight before a crew would be on board the station.

Throughout the first few days in orbit, the Chief Operations and Control Group at Yevpatoriya led by Yakov Ya. Sirobaba tested the attitude control systems, life-support systems, the radio communication systems, and all appeared to be working without fault. By 11 April at least two major orbital corrections had been made, on 4 and 8 April, resulting in a new orbit of 261 x 296 kilometres. During this time, ground controllers also switched on the *Agat-1* complex with its ASA-34 camera. The last "normal" contact with the station was at 1230 hours Moscow Time on 14 April when the station flew out of radio visibility over ground stations. Trouble struck on the 13th day of flight on 15 April on *Salyut-2*'s 188th orbit. When the station appeared back into radio visibility at 0316 hours Moscow Time on 15 April, two ground stations (Ussuriysk and Yelizovo) detected the absence of primary telemetry information from the major systems of the station; according to "support" telemetry, pressure in the main hull had dropped by half, and precise measurements of the station's orbital trajectory showed that its path had deviated slightly, as if given some kind of thrust. (The new orbit was 259.5 x 294.9 kilometres at 51.6° inclination). Judging by the information, it appeared that some kind of catastrophic failure had occurred on the station squelching the possibility that any crew would be heading in its direction any time soon. Early the next morning, the senior members of the State Commission, including Col.-Gen. Grigor'yev, Chief Directorate of Space Assets Commander Lt.-Gen. Andrey G. Karas', and Chelomey met at the latter's offices to discuss the situation. An accident investigation commission under Karas' was established. Through 15 and 16 April, controllers were unable to establish main telemetry contact, and finally at 0912 hours on 16 April, controllers ceased all attempts to reestablish contact with the station [52].

Over the next few days, engineers pored over ground models of the Almaz to determine the cause of this sudden event by simulating various conditions. Specialists also flew to the Yevpatoriya Flight Control Center in Crimea to look into the matter. The initial prognosis was that there might have been some ground error, but this hypothesis was eliminated when investigators found that each command transmitted to Salyut-2 had been without fault [53]. As the investigation was ongoing, on 18 April, Soviet sources in Moscow were denying that piloted visits had ever been planned for Salyut-2 [54]. Eventually on 28 April, the Soviet news agency TASS announced that Salyut-2, "having checked the design of improved on-board systems and carried out experiments in space, had completed its flight program," notably omitting the word "successfully" which it normally used in such press releases [55]. The station, lost and tumbling in space, decayed from orbit the following day, on 29 April 1973, about 3,000 kilometres east of New Guinea into the equatorial regions of the Pacific Ocean. Popovich, Artyukhin and the remaining cosmonauts training for their long-awaited flight would have to wait longer to begin their missions. Chelomey did not expect to

TABLE 8: *Major Flight-Testing Milestones in the Almaz Program.*

Date	Vehicle	Event
1973		
3 Apr 1973	Salyut-2	launch of first Almaz station, OPS-1
29 Apr 1973	-	Salyut-2 reentry
1974		
1974	-	ground-testing of TKS launch escape system begins
25 Jun 1974	Salyut-3	launch of second Almaz station, OPS-2
3 Jul 1974	Soyuz-14	launch of first crew to Salyut-3
4 Jul 1974	-	Soyuz-14 crew docks with Salyut-3
19 Jul 1974	-	Soyuz-14 crew returns to Earth
26 Aug 1974	Soyuz-15	launch of second crew to Salyut-3
27 Aug 1974	-	Soyuz-15 crew fails to dock with Salyut-3
28 Aug 1974	-	Soyuz-15 crew returns to Earth
23 Sep 1974	-	Salyut-3 film capsule recovered
24 Jan 1974	-	Salyut-3 reenters
1976		
22 Jun 1976	Salyut-5	launch of third Almaz station, OPS-3
6 Jul 1976	Soyuz-21	launch of first crew to Salyut-5
7 Jul 1976	-	Soyuz-21 crew docks with Salyut-5
24 Aug 1976	-	Soyuz-21 crew returns to Earth
14 Oct 1976	Soyuz-23	launch of second crew to Salyut-5
15 Oct 1976	-	Soyuz-23 crew fails to dock with Salyut-5
16 Oct 1976	-	Soyuz-23 crew returns to Earth
15 Dec 1976	Kosmos-881 Kosmos-882	launch of first dual TKS Return Apparatus, LVI-1
1977		
1977	-	ground-testing of TKS launch escape system ends
7 Feb 1977	Soyuz-24	launch of third crew to Salyut-5
8 Feb 1977	-	Soyuz-24 crew docks with Salyut-5
25 Feb 1977	-	Soyuz-24 crew returns to Earth
26 Feb 1977	-	Salyut-5 film capsule recovered
17 Jul 1977	Kosmos-929	launch of first complete TKS
5 Aug 1977	-	launch of second dual TKS Return Apparatus, LVI-2
8 Aug 1977	-	Salyut-5 reenters
17 Aug 1977	-	Kosmos-929 Return Apparatus recovered
1978		
2 Feb 1978	-	Kosmos-929 FGB reenters
30 Mar 1978	Kosmos-997 Kosmos-998	launch of third dual TKS Return Apparatus, LVI-3
1979		
23 May 1979	Kosmos-1100 Kosmos-1101	launch of third dual TKS Return Apparatus, LVI-4
1981		
25 Apr 1981	Kosmos-1267	launch of second complete TKS
24 May 1981	-	Kosmos-1267 Return Apparatus recovered
19 Jun 1981	-	Kosmos-1267 docked with Salyut-6
Jul 1981	-	first launch of Almaz-T postponed
1982		
28 Jul 1982	-	Kosmos-1267/Salyut-6 reenters
1983		
2 Mar 1983	Kosmos-1443	launch of third complete TKS
10 Mar 1983	-	Kosmos-1443 docks with Salyut-7
21 Apr 1983	-	Soyuz T-8 crew fails to dock with Salyut-7/Kosmos-1443
28 Jun 1983	-	Soyuz T-9 crew docks with Salyut-7/Kosmos-1443
30 Jun 1983	-	Soyuz T-9 crew opens hatch into Kosmos-1443
14 Aug 1983	-	Kosmos-1443 undocks from Salyut-7/Soyuz T-9
23 Aug 1983	-	Kosmos-1443 Return Apparatus recovered
18 Sep 1983	-	Kosmos-1443 reenters

