Part 1
Soyuz

1.1 General Description

The following description of Soyuz is excerpted from an article in the Soviet newspaper *Pravda* (November 17, 1968).[1] It describes the Original Soyuz, the earliest flown version of Soyuz, yet fits the current Soyuz derivative, the Soyuz-TM, in most particulars.

The Soyuz consists of the following main modules: the orbital module . . . a descent capsule [descent module], intended for putting crews into orbit and returning them to Earth; and the service module, which houses the . . . engines.

The orbital module is in the fore part of the ship and is connected with the descent capsule. The service module is placed behind the descent capsule.

When the ship is being placed into orbit, it is protected against aerodynamic and thermal overloads by a nose faring, which is jettisoned after the passage through the dense layers of the atmosphere.

The cosmonaut's cabin [descent module] . . . is covered on the outside by a . . . heat-resistant covering to protect it from intensive aerodynamic heating during descent to Earth.

After the vehicle has been slowed down by the atmosphere in its descent from orbit, the braking parachute opens . . . then the main parachute which is used for landing opens. Directly before landing—at a height of about 1 meter above the Earth—the solid-fuel braking engines of the soft-landing system are switched on.

[In the] service module . . . a hermetically-sealed . . . container carries the equipment for the thermo-regulation system, the system of unified electric power supply, the equipment for long-range radio communications and radio telemetry, and instruments for the system of orientation and control. The non-pressurized part of the service module contains the liquid-fuel propulsion installation [system] which is used for maneuvering in orbit and . . . for . . . descent back to Earth. The installation has two engines (the main one and the spare one). The ship has a system of low-thrust engines for orientation.

The pick-ups [sensors] for the orientation system are located outside the service module. Mounted on . . . the service module are the solar batteries [arrays]. To ensure that the solar batteries are constantly illuminated, they are oriented towards the Sun by rotating the ship.

The . . . spaceship is equipped with an automatic docking system. The on-board systems of the ship may be controlled either by the cosmonaut from the control panel, or automatically. The ship's equipment allows for the craft to be piloted . . . quite independently of ground control.

1.2 Historical Overview

Figure 1-1 is a Soyuz family tree depicting the evolutionary relationships described in this section.

1.2.1 First Prospectus for Circumlunar Travel (1962)

On March 10, 1962, Sergei P. Korolev, Chief Designer of the Soviet space program and head of Special Design Bureau-1 (Russian acronym OKB-1), ancestor of today's RKK Energia (until recently, NPO Energia), approved a prospectus titled, "Complex for the Assembly of Space Vehicles in Artificial Satellite Orbit (the Soyuz)." The prospectus described the L1, a three-man spacecraft broadly resembling Soyuz as built. It had four modules. In order from fore to aft, these were an attitude control module, a living module, a reentry/command module,

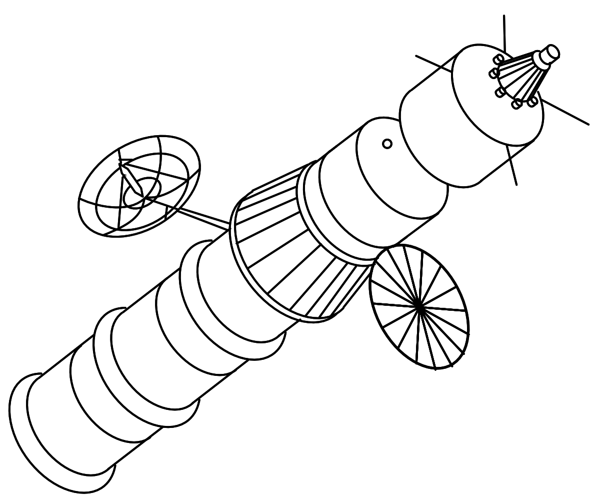

Figure 1-2. L1 Soyuz manned circumlunar concept (1962). Should not be confused with the L1 (Zond) spacecraft (figure 1-9). The cone at the front (right) of the L1 Soyuz is an attitude control module; behind it are cylindrical orbital and descent modules, and a frustum-shaped service module. The round appendage (right) is a solar array, and the dish, a high-gain antenna. At the rear of the L1 are three booster modules.

