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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

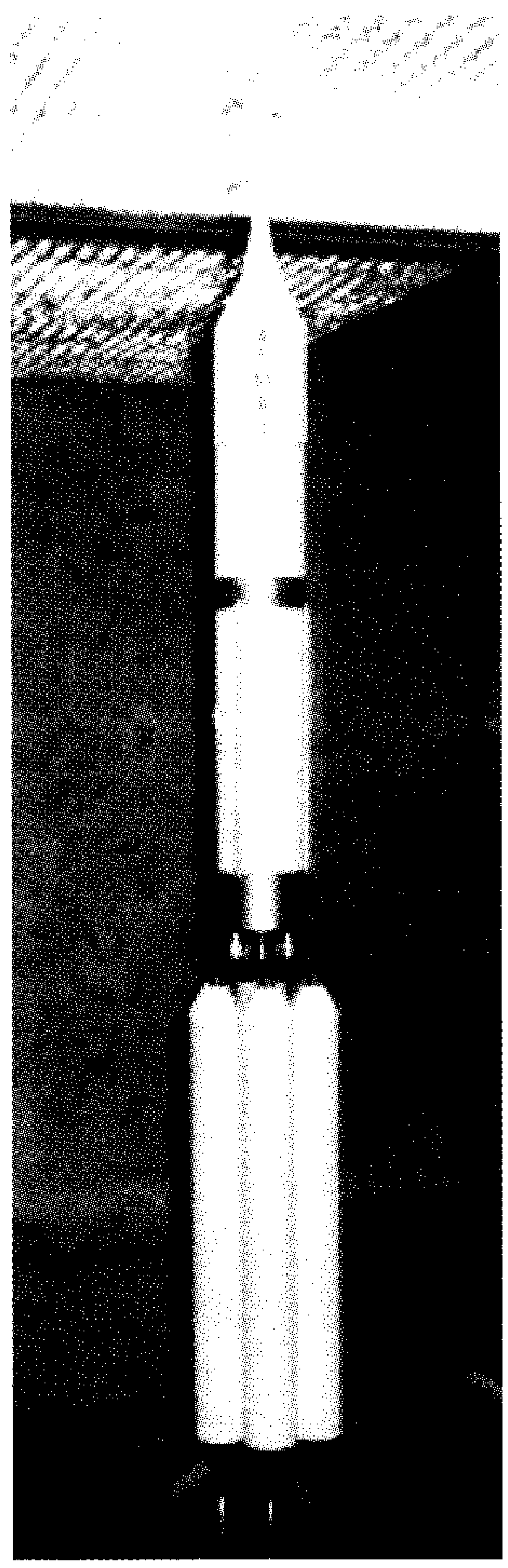

Fig. 1 This is a model of an unusual variant of the UR-500K Proton launcher with the Almaz station as a payload. Note the use of a launch escape tower, indicating that the station would have been launched with a crew on board. Actual flight versions of the Almaz were launched in the 1970s without the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