TABLE 8: *Major Flight-Testing Milestones in the Almaz Program (Contd).*

Date	Vehicle	Event
1985		
27 Sep 1985	Kosmos-1686	launch of third TKS
2 Oct 1985	-	Kosmos-1686 docks with Salyut-7/Soyuz T-13
21 Nov 1985	-	Soyuz T-13 undocks from Salyut-7/Kosmos-1686
1986		
6 May 1986	-	Soyuz T-15 crew docks with Salyut-7/Kosmos-1686
25 Jun 1986	-	Soyuz T-15 crew undocks from Salyut-7/Kosmos-1686
22 Aug 1986	-	Salyut-7/Kosmos-1686 put into storage orbit
29 Nov 1986	-	launch of first Almaz-T
1987		
25 Jul 1987	Kosmos-1870	launch of second Almaz-T
1989		
29 Jul 1989	-	Kosmos-1870 reenters
1991		
7 Feb 1991	-	Salyut-7/Kosmos-1686 reenters
31 Mar 1991	Almaz-1	launch of third Almaz-T
1992		
17 Oct 1992	-	Almaz-1 reenters

TABLE 9: *Launches of the Almaz Orbital Piloted Station (OPS).*

Mission	Name	Vehicle No.	Launch Date	Launch Time (Moscow Time)	Launch Vehicle	Launch Site	Orbit
OPS-1	Salyut-2	0101	Apr 3 1973	1200:00	8K82K no. 283-01	81L	215 X 260 @ 51.6°
OPS-2	Salyut-3	0102	Jun 25 1973	0138:00	8K82K no. 283-02	81L	219 X 270 @ 51.6°
OPS-3	Salyut-5	0103	Jun 22 1976	2104:00	8K82K no. 290-02	81L	219 X 260 @ 51.6°
OPS-4		0104	not launched				
OPS-5	Zvezda	0105	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.

have the next Almaz station ready for flight before at least the end of the year.

The Karas' commission arrived at the conclusion that there had been a manufacturing flaw in the main engine of the Almaz station, which when fired, had caused punctures in the main hull [56]. In their official report to the Central Committee, issued in early June 1973, Grigor'yev and Chelomey noted the following:

> There was a gas leak in the welded connection of the turbopump of the compressed nitrogen tanks in the DU [engine unit]'s pressure system. The influence of this moment led to a continuous working of the low-thrust stabilization engines and significantly increased its temperature, that caused overheating...of the radio-telemetric system and depressurized the station, and also disrupted the work of the engines for major stabilization leading to subsequent tumbling [of the station] [57].

One cosmonaut who trained for Almaz later confirmed that there had been "an electrical fault in one of the station's devices which had eventually caused the rupture of the external hull" [58]. Western reports, presumably filtered through to the open media from classified sources, suggested that the actual hull breach had been so violent that the station's solar panels and boom-mounted rendezvous radar and radio transponder had been ripped off, leaving Salyut-2 tumbling in space. The engine, these reports suggested, could not be turned off once it was turned on [59].

Some of the station's designers begged to differ with the verdict of a malfunctioning engine, and there was apparently never any unanimity with a possible explanation. For example, one early and plausible view had been that the station might have been hit by debris from the Proton booster during orbital insertion, a view also put forward by independent Western analysts in the mid-1970s [60]. Unwilling to believe that there had been a failure in the station's engine system, a team of engineers in

Chelomey's design bureau initiated their own investigation of the failure. Their conclusions, which were issued at the end of the year, were based on a thorough investigation into the more than 20 pieces of debris that accompanied Salyut-2's initial injection into orbit around the Earth. Their research indicated that an explosion of the Proton-K's third stage in orbit had produced the debris. The engineers identified five specific objects from this cloud of debris that might have impacted with Salyut-2 on 15 April, the day of the massive failure. Their conclusions were supported by an independent investigation mounted by TsNII-50, the Ministry of Defense's main space systems research institute [61].

Perhaps the most curious reason advanced for the failure, a claim no doubt proposed to exonerate its designers of any fault, was that a meteorite had hit the station and blown a hole in its hull. Chelomey himself was said to subscribe to this opinion [62]. April was all-round a bad month for the General Designer. On 25 April, one of his radar ocean reconnaissance satellites, the US-A, failed to reach orbit, depositing its nuclear isotope payload in the Pacific Ocean. U.S. Air Force planes apparently flew high above the Pacific to sample the upper atmosphere for radiation from the accident [63].