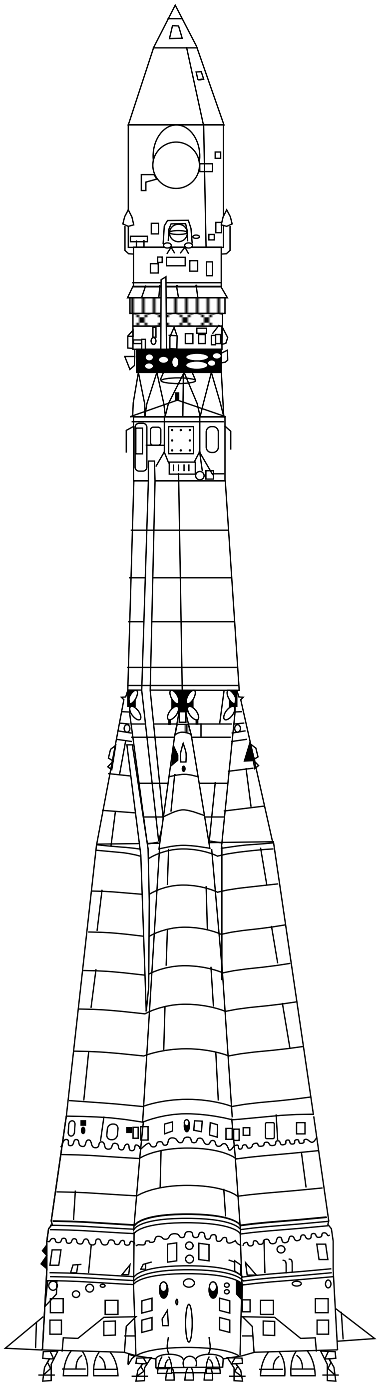

Figure 1-3. Vostok rocket. This is a two-and-a-half-stage derivative of the one-and-a-half-stage rocket which launched Sputnik 1 (1957). Its original ancestor was the SS-6 “Sapwood” ICBM. It served as the basis for the Soyuz launcher (figure 1-7), in service today. Weight of payload launched to 200-km, 51° circular orbit is 4730 kg.

and a service module. In orbit the L1 was to be joined tail-on to the top of a stack of propulsion modules to create a circumlunar ship (figure 1-2). The L1 and each of the propulsion modules were to be launched separately on Vostok launch vehicles (figure 1-3).

The same prospectus described a manned spacecraft called Siber (or Sever) (“north”). This was a three-person vehicle meant to deliver crews to a space station.[2]

1.2.2 Second Prospectus for Circumlunar Travel (1963)

On May 10, 1963, Korolev approved a second prospectus, “Assembly of Vehicles in Earth Satellite Orbit.” In this prospectus, the “Soyuz complex” consisted of spacecraft designated A, B, and C. Soyuz-A (figure 1-4) corresponded to the L1 vehicle of the 1962 prospectus. Soyuz-B was an unmanned propulsion module launched dry with a detachable fueled rendezvous propulsion unit. Soyuz-C was an unmanned tanker for fueling the propulsion module in orbit. Only Soyuz-A was to be manned.

The Soyuz complex (figure 1-5) required five or six launches of the Vostok launch vehicle to carry out a circumlunar mission. The Soyuz-B booster, with an attached rendezvous propulsion unit, was launched first. Up to four Soyuz-C tankers were then launched to fuel the booster. Soyuz-A, with three cosmonauts aboard, then docked nose-to-nose with the booster. The Soyuz-B rendezvous propulsion unit was discarded, and the booster fired to push Soyuz-A around the Moon on a free-return trajectory.

The Soyuz A-B-C complex had a total mass of about 18,000 kg. The Soyuz-A manned spacecraft accounted for 5800 kg of that mass (Soyuz-TM masses about 7070 kg). Total length of the complex was about 15 m. The Soyuz-A was 7.7 m long (compared to 6.98 m for Soyuz-TM).[3, 4]

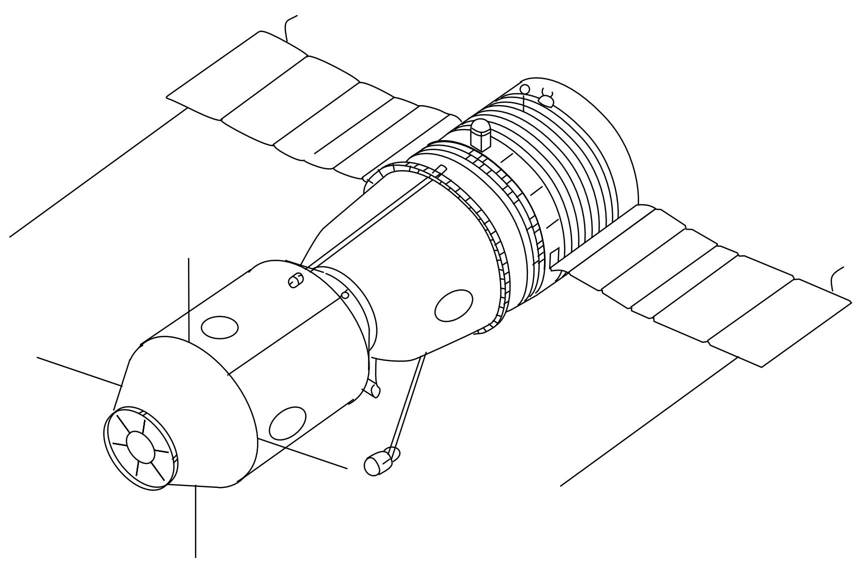

Figure 1-4. Soyuz-A manned spacecraft concept (1963). It was to have been part of the Soyuz A-B-C circumlunar complex.