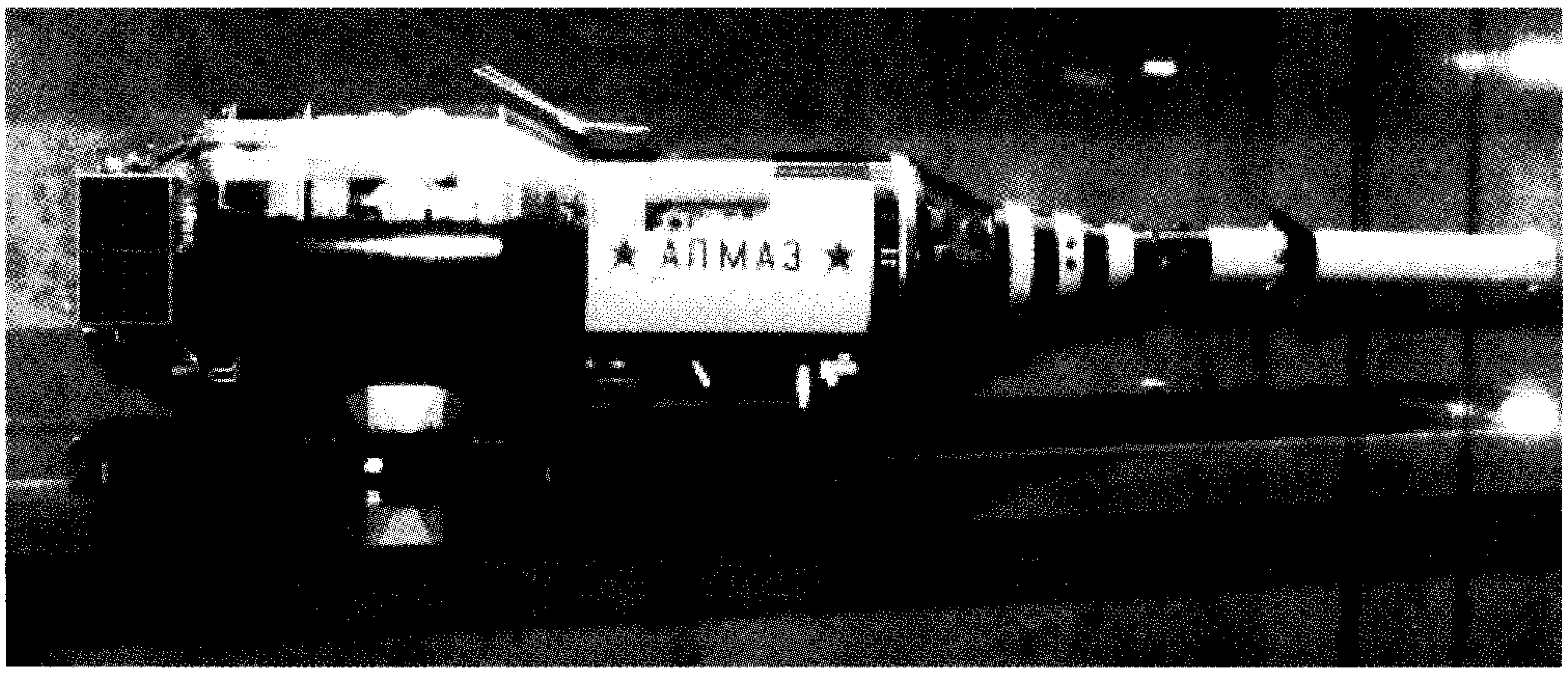

Fig. 2 This is a model of the original Almaz Orbital Piloted Station (OPS). On the right is the conical Return Apparatus (VA) with its launch escape tower. The middle area (with the word "Almaz" written in Cyrillic) is the living quarter of the station. The larger diameter section on the left contains 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
TsK = Central Committee of the Communist Party
SM = Council of Ministers
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