10. The Second Almaz Station

The failure prompted the Soviet government to issue new schedules for the Almaz program. The Military-Industrial Commission and its subordinate Ministry of General Machine Building issued decrees on 16 May and 31 May 1973 respectively that called for the delivery of all subsystems of the next Almaz station by July of the same year [64]. Launch was apparently planned for sometime in late 1973. By September 1973, however, there were again delays in the delivery of subsystems, principally the *Agat-1* imaging complex, the electro-mechanical stabilization system for the whole station, and the water regeneration system [65]. Additionally, continuing problems continued to dog the basic Soyuz ferry. These problems were much more serious than the earlier concerns about the parachute system. In a letter to Chelomey dated 22 June 1973, Mishin had expressed serious reservations about using the 7K-T Soyuz as a ferry for Almaz due to the requirement to install a "supplementary voltage stabilizer, the absence of which in an emergency situation could lead to danger to the lives of cosmonauts and reduce the probability of completing the flight program" [66]. Later, in December, Chelomey enumerated several major problems relating to the use of the 7K-T Soyuz in conjunction with the Almaz station including the lack of high cargo capacity of the Soyuz, the impossibility of repeated dockings between the Soyuz and Almaz, the weak docking system between the two that might cause danger to cosmonauts during "dynamic operations," and an insufficient power supply in the Soyuz. He proposed that the Soyuz *not* be used for any further ferry missions to the Soyuz. Instead, Chelomey decided to go back to the original "Tactical-Technical Requirement" issued by the Ministry of Defense back in 1967 when the specifications for Almaz had been developed. In that original conception, Almaz was to fly in two stages, the first with its own Return Apparatus in which the crew would be launched, and the second with the large Transport-Supply Ship. Chelomey argued that all resources at the Khrunichev Plant and his own Fili Branch be redirected from work on Mishin's DOS to work on the first phase of Almaz with its Return Apparatus [67]. On one level, Chelomey's appeal underlines his increasing reluctance to work with Korolev's old design bureau – and to move independently ahead on his own programs. But if Chelomey had any illusions that he would be able to proceed without cooperating with Mishin, it was not to be. It seems likely, though unconfirmed, that sometime in early 1974, the government "forced" Chelomey to rely on Mishin's Soyuz spaceship as a delivery vehicle. Thus, the next Almaz would be launched without its own Return Apparatus [68].

10.1 The Launch of OPS-2/Salyut-3

Prior to the launch of the second Almaz space station, there was a single automated test of the 7K-T Soyuz ferry spacecraft under the designation Kosmos-656. Equipped to dock with the Almaz stations, the spacecraft carried out a short two-day mission beginning 27 May. The successful flight cleared the way for the second launch attempt of the Almaz station on 25 June 1974 at 0138 hours Moscow Time when a Proton-K inserted the station, vehicle no. 0102, into an initial orbit of 219 x 270 kilometres at a 51.6° inclination (as announced) [69]. The spacecraft was named Salyut-3 upon orbital insertion. Controllers put the station through a series of orbital maneuvers in the ensuing days, the last being on 1 July.

10.2 The Soyuz-14 Mission

Two days after Salyut-3's last orbital correction, at 2151 hours 8 seconds Moscow Time on 3 July 1974, cosmonauts Col. Pavel R. Popovich and Lt.-Col.-Engineer Yuriy P. Artyukhin lifted off after almost three years of accumulated delays.

Popovich, the Commander of the mission had earlier flown the Vostok-4 flight in 1962 and had also trained extensively for the L1 and L3 lunar programs until November 1969 when he had been assigned to the Almaz program. Flight Engineer Artyukhin was making his first space flight although he had been in the cosmonaut group since 1963. He had also trained in the abandoned L1 program until January 1970 and then had briefly trained for the *Kontakt* project to rehearse a lunar docking system. Initial orbital parameters for their Soyuz-14 spacecraft were announced as 195.9 x 242.7 kilometres at 51.62°. At 1,000 metres distance from the station, the automatic rendezvous system was used to bring the Soyuz to within 100 metres, after which Popovich docked manually. Artyukhin followed by Popovich entered the station about five hours later at 0430 hours on 5 July, and began activating the station's systems. Initial duties included adjusting the internal temperature, moving ventilators, and defining attachment points on the station's walls for portable units. Popovich was heard calling the station "a beauty" [70]. It was a momentous occasion for Chelomey, for it had been a long 15 years since he had made his first claims for the Soviet space program. It had taken him that long to have a cosmonaut on board one of his spacecraft. (See Table 10 for a list of all piloted missions to Almaz stations).

As evidenced by cosmonaut activities, operations of the Almaz were significantly different from the "civilian" DOS stations. The Soviets claimed, for example that Salyut-3 was the first space station to be constantly oriented toward the Earth – no doubt to keep its cameras continuously pointed at military sites. Special targets were reportedly deployed at the Baykonur Cosmodrome to test the ability of the cosmonauts to see detail on the ground. The Soviets claimed at the time that communications with the station on all channels (voice and telemetry) were continuous with the Flight Control Center at Yevpatoriya although Westerners often monitored the crew making contact with tracking support ships in the Atlantic (often via a *Molniya* satellite) principally the *Kosmonavt Yuriy Gagarin* in the Western Atlantic and the *Kosmonavt Vladimir Komarov* in Cuban waters. In keeping with the sensitive nature of the mission, the cosmonauts used a variety of code words during transmissions. The crew also used frequencies for communications sessions that were very different from "standard" Soyuz missions. Prior to docking, the cosmonauts transmitted on 121.75 MHz but changed to 143.625 MHz once on board the station [71]. All the official announcements during the flight focused on experiments of a primarily civilian nature. Despite the best efforts of the Soviets, they were unable to conceal the military nature of the mission. By the end of the month, the American trade publication *Aviation Week and Space Technology* was reporting that the Soyuz-14 crew had conducted military reconnaissance from orbit [72]. By March 1975, the same journal correctly noted that "the Soviets are pursuing two space station [programs] – military reconnaissance and science" [73].