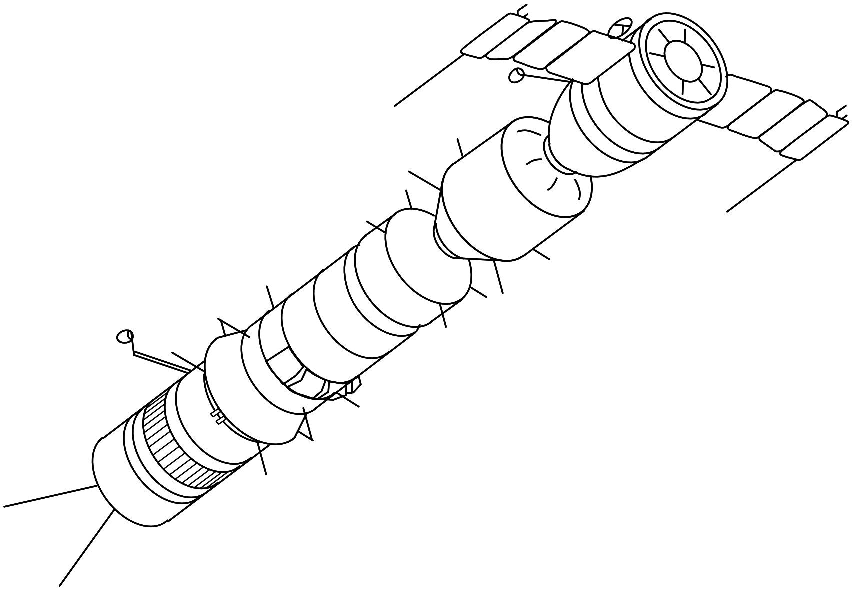

Figure 1-5. Soyuz A-B-C circumlunar concept. The drawing shows Soyuz-A (right), Soyuz-B booster, and Soyuz-C tanker with twin whip antennae (left).

The Soviet lunar effort thus became a two-pronged enterprise. Both prongs depended heavily on the Original Soyuz spacecraft. It was patterned after the Soyuz-A component of the 1963 prospectus. It carried a simple docking system which permitted crew transfer only by extravehicular activity (EVA). The Original Soyuz served the same role as the Gemini spacecraft did in U.S. lunar plans, and more besides. Like Gemini, the Original Soyuz was an interim vehicle, filling the gap between the earliest manned programs and the lunar program. Like Gemini, the Original Soyuz provided the means for preparing men, machines, and procedures in space for the lunar program. Unlike Gemini, the Original Soyuz provided the structural basis for the lunar spacecraft.

1.2.3 Polyot 1 and 2 (1963-1964)

The mysterious Polyot 1 (November 1963) and Polyot 2 (April 1964) maneuverable satellite flights were once thought to have been tests of Korolev's Soyuz-B component. In 1992, however, a Russian book stated that the Polyots were anti-satellite (ASAT) weapon test vehicles developed by V. N. Chelomei's OKB-52 organization (ancestor of today's NPO Mashinostroyeniye). A Russian article published the same year stated that the Polyots were tests of the propulsion systems for OKB-52's Almaz military space stations. Another account had the Polyots testing engines to be used in Chelomei's reusable space plane program. It is possible that the Polyots tested engines to be used in all three programs. In any case, the Polyots were not directly related to the Soyuz program.[5, 6]

1.2.4 Manned Lunar Program (1964-1976)

Soviet Communist Party Central Committee Command 655-268 officially established the Soviet manned circumlunar and lunar landing programs on August 3, 1964. The preliminary plan for the Soviet manned lunar landing program was approved by Korolev on December 25, 1964. The N-1/L3 program, as it was called, would have landed a single cosmonaut on the Moon in 1967-68. The mission plan assumed successful development of a large rocket called the N-1. Studies leading to the N-1 had begun in 1956, and work began in earnest in 1960.[7, 8]

The circumlunar program was retained. By late 1965, however, relying on multiple launches of components and extensive use of Earth-orbit rendezvous to assemble the circumlunar spacecraft was abandoned in favor of a single launch using a four-stage Proton rocket.[9]

By the end of 1965, the Soviet manned lunar program included three vehicles, all based to a greater or lesser degree on the Original Soyuz. They were

- The L1, a stripped-down version of the Original Soyuz known as Zond ("probe") meant for circumlunar flights
- The L2, a beefed-up version of the Original Soyuz called the Lunar Orbit Module—the Soviet counterpart to the U.S. Apollo command and service module (CSM)
- The L3, the lunar lander

The Soviet lunar program was hobbled by underfunding and more than its share of misfortune. In January 1966, Korolev died from complications during surgery. The Soyuz 1 disaster, in April 1967, set back the lunar landing schedule by 18 mo. Bitter personal rivalries between leaders in the Soviet space program also interfered with the goal of landing a cosmonaut on the Moon.