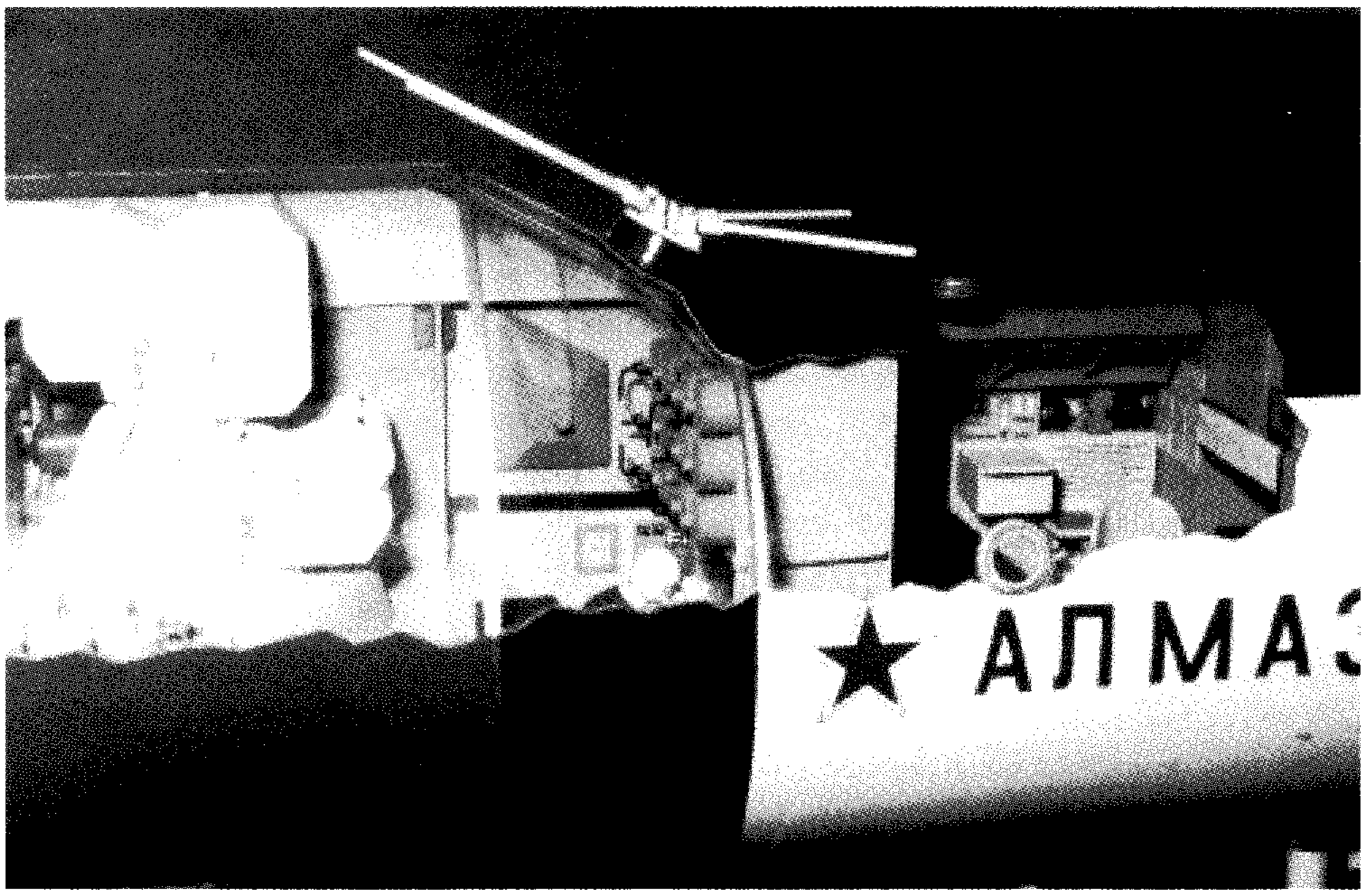

Fig. 3 This is a closeup of a model of the Almaz station. On the right is the living area of the station. The large white contraption on the left is the *Agat-1* photo-reconnaissance system. (Copyright Dietrich Haeseler).

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.

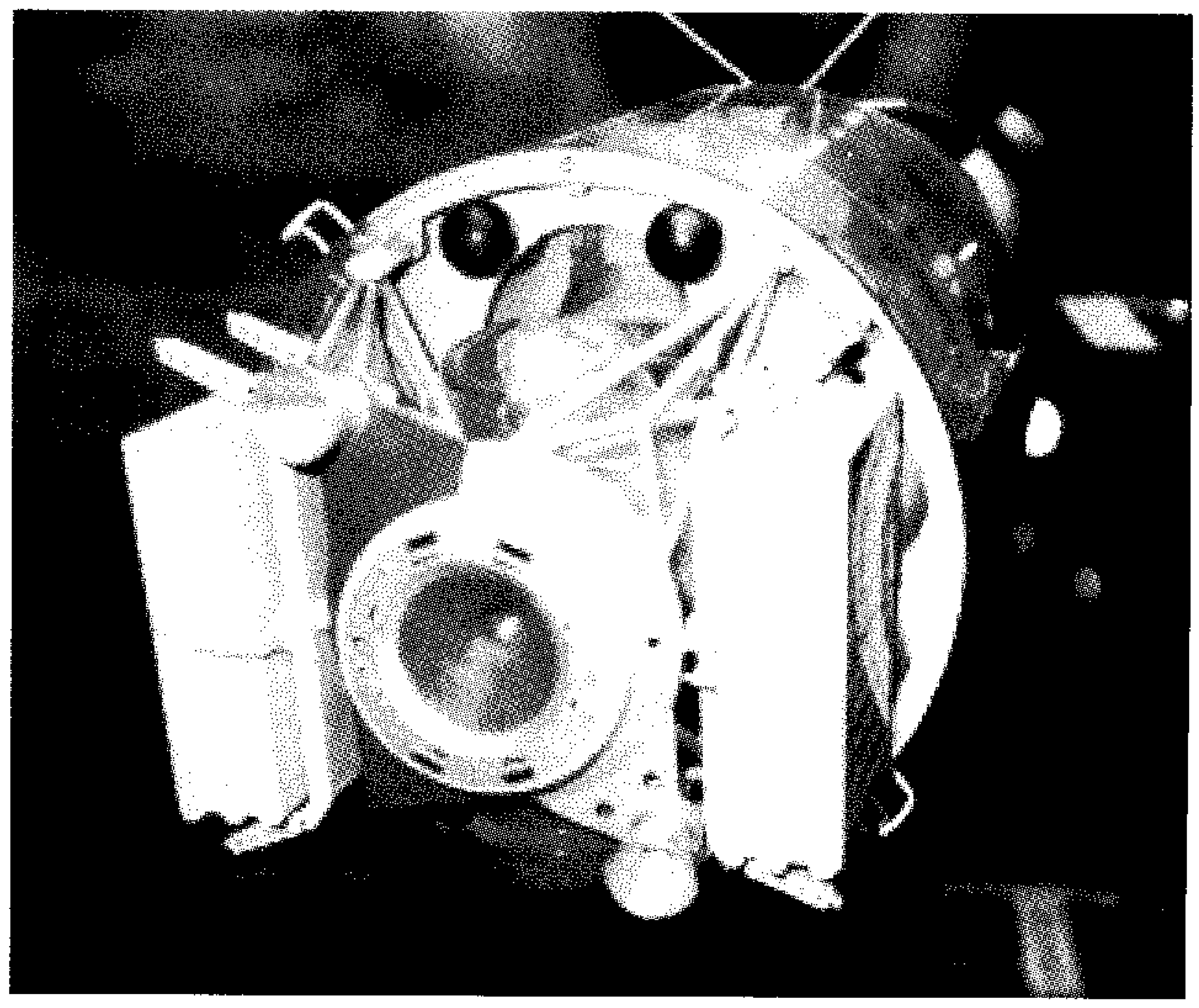

Fig. 4 This is a rear view of a model of the Almaz station. The circular object in the foreground is the main docking port. The vertical objects on each side are folded solar arrays which would unfurl once in orbit. Two nozzles of the main Almaz engine are visible on either side of the docking port.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