According to recent information, the experiments and observation program for the crew was very complex and laborious. All their activities were planned to the minute, including such operations as observation, photography, and data transmission. The crew carried out extensive photography with the *Agat-1* telescope. The exposed film was developed on board and data transmitted to the ground. The military clients were, however, less then pleased with the quality of information. One military official later recalled that systems for data transmission and computer processing of the film were not advanced enough at the time to provide information of a very useful level. The military had to wait for the actual exposed film, which would be returned in the small capsule, to see more detailed information on the targets – a wait which effectively reduced the usefulness of the data [74].

One interesting military experiment, revealed in 1993, involved tracking the American Skylab space station. The NII-2 from the Soviet Air Defense Forces, was at the time directing comprehensive studies to identify "enemy" objects in space, using both ground- and space-based sensors. These tests were in support of the Space Control System (SKKP), the Soviet equivalent of the American SPADATS. On a target designation provided by the Space Control Center (TsKKP) based in Moscow, Popovich and Artyukhin, using the *Sokol'* optical monitoring device detected and tracked the Skylab station. The crew had trained for this experiment on the ground at a special simulator at the premises of the NII-2, where the cosmonauts had rehearsed detecting objects in space against the background of a starry sky, using the *Belka* digital computer developed by the Ukrainian Academy of Sciences' Institute of Cybernetics. The Soyuz-14 crew evidently also performed experiments on detecting nuclear energy sources on targeted vehicles [75].

Over the course of two weeks, the two cosmonauts also conducted a variety of scientific experiments that covered a host of disciplines. These have been described in many other Western sources

TABLE 10: *Piloted Missions to the Almaz Space Stations.*

Mission	Spacecraft	Spacecraft Type	Launch Date	Landing Date
SOYUZ-14	11F615A9 no. 62	7K-T	Jul 3 1974 2151:08 MT	Jul 19 1974 1521:36 MT
Prime Crew		**Backup Crew**		**Duration**
P. R. Popovich		G. V. Sarafanov		15d 17h 30m 28s
Yu. P. Artyukhin		L. S. Demin		

Mission	Spacecraft	Spacecraft Type	Launch Date	Landing Date
SOYUZ-15	11F615A9 no. 63	7K-T	Aug 26 1974 2258:05 MT	Aug 28 1974 2310:16 MT
Prime Crew		**Backup Crew**		**Duration**
G. V. Sarafanov		B. V. Volynov		2d 0h 12m 11s
L. S. Demin		V. M. Zholobov		

Mission	Spacecraft	Spacecraft Type	Launch Date	Landing Date
SOYUZ-21	11F615A8 no. 41	7K-T	Jul 6 1976 1508:45 MT	Aug 24 1976 2132:17 MT
Prime Crew		**Backup Crew**		**Duration**
B. V. Volynov		V. D. Zudov		49d 6h 23m 32s
V. M. Zholobov		V. I. Rozhdestvenskiy		

Mission	Spacecraft	Spacecraft Type	Launch Date	Landing Date
SOYUZ-23	11F615A9 no. 65	7K-T	Oct 14 1976 2038:18 MT	Oct 14 1976 2045:13 MT
Prime Crew		**Backup Crew**		**Duration**
V. D. Zudov		V. V. Gorbatko		2d 0h 6m 35s
V. I. Rozhdestvenskiy		Yu. N. Glazkov		

Mission	Spacecraft	Spacecraft Type	Launch Date	Landing Date
SOYUZ-24	11F615A9 no. 66	7K-T	Feb 7 1977 1910 MT	Feb 25 1977 1236 MT
Prime Crew		**Backup Crew**		**Duration**
V. V. Gorbatko		A. N. Berezovoy		17d 17h 25m 58s
Yu. N. Glazkov		M. I. Lisun		

Sources: All orbital data and mission durations are from V. P. Glushko, ed., *Kosmonavtika entsiklopediya,* (Moscow: Sovetskaya entsiklopediya, 1985), p.371. Launch and landing times are taken from 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).

and will not be repeated here. (See Table 11 for a summary of civilian experiments). An exact ground simulator of the Almaz station, known as the *Analog*, was used at the Gagarin Cosmonaut Training Center (TsPK) to duplicate potential problems that the crew faced in orbit and for suggesting solutions. The onboard crew's daily routine consisted of eight hours of sleep, eight hours of work, and the remaining eight hours for exercise, rest, cleaning and making log entries [76]. Food consisted of a large variety of items including spicy tomato sauce, wheat bread with ham, tinned minced bacon, fruit sticks, prunes and nuts, cottage cheese with black currants, honey cake, white coffee, vitamins, and different types of soups [77]. Throughout their mission, the crew exercised regularly, usually twice daily, at the beginning and end of each work day. They used a universal trainer that enabled them to simulate walking, running, high and long jumping, and weight-lifting. The cosmonauts wore special suits, the NRK-1 *Atlet* ("Athlete") and the TNK-2 *Pingvin* ("Penguin") during their calisthenics. In general, the cosmonauts were said to be in great spirits – Popovich with his dry humor, Artyukhin, a little more reserved. Both men received excellent evaluations for their work. They apparently fulfilled 100%

TABLE 11: *Named Civilian Experiments Conducted on Board Salyut-3.*

Name/Instrument	Activity
Amak-3	monitoring of blood composition
Impul's	investigation of the vestibular system in weightlessness
Levkoy-3	measurement of intra-cranial pressure and the ability of blood vessels to carry blood
Mars	psychological instrument
Polinom-2M	study of heart performance and circulatory system in orbit
Priboy	test of the purification of water
Rezeda-5	measurement of the capacity of lungs and inhalation/exhalation rates
RSS-2	hand-held spectograph for observations of clouds and storms.
Saturn	psychological instrument
Veter	vacuum capacity device (failed on Soyuz-14)

Sources: 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.70; Bert Dubbelaar, *"The Salyut Project"*, (Moscow: Progress Publishers, 1986), pp.25-27. B.I. Ushakov *et al.*, eds. Istoriya Otechestvennoy kosmicheskoy meditsiny (po materialam voyennomeditsinskikh uchrezhdeniy), Voronezh: VGU, 2001, pp.56-57, 108.

of their originally assigned work, and all experimental data was later transferred to both the Ministry of Defense and the Academy of Sciences.