The repeated failure of the N-1 rocket administered the coup de grace, however. The first N-1 test flight occurred on February 20, 1969. It ended in first stage failure. First stage malfunctions also ended the second (July 3, 1969), third (June 27, 1971), and fourth (November 23, 1972) N-1 test flights. A fifth N-1 test was scheduled for August 1974, and a sixth for late 1974. In May 1974, the August test was postponed, though research funding for the N-1 continued. The N-1 program was finally cancelled in February 1976.[10, 11, 12, 13]

1.2.5 Salyut 1 (1970-1971)

The Original Soyuz survived the Moon program to become the ancestor of all subsequent Soyuz and Soyuz-derived craft. Spacecraft designer Konstantin Feoktistov stated that the Original Soyuz missions in 1966-1970 provided engineering data for its conversion into a space station transport. Plans for the conversion were drawn up in the first half of 1970.[14]

Soyuz 10 and Soyuz 11 carried docking systems permitting internal crew transfer. In this work these vehicles are called the Salyut 1-type Soyuz. Apart from their docking systems, they differed only slightly from the Original Soyuz. The three Soyuz 10 cosmonauts became the first people to dock with a space station, but were unable to enter Salyut 1. This was blamed on a "weak" docking unit.[15] The Soyuz 11 crew occupied Salyut 1 in June 1971. Because Soyuz cosmonauts wore pressure suits only for EVAs, the Soyuz 11 crew perished during reentry when pyro shock jarred open a 1-mm pressure equalization valve, allowing the Soyuz 11 descent module to vent its atmosphere into space.[16]

1.2.6 Early Soyuz Ferry (1973-1977)

The Soyuz spacecraft underwent further redesign in the aftermath of the Soyuz 11 accident. Putting the cosmonauts in pressure suits during "dynamic operations" (such as liftoff, docking, reentry, and landing) forced Soviet engineers to pull one crew couch. The solar arrays were replaced by chemical batteries to save weight, restricting Soyuz to 2 days of autonomous flight. Removing the arrays also improved the spacecraft's maneuverability. In addition, the Soviets modified the Soyuz orbital module to improve its ability to carry cargo to Salyut stations. These modifications produced the Soyuz Ferry.[17]

1.2.7 Apollo-Soyuz Test Project (1973-1976)

The Apollo-Soyuz Test Project (ASTP) sprang directly from letters exchanged between NASA Administrator Thomas O. Paine and Soviet Academy of Sciences President Mstislav Keldysh in 1969 and 1970. (Of course, U.S.-Soviet space cooperation dates from nearly the beginning of spaceflight—see Portree, David S. F., "Thirty Years Together: A Chronology of U.S.-Soviet Cooperation", NASA Contractor Report 185707, February 1993.) Several proposals for a joint manned mission were floated. For a time, an Apollo CSM docking with a Salyut space station held center stage. In April 1972, the sides met in Moscow to finalize the agreement for an Apollo-Salyut docking. The Soviets surprised the Americans by announcing that modifying a Salyut to include a second docking port for Apollo was neither technically nor economically feasible. They offered a Soyuz docking with Apollo instead.[18]

The Soyuz Ferry needed substantial modifications to fulfill its new role as international ambassador. These included restoration of solar arrays to permit a 5-day stay in orbit, deletion of the Igla ("needle") approach system boom and transponders, addition of Apollo-compatible ranging and communications gear, and substitution of the Soyuz Ferry probe and drogue docking system with the APAS-75 (androgynous peripheral assembly system) (see figure 1-22). The Soviet Union built five ASTP Soyuz. Three flew as precursors (two unmanned and one manned), and one backed up the prime ASTP Soyuz, Soyuz 19.

In the event, Soyuz 19 performed well. Its backup flew as Soyuz 22 on an Earth observation mission (1976). It was the last manned Soyuz flown without the intention of docking with a space station.

1.2.8 Progress and Soyuz (1977-Present)

Since 1977, Soyuz and its derivatives linked with the manned space program have had one function—to support manned space stations. Since the launch of Salyut 6 in 1977, the Soviet/Russian station programs have had the following attributes with implications for Soyuz evolution:

- Multiple docking ports
- Design lifetimes of more than 1 year, with the option to remain in orbit for several years through on-orbit repairs, upgrades, and refurbishment
- Extended-duration stays by teams of two or three cosmonauts

Extended-duration stays called for resupply, which in turn called for a specialized resupply spacecraft. This drove development of the Progress freighter, design of which began in 1973—the same year work began on

Salyut 6. Progress craft deliver propellants, pressurant, air, air regenerators, water, food, clothing, bedding, mail, and other supplies. Resupply by specialized spacecraft in turn called for multiple docking ports, one for the resident crew's Soyuz Ferry and at least one for the resupply spacecraft.

Progress freighters not only resupply the stations—they also deliver repair parts and new apparatus, permitting the stations' useful lives to be extended well beyond their original design lifetimes. Along with Soyuz, Progress stood in for the malfunctioning orbit maintenance engines on the Salyuts, preventing premature reentry. (Kvant docked at the Mir base block rear port in 1987, blocking the base block's orbit maintenance engines. Since then, Mir has relied exclusively for orbit maintenance on Progress and Soyuz craft.)