The State Commission was concerned early on in the mission of the potential hazards to the crew as a result of prominent solar flares on 4, 6, and 8 July; after further measurements, the Commission concluded that the increased radiation levels would not pose a threat to the cosmonauts. On 8 July, American astronauts assigned to the Apollo-Soyuz Test Project (ASTP), who were at Zvezdnyy gorodok at the time, sent their congratulations to the two orbiting cosmonauts. Three days later, Soviet officials announced that the mission was half over, no doubt to preclude rumors at the end of their time in space that the flight had been shortened [78]. The following day was the first day of rest for the crew. On 13 July, Popovich and Artyukhin performed a preliminary check of the Soyuz-14 spacecraft's systems.

On 17 July, the cosmonauts tested the Soyuz-14 vehicle and the crew started loading film and experiment results into the Descent Apparatus. The crew also packed exposed film into the small return capsule. Undocking occurred without event, and Popovich and Artyukhin had the honor of being the very first Soviet crew to complete a space station mission alive when they landed at 1521 hours 36 seconds Moscow Time on 19 July after a 15 days 17 hour 30 minute 28 second long mission. Touchdown point was 140 kilometres southeast of Dzhezkazgan, within 2,000 metres of the pre-planned target. The cosmonauts climbed out of the capsule without waiting for the recovery forces. They were reportedly fully recovered from their two weeks in weightlessness within a few days. The crew were said to have left Salyut-3 with enough supplies to last the next crew for at least six months.

10.3 The Soyuz-15 Mission

The second crew finished preparations for the next visit to Salyut-3 through the end of July and the beginning of August. The 32-year old Lt.-Col. Gennadiy V. Sarafanov, "a young and brilliant pilot [who] made friends with the station developers" was assigned as Commander of the mission [79]. His Flight Engineer was 48-year old Col.-Engineer Lev S. Demin, a "Candidate of Technical Sciences" who had written his thesis on anti-ballistic missile systems. A cosmonaut since 1963, Demin was the oldest person to fly into space at the time of his mission. The crew had trained for a 25-day long mission, the longest yet in the Almaz program [80].

The night launch of Soyuz-15 occurred without incident as scheduled on 26 August 1974 at 2258 hours 8 seconds Moscow Time, and the crew entered an initial orbit of 193.4 x 235.2 kilometres at 51.62° inclination. Sarafanov and Demin conducted at least one orbital maneuver during their first hours in orbit. They detected no anomalies during this period, and following a thorough check of the ship's systems, the crew were set to begin their first sleep period. It appears that the cosmonauts did not complete their planned sleep period, and in fact may not have slept at all. Flight controllers in Yevpatoriya wanted to conduct some final communications sessions with the crew prior to their docking, expected to occur out of contact with the ground segment, and thus the crew were forced to begin their second "day" in space earlier. The preliminary automatic approach to Salyut-3, using the *Igla* rendezvous system, began soon after, and following a several hour-long chase the crew finally made visual contact with the station. Several more Soyuz engine firings were planned to bring the two craft to within docking distance. At this point, on their 16th orbit, both crew members sensed that during each of the ensuing automatic firings of the propulsion system, the Soyuz-15 engine was firing exactly reverse to the plan, i.e. it was braking when acceleration was required, and vice-versa. The cosmonauts in their small ferry swiftly swerved past the target at a distance of only seven metres. Following the first aborted attempt, the crew attempted a second effort to approach the station, but once again there were uncontrolled engine burns and the Soyuz flew past Salyut-3 at a distance of about 30-50 metres [81]. Controllers and the crew conducted hurried conversations at this point assess possible courses of action. The crew were asked to report on all essential systems on board the Soyuz, and test several systems with direct commands. The crew asked for permission to try a manual approach, but Yevpatoriya was reluctant to grant permission for such a move due to excessive propellant use during the first tries. As the spacecraft began to move out of communications range with ground control stations in the USSR, the last words Sarafanov relayed were "We will make her work" [82]. It is not clear if Sarafanov attempted any manual attempt to dock at this point, but as soon as the spacecraft resumed communications with ground stations, Sarafanov and Demin received the following message: "Cease further attempts. Prepare for a landing. Do not suspend activity – return at night" [83].

The Soyuz ferry was capable of only two full days of autonomous flight on its internal batteries, and Sarafanov and Demin were forced to immediately begin plans for reentry. The ensuing few hours were taken up with house-keeping activities, but a second potentially hazardous situation arose prior to reentry. When the spacecraft was ordered to maneuver into the correct attitude for the deorbit burn, there was a sharp and unexpected spike in the current level on the instrument panel. The crew remained surprisingly calm; Demin joked that, "All we need now is a fire," to which Sarafanov replied, "They might as well bring an ambulance to the landing region!" As it happened, the braking engines performed without fault, and the Descent Apparatus carrying the two cosmonauts reentered without any further problems. The tracking ship *Morzhovets* stationed in the Atlantic reported to Yevpatoriya that the reentry burn had been performed as planned. The two cosmonauts eventually landed successfully at 2310 hours 16 seconds Moscow Time on 28 August, 48 kilometres southwest of the city of Tselinograd in Kazakhstan. A thunderstorm with heavy lightning was raging at the site, but rescue teams were quick to locate the crew in the dark night within 55 seconds of touchdown; the cosmonauts were able to leave the Descent Apparatus just 17 minutes following landing. The mission had lasted a total of 2 days 0 hours 12 minutes and 11 seconds.

Officially at the time, Soviet officials announced that the flight was meant to be a test of a fully automatic rendezvous and docking system to be used on future robot supply ships. When this system failed, the Soviets claimed, the cosmonauts did not try to dock manually since that was not part of the original program. This fiction was further exaggerated by claims that even if the crew had docked with Salyut-3, they would have quickly undocked, since that was the only objective of the mission [84]. In going to such great lengths to conceal a failure, reports even claimed that one of the goals of the mission had been to test the psychological compatibility of crewmen of very different ages. Unfortunately, one newspaper report, authored in anticipation of a successful docking – but written before the failure – was inadvertently published before it could be recalled. The title of the story was "New Visitors for Space Station" [85].

Behind the veil of secrecy, the government formed a commission on 3 September to investigate the cause of the failure. Despite exemplary performances by both cosmonauts, the crew were officially blamed for "cutting off the flight program" [86]. A negative evaluation of the crew was evidently motivated by heavy lobbying from senior engineers at NPO Energiya who were unwilling to believe that their handiwork was to blame. At the same time, one of the recommendations of the accident commission was to suggest that the "Soyuz rendezvous and docking system [i.e. the *Igla* system]...be 'doctored'," suggesting that it was most likely the *Igla* system which was at fault [87]. For Sarafanov and Demin, the unfair judgement against them may have affected their future careers. Although Sarafanov continued to train as part of the Almaz cosmonaut group until 1980, neither cosmonaut ever flew a second space mission. Astonishingly, as late as 20 years following the mission, neither individual had been allowed to read the official report pointing the finger of blame at the them. This report still remains classified in the archives of RKK Energiya (the current name of NPO Energiya); despite a formal request from a respected Russian journalist, Energiya denied access to the results of the report as late as September 1994 [88].

NPO Energiya Deputy Chief Designer Boris Ye. Chertok, who participated in the work of the accident investigation commission, added some key details about the failure in 1999. He noted that during Soyuz-15's approach to Salyut-3, that not only did the *Igla* system fail, but it gave false commands. When the ferry vehicle was only 350 metres from its target, *Igla* believed that it was 20 kilometres away. Using this erroneous information, *Igla* turned on its engines for long-range approach. The two vehicles had, in fact, passed by each other at a relative velocity of 72 kilometres per hour. An impact at that time would have certainly killed the crew. The crew were saved, Chertok, claimed, because at a distance of 20 kilometres, the approach program included some amount of lateral drift to put the two ships out of direct line-of-sight. After two more such automatic attempts, both of which failed, the crew were then ordered to shut down *Igla* and prepare for a return to Earth – since remaining propellant loads would not allow a third try [89]. An official Energiya publication from 1996 clearly held the crew responsible for not switching off *Igla* earlier during the first time that the system malfunctioned. The authors noted that "the ship's crew were not able to evaluate a non-standard situation and [thus] allowed a dangerous flight close by the station" [90].

If there were discussions about launching a third visit to the station in late October, these plans never materialized since a thorough reworking of the Soyuz's *Igla* system would require a longer time than the planned lifetime of Salyut-3 (about three months). Although there were no further piloted launches to the station, the station performed a modest program of automatic photo-observations in August and September. On 19 September, the Soviet press announced that the "original program" of research on board Salyut-3 would be concluded on 23 September. That day, the main 90-day program for the station was completed: on a command from ground control, the Almaz station was properly oriented and the small recoverable capsule fixed at the bottom of the spherical airlock chamber was "catapulted" from the station [91]. During reentry, there was a failure in a timing instrument: the main parachute was not deployed and the heatshield did not separate. Despite these malfunctions, the capsule successfully landed (albeit with heavier g-loads) at about 1236 hours Moscow Time. It is quite likely that the capsule used the same landing window that the Soyuz-15 cosmonauts might have used, had they managed to board the station [92]. The capsule cover was deformed, but the film cartridges were safely rescued and delivered to the Ministry of Defense [93].

Salyut-3 continued an unspecified program of work through the ensuing months. Several orbital maneuvers were carried out during this period. The only noted experiment was one "to determine ballistic and aerodynamic characteristics and the influence of gravitational forces and moments on changes in position of the solar arrays" [94]. One recent Russian source suggests that during automated flight of the station, the Nudel'man rapid-fire cannon was actually tested in orbit. The weapon was evidently automatically "fired in open space – on the side of the Earth, and as telemetry data showed, the station strongly vibrated, but no damage occurred" [95]. Other sources claim that the weapon was never carried on board any Almaz station [96].

On 25 December 1974, the Soviets announced that termination of the Salyut-3 program was imminent, and coincidentally or not the very next day Salyut-4 (the fourth "civilian" station, DOS-4) was launched into orbit. The first Almaz station was finally deorbited over the Pacific Ocean by ground command on 24 January 1975. Little is known about the last days of Salyut-3 although one source indicated later that "the station was removed from orbit because of problems that had arisen in it" [97]. By the time of the December 1974 announcement, the Salyut-3 station had hosted 400 scientific and technical experiments, had 8,000 control commands transmitted to it, performed more than 200 "dynamic operations," conducted 70 television and 2,500 telemetric communications sessions, carried out 500,000 thruster firings, and produced about 5,000 kilowatt-hours of power from its solar panels. A stable atmosphere and pressure was also reportedly maintained throughout its lifetime [98].