The Soyuz Ferry had a limited endurance docked to a station—about 60 to 90 days. Two alternatives were available if long-duration crews were to remain aboard for longer periods:

- The Soyuz Ferry could be upgraded to increase its endurance. This drove development of the Soyuz-T, which had an endurance of about 120 days, and the Soyuz-TM, which can stay with a station for at least 180 days.
- As a resident crew's Soyuz neared the end of its rated endurance, a visiting crew could be sent to dock at the second port in a fresh Soyuz. They would return to Earth in the aging spacecraft, leaving the fresh one for the resident crew. A variation on this theme had an unmanned Soyuz being sent to the station to replace the resident crew's aging spacecraft. This was done only once, when Soyuz 34 replaced Soyuz 32.

Soyuz-T development appears to have been influenced by ASTP Soyuz development. Soyuz-T development in turn affected development of the Progress upgraded for Mir (first flown to Salyut 7 as Cosmos 1669 in 1985). Soyuz-T begat Soyuz-TM: the primary difference between the two craft was that Soyuz-T used the old Igla ("needle") approach system, while Soyuz-TM used the Kurs ("course") system. Many Soyuz-TM modifications were in turn applied to Progress-M, the most recent new Soyuz derivative.

Soyuz-derived craft might have played yet another role in the Soviet/Russian manned space program. By 1980, work commenced to convert Progress craft into specialized space station modules for the first truly multimodular station—what became Mir. But these were replaced by space station modules derived from an entirely different type of vehicle (see part 3, "Space Station Modules"). The Gamma astrophysics satellite would have been the first Progress-derived module, but it was redesigned to fly as an independent satellite.[19]

1.2.9 Soyuz Generations

The manned Soyuz spacecraft can be assigned to design generations. Soyuz 1 through 11 (1967-1971) were first-generation vehicles. The first generation encompassed the Original Soyuz and Salyut 1 Soyuz. The second generation, the Soyuz Ferry, comprised Soyuz 12 through 40 (1973-1981). ASTP Soyuz served as a technological bridge to the third-generation Soyuz-T spacecraft (1976-1986). Soyuz-TM is fourth-generation. These generation designations provide a useful shorthand method for referring to the vehicles. They also parallel similar designations applied to Soviet/Russian space stations and other spacecraft.[20]

1.2.10 Crew Code Names

Code names used as call signs in radio communications are a traditional fixture of the Soviet/Russian space program. They date from the first manned spaceflight (Vostok 1 on April 12, 1961) and reflect the evolution of Soviet spacecraft and procedures. When they were first adopted, one code name was adequate—Vostok was a single-seater. With the modification of Vostok into the multiseater Voskhod and the development of the multiseater Soyuz, code name conventions changed.

The crew code names listed with the names of cosmonauts in the "Mission Description" subsections which follow are in actuality the code names of each mission's commander. For example, the Soyuz-TM 12 flight crew was called Ozon ("Ozone") because that was commander Anatoli Artsebarski's code name. Following tradition, his flight engineer, Sergei Krikalev, was called Ozon Dva ("Ozone-2"). Helen Sharman, a cosmonaut-researcher, sat in Soyuz-TM 12's third seat. Cosmonaut-researcher is a designation roughly equivalent to the designation Payload Specialist in the U.S. Shuttle program. As cosmonaut-researcher, Sharman was called Ozon Tri ("Ozone-3").

Spacecraft swaps and partial crew exchanges in the space station era also changed code name conventions. Crew code names travel with the commander, and crew members take on the code name of the commander with whom they travel. For example, Helen Sharman returned to Earth in Soyuz-TM 11 with commander Viktor Afanasyev (code name Derbent) and flight engineer Musa Manorov (Derbent Dva). She thus became Derbent Tri for her return to Earth. Sergei Krikalev became Donbass Dva after

Alexandr Volkov (code name Donbass) replaced Artsebarski as his commander aboard Mir.

In this work, crewmembers are listed commander first, flight engineer second, and cosmonaut-researcher last. Missions in which this convention does not hold true are noted.

1.3 The Original Soyuz (1966-1970)

The three-seater Original Soyuz (figure 1-6) was the first ancestor of the Soyuz-derived vehicles in use today. The Original Soyuz played much the same role in the Soviet manned lunar program as Gemini did in the U.S. manned lunar program. That is, it provided experience in essential techniques and technologies for lunar flight.

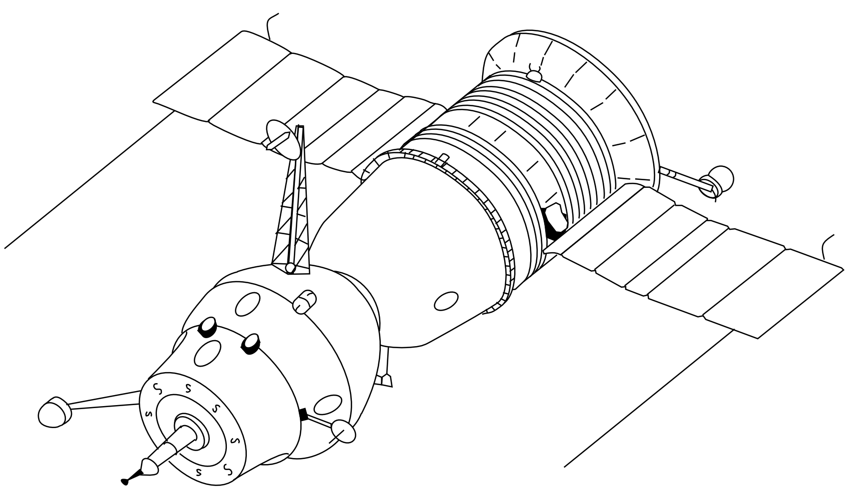

Figure 1-6. Original Soyuz spacecraft.

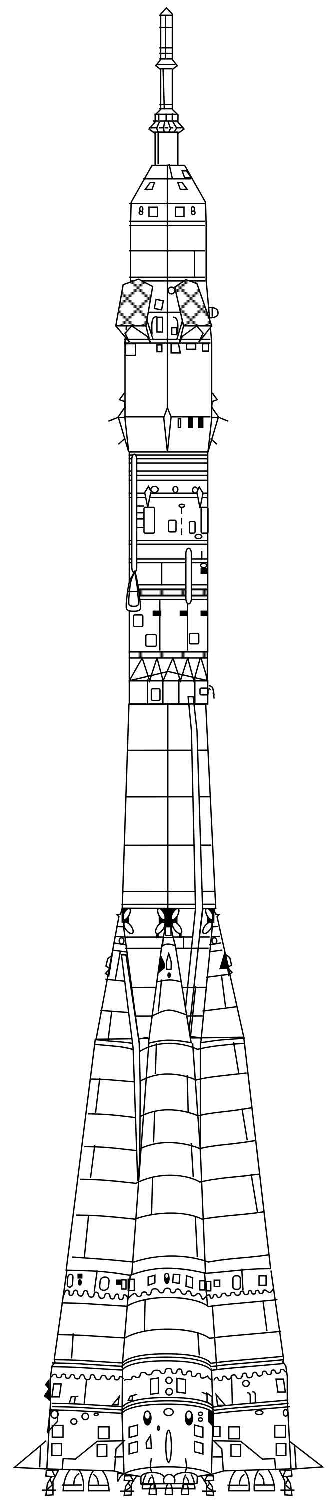

Figure 1-7. Soyuz rocket. With more than 1000 launches to its credit since 1963, the two-and-a-half-stage Soyuz rocket has flown more than any other. Propellants are liquid oxygen and kerosene. Weight of payload launched to 200-km, 51° circular orbit is 7000 kg.

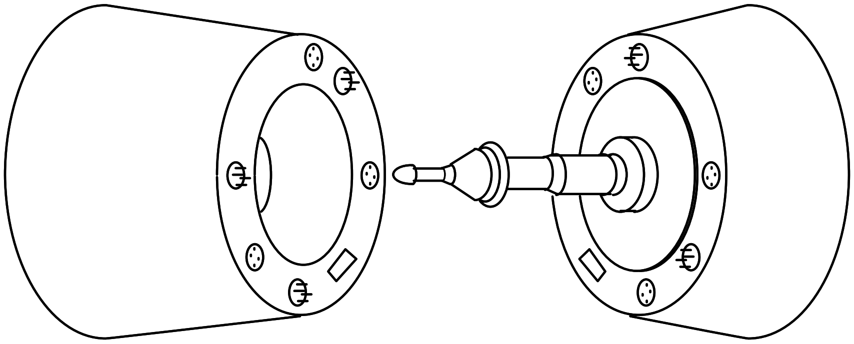

Figure 1-8. Original Soyuz probe and drogue docking system. The active unit (right) consisted of a probe and latches; the passive unit, a receiving cone, socket, and catches. The passive unit's frustum was longer than the active unit's because it was designed to accept the probe. The probe acted as a shock absorber. Its tip contained sensors which registered contact with the cone, disabled the active craft's control system, and fired thrusters on the active craft to force the spacecraft together. The probe entered the socket at the apex of the cone, whereupon catches and a restraining ring locked it into place. Plugs and sockets in the rims of the docking units then established electrical and intercom connections between the spacecraft.[21]

1.3.1 Original Soyuz Specifications

Launch weight	about 6600 kg
Launch vehicle	Soyuz
Length	about 9 m
Span across solar arrays	10 m
Diameter of habitable modules	2.2 m
Maximum diameter	2.72 m
Habitable volume	10 m^3
Number of crew	1-3

1.3.2 Original Soyuz Notable Features

- Launched on a Soyuz rocket (figure 1-7). All Soyuz variants except the L1 and L2 have launched on this rocket.
- Except during EVA, its crew did not wear space suits.
- Made no provision for internal crew transfer after docking. Crew transfer involved EVA between two docked craft.
- Used a simple probe and drogue docking system (figure 1-8).
- Had handrails on the outside of its orbital module to facilitate external crew transfer after docking.
- Orbital module served as an airlock for external crew transfer; it also served as a laboratory, a storage compartment, and living space for the crew.
- Carried a toroidal tank in its aft skirt. This was an electronics compartment or propellant tank (it was never flown carrying propellants).