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 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].

(This paper continues with the Third Almaz Station in Part 2: 1976 - 1992 which is scheduled to appear in the following issue.)

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32. For a detailed account of the Soyuz-11 accident and its aftermath, see Siddiqi, *Challenge to Apollo*, pp.776-786.
33. Semenov, *Raketno-Kosmicheskaya Korporatsiya...*, p.190.
34. Shamsutdinov, "Cosmonauts of 'Almaz'".
35. For a reproduction of the letter, see Yevteyev, *Operezhaya vremya: ocherki*, pp.332-333.
36. For a reproduction of this letter, see Semenov, *Raketno-Kosmicheskaya Korporatsiya...*, pp.295-296. An additional point in the letter dealt with the use of only the Soyuz (a variant known as the 7K-M) instead of the Salyut space station for the Apollo-Soyuz Test Project.
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38. Zhil'tsov, *Gosudarstvennyy kosmicheskiy...*, pp.78, 89. The order also specified details of manufacture. All production would be carried out at the M. V. Khrunichev Machine Building Plant for the prime customer which was the TsKBM (for all components except the Transfer Compartment and the Engine Unit for which the customer was the TsKBM Fili Branch). Additionally, the order specified that the Khrunichev Plant would complete production preparation for the manufacture of TKS blocks in the fourth quarter of 1972.
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42. For a reproduction of Chelomey's final "sign-off" on Almaz, see Yevteyev, *Operezhaya vremya: ocherki*, pp.339-340. See also Ivan Yevteyev, *Yeshche odnimalos' plamya...: ocherki*, Moscow: Inter-vesy, 1997, p.98.
43. For a brief biography of Grigor'yev, see I. D. Sergeyev, ed., *Khronika osnovnykh sobytiy istorii raketnykh voysk strategicheskogo naznacheniya*, Moscow: RVSN, 1994, pp.58-59. For Grigor'yev's appointment as Almaz State Commission Chairman, see Yevteyev, *Operezhaya vremya: ocherki*, p.367.
44. Kerim Kerimov, *Dorogi v kosmos (zapiski predsedatelya Gosudarstvennoy komissii)*, Baku: Azerbaydzhan, 1995, p.71. The Soyuz State Commission was headed Maj.-Gen. Kerim A. Kerimov, who also headed the regular Soyuz and DOS-Salyut State Commissions.
45. For a reproduction of this letter, see Yevteyev, *Operezhaya vremya: ocherki*, pp.340-341.
46. Semenov, *Raketno-Kosmicheskaya Korporatsiya...*, p.273; Afanas'yev, "Unknown Spacecraft"; S. Shamsutdinov and I. Marinin, "Flights Which Never Happened" (in Russian), *Aviatsiya i kosmonavtika*, no. 3, pp.43-44, 1993;