1.3.3 Original Soyuz Mission Descriptions

Dates are launch to landing.

Cosmos 133 November 28-30, 1966

First flight of the Original Soyuz. It carried no crew. The spacecraft could not be controlled while its main engine was firing, so could not be positioned for reentry. Controllers ordered it to self-destruct when it looked as if it would land in China.[22]

Launch failure December 1966

An on-pad explosion of its Soyuz launch vehicle ended this second test of the Soyuz spacecraft. The Soyuz orbital module and descent module were dragged to safety by the launch escape system.[23]

Cosmos 140 February 7-9, 1967

Cosmos 140 was able to follow the nominal Soyuz Earth-orbital mission plan up to reentry. During reentry a maintenance plug in the forward heatshield burned through, causing severe structural damage. The descent module crashed through ice in the Aral Sea and sank in 10 m of water.[24]

Soyuz 1 April 23-24, 1967

Vladimir Komarov
Crew code name—Rubin

First manned Soyuz spacecraft, meant to play the active role in a docking with a second spacecraft which would have been called Soyuz 2. Soyuz 2 would have carried three cosmonauts, two of whom would have transferred by EVA to Soyuz 1. The mission was scheduled to coincide with the anniversary of Lenin's birth. Upon reaching orbit, one of the craft's two solar arrays failed to deploy. Exhaust residue from the attitude control jets fouled the craft's ion orientation sensors, making control difficult. The second Soyuz launch was cancelled. Komarov carried out a manual reentry on orbit 18, after a failed attempt at an automated reentry on orbit 17. During descent, a "pressure design flaw" prevented the parachute from deploying properly. The Soyuz 1 descent module crashed and cosmonaut Komarov was killed.[25]

Cosmos 186 October 27-31, 1967

Cosmos 188 October 30-November 2, 1967

Automated docking between two unmanned Soyuz. Cosmos 186, launched first, was the active spacecraft.[26]

Cosmos 212 April 14-19, 1968

Cosmos 213 April 15-20, 1968

Automated docking between two unmanned Soyuz, similar to the Cosmos 186-Cosmos 188 docking flight.

Cosmos 238 August 28-September 1, 1968

Unmanned Soyuz meant either to requalify the Original Soyuz for manned flight after the Soyuz 1 accident or to serve as a docking target for a manned Soyuz spacecraft, launch of which had to be cancelled. Presumably Cosmos 238 would have been renamed Soyuz 2 if the manned craft (which would have been called Soyuz 3) had reached orbit.[27]

Soyuz 2 October 25-28, 1968

Soyuz 3 October 26-30, 1968

Georgi Beregevoi
Crew code name—Argon

Soyuz 3 was the active craft for the docking with the unmanned Soyuz 2 craft. The craft were unable to dock, though automatic systems brought the ships to within 200 m, and Beregovoi brought Soyuz 3 still closer to Soyuz 2 under manual control.[28, 29] Before launch the flight was called a prelude to manned space stations.[30]

Soyuz 4 January 14-17, 1969

Launch crew—Vladimir Shatalov
Crew code name—Amur

Landing crew—Vladimir Shatalov, Yevgeni Khrunov, Alexei Yeliseyev
Crew code name—Amur

Soyuz 5 January 15-18, 1969

Launch crew—Boris Volynov, Yevgeni Khrunov, and Alexei Yeliseyev
Crew code name—Baykal

Landing crew—Boris Volynov
Crew code name—Baykal

Soyuz 4 and Soyuz 5 carried out the first docking between manned Soviet spacecraft. Soyuz 4 played the active role in the docking. After docking, Soyuz 4 and Soyuz 5 were described as comprising the first multimodular space station.[31] More importantly, however, this was a test of rendezvous and docking and EVA procedures, with implications for the manned lunar program.[32] Yeliseyev and Khrunov transferred by EVA from Soyuz 5 to Soyuz 4. The two craft remained docked for 4 hr, 35 min.

Afanaseyev states that, after Soyuz 4 and Soyuz 5, two additional Soyuz craft were to have rendezvoused and docked to prepare for manned lunar landing missions. However, the remaining Original Soyuz craft were "re-assigned for the performance of engineering experiments in a group flight . . . and in a long-duration flight."[33] These were the Soyuz 6, 7, and 8 and Soyuz 9 missions, respectively.