Polyachenko and Tumanov, "The Controllable 'Almaz'".
47. A. P. Zavalishin, *Baykonurskiye universitety: zapiski veterana-ispytatelya*, Moscow: Mashinostroyeniye, 1999, p.51.
48. Chugunova, "Chelomey's Cosmonauts".
49. Sagdeev, *The Making of a Soviet Scientist*, p.207.
50. *Soviet Space Programs, 1971-75: Overview, Facilities and Hardware, Manned and Unmanned Flight Programs, Bioastronautics, Civil and Military Applications, Projections of Future Plans*, Prepared for the Committee on Aeronautical and Space Sciences, U.S. Senate, 94th Congress, 2nd Sess., Washington, D.C.: U.S. Government Printing Office, August 1976, p.195.
51. Z. Zhafyarov and V. Petrovskiy, "Readers' Letters" (in Russian), *Novosti kosmonavtiki*, no. 1, pp.66-67, 2000.
52. Most of this information is from an official document from Grigor'yev and Chelomey to the Central Committee reproduced in Yevteyev, *Operezhaya vremya: ocherki*, pp.346-347.
53. Vladimir Polyachenko, "The Pep of 'Almaz'" (in Russian), *Kryl'ya rodiny*, no. 4, pp.30-32, 1992; Pokrovskiy, *Kosmos nachinayetsya na zemlye*, pp.411-412.
54. Johnson, *Handbook of Soviet Manned Space Flight*, p.236.
55. *Soviet Space Programs, 1971-75*, p.195.
56. Polyachenko, "The Pep of 'Almaz'", April 1992; Afanas'yev, "Unknown Spacecraft".
57. The complete document is reproduced in Yevteyev, *Operezhaya vremya: ocherki*, p.348.
58. Neville Kidger, "Almaz: A Diamond out of Darkness", *Spaceflight*, **36**, pp.86-89, 1994.
59. Thomas O'Toole, "Soviet Union Still Trails U.S. in Space", *The Washington Post*, June 17, 1973, pp.A1, A8; "Salyut Elements Separate, Signals Lost", *Aviation Week & Space Technology*, April 30, 1973, p.21.
60. For the Russian claim, see Pokrovskiy, *Kosmos nachinayetsya na zemlye*, p.412. For the Western claim, see *Soviet Space Programs, 1971-75*, p.195. Western radars tracked a total of 26 pieces, although there was some uncertainty as to when the pieces had originally appeared in orbit. Analysts speculated that the pieces of debris detected around the station may have been produced by an explosion of the Proton-K upper stage or the Salyut-2 propulsion system. See "Salyut 2", *Spaceflight*, **15**, pp.293, 1973.
61. Zhafyarov and Petrovskiy, "Readers' Letters."
62. Sagdeev, *The Making of a Soviet Scientist*, pp.176, 207-208.
63. Thomas O'Toole, "2nd Russian Space Shot Fails", *The Washington Post*, May 4, 1973, p.A1; "Soviet Space Attempt on April 25", *Space Daily*, May 8, 1973, p. 46. Note that both these reports incorrectly identified both the launch vehicle (the Proton-K) and the payload (Lunokhod). The actual launch vehicle was a Tsiklon-2 booster. See also, Asif Siddiqi, "Staring at the Sea: The Soviet RORSAT and EORSAT Programmes", *JBIS*, **52**, pp.397-416, 1999.
64. Yevteyev, *Operezhaya vremya: ocherki*, p.349.
65. Yevteyev, *Operezhaya vremya: ocherki*, pp.349-350.
66. Yevteyev, *Operezhaya vremya: ocherki*, p.348.
67. There is some confusion as to whether Chelomey wanted Almaz to be crewed during this first phase. In a document dated 28 December 1973, addressed to Minister of General Machine Building S. A. Afanas'yev, Commander-in-Chief of the Strategic Missile Forces V. F. Tolubko, and Chief Designer of TsKBEM V. P. Mishin, Chelomey noted that the next four Almaz stations would fly in automated mode. But in another document, dated the same day, and addressed only to Afanas'yev, he implicitly recommended that the next Almaz be launched with a crew. Both documents are reproduced in Yevteyev, *Operezhaya vremya: ocherki*, pp.348-351.
68. See Chertok, *Rakety i lyudi: lunnaya gonka*, p.434 for a possible hint of this.
69. V. P. Glushko, ed., *Kosmonavtika entsiklopediya*, Moscow: Sovetskaya entsiklopediya, 1985, p.343.
70. Polyachenko, "The Pep of 'Almaz'", April 1992.
71. Gordon R. Hooper, "Missions to Salyut 5", *Spaceflight*, **19**, pp.138-145, 1977; *Soviet Space Programs, 1971-75*, pp.200-203.
72. "Salyut Recon", *Aviation Week and Space Technology*, July 29, 1974, p.11.
73. "Soviets Solidify Manned Flight Effort", *Aviation Week and Space Technology*, March 17, 1975, p.71.
74. I. Afanas'yev, "Secret 'Parcel' From Orbit" (in Russian), *Novosti kosmonavtiki*, no. 11, pp.68-70, 1999.
75. Yu. V. Votintsev, "Unknown Troops of the Vanished Superpower" (in Russian), *Voyenno-istoricheskiy zhurnal*, no. 11, pp.12-27, 1993.
76. *Soviet Space Programs, 1971-75*, p.202.
77. Sven Grahn, "Future Salyut Missions", *Spaceflight*, **16**, pp.392-393, 1974.
78. "Soyuz 14 Mission Report", *Spaceflight*, **16**, pp.430, 1974.
79. Polyachenko, "The Pep of 'Almaz'", April 1992.
80. Mikhail Rebrov, "Bitter Aftertaste of Glory" (in Russian), *Krasnaya zvezda*, September 9, 1994, p.2. An analysis of the launch windows for the flight confirms that a mission of 17 to 25 days duration was planned. See Phillip Clark, *The Soviet Manned Space Program: An Illustrated History of the Men, the Missions, and the Spacecraft*, New York: Orion, 1988, p.70.
81. Rebrov, "Bitter Aftertaste of Glory"; See also, "Russia's 'Universal Spacecraft'", *Spaceflight*, **18**, pp.95-98, 1976.
82. Polyachenko, "The Pep of 'Almaz'", April 1992.
83. Rebrov, "Bitter Aftertaste of Glory."
84. *Soviet Space Programs, 1971-75*, p.204.
85. James E. Oberg, *Red Star In Orbit*, New York: Random House, 1981, p.133.
86. Rebrov, "Bitter Aftertaste of Glory." The document creating the accident commission, dated 3 September 1974, is reproduced in Yevteyev, *Operezhaya vremya: ocherki*, pp.351-352. The four subcommissions were headed by V. V. Favorskiy (GUKOS), A. F. Bogomolov (OKB-MEI), V. A. Shatalov (VVS), and V. S. Avduyevskiy (TsNIIMash).
87. Polyachenko, "The Pep of 'Almaz'", April 1992.
88. Rebrov, "Bitter Aftertaste of Glory".
89. Chertok, *Rakety i lyudi: lunnaya gonka*, pp.434-435.
90. The official Energiya source also gives different figures than Chertok in terms of the first approach sequence. Energiya notes that the spacecraft's *Igla* system indicated that the Soyuz was three kilometres from the station when it was actually 300 metres from the station. See Semenov, *Raketno-Kosmicheskaya Korporatsiya...*, p.191.
91. Polyachenko, "The Pep of 'Almaz'", April 1992.
92. Clark, *The Soviet Manned Space Program*, p.71.
93. Afanas'yev, "Secret 'Parcel' From Orbit".
94. Johnson, *Handbook of Soviet Manned Space Flight*, p.243.
95. Kholodov, "Unknown Pages from the Mastery of Space".
96. "Aerospace Salon: Officially Never Disclosed".
97. V. P. Mishin, "Why Didn't We Fly to the Moon?" (in Russian), *Znaniye: tekhnike: seriya kosmonavtika, astronomiya*, no. 12, pp.3-43, 1990.
98. *Soviet Space Programs, 1971-75*, p.200.
99. Marinin and Shamsutdinov, "The Invisible Plane of 'Almaz'".
100. Shamsutdinov, "Cosmonauts of 'Almaz'".

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