Soyuz 6 October 11-16, 1969

Georgi Shonin, Valeri Kubasov
Crew code name—Antey

Soyuz 7 October 12-17, 1969

Anatoli Filipchenko, Viktor Gorbatko, Vladislav Volkov
Crew code name—Buran

Soyuz 8 October 13-18, 1969

Vladimir Shatalov, Alexei Yeliseyev
Crew code name—Granit

A unique joint flight of three Original Soyuz spacecraft carrying a total of seven cosmonauts. Soyuz 6 was a test of equipment to be used on future space stations. It carried welding equipment in its orbital module and had no docking apparatus. It was also intended to photograph the docking between Soyuz 7 and Soyuz 8, which did not occur.[34]

Soyuz 9 June 1-19, 1970

Andrian Nikolayev, Vitali Sevastyonov
Crew code name–Sokol

Remained aloft for 17 days, 17 hr, beating the U.S. space endurance record set by the Gemini 7 astronauts in 1965. The mission gathered biomedical data in support of future space station missions.

1.4 L1 (Zond): Circumlunar Spacecraft (1967-1969)

The L1 (Zond) (figure 1-9) was meant to carry one or two cosmonauts on a circumlunar flight. It never flew manned, but did complete several unmanned circumlunar missions.

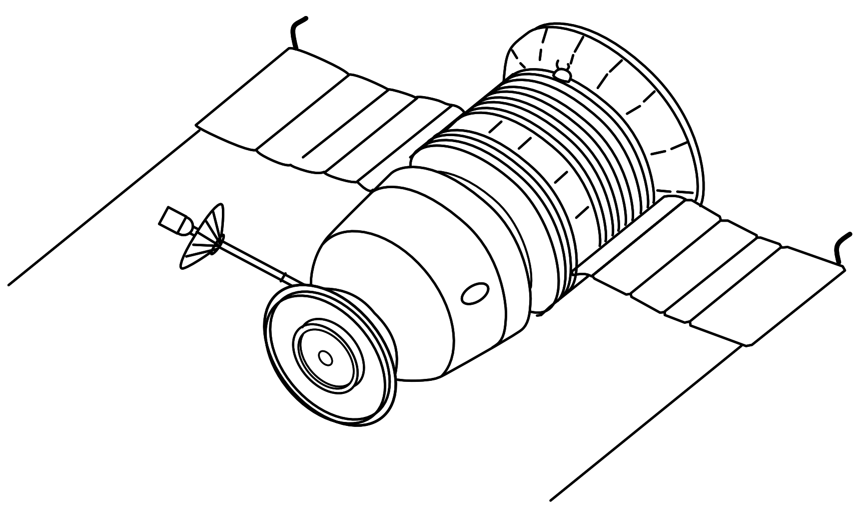

Figure 1-9. L1 (Zond) circumlunar spacecraft.

1.4.1 L1 Specifications

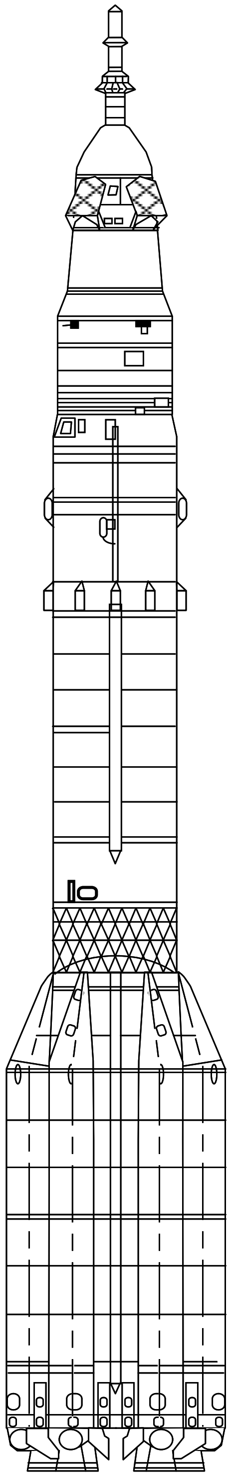

Figure 1-10. Proton configured for L1 (Zond). Note the modified Soyuz shroud (top).

Launch weight (Zond 4 through 6)	5140 kg
Launch weight (Zond 7, 8)	5390 kg
Launch vehicle	Proton (four-stage); N-1
Length at launch	5.0 m
Length after support cone ejection	4.5 m
Span across solar arrays	9 m
Diameter of habitable module	2.2 m
Maximum diameter	2.72 m
Habitable volume	3.5 m^3
Number of crew	1-2*

*Never carried a crew.

1.4.2 L1 Notable Features

- Typically launched atop a four-stage Proton rocket (figure 1-10). The first three stages burn N_2O_4 and UDMH propellants. The Block D fourth stage, with its restartable motor, was originally intended for use with the N-1 rocket as part of the manned lunar landing program. It burns kerosene and liquid oxygen. It would have inserted the L2 and L3 into lunar orbit and provided most of the ΔV for powered descent of the L3 to the lunar surface. The L1 used it for translunar injection.
- Launched under a modified Soyuz launch shroud.
- Launch escape system's solid rocket motors smaller than those on the Soyuz shroud, in keeping with the lower mass it was designed to drag to safety.
- Had an inverted cone-shaped support structure around the hatch at the top of the descent module to attach it to the Soyuz launch shroud, and through that to the escape system. This was ejected in Earth parking orbit or after translunar injection.
- Lacked an orbital module.
- Lacked docking systems.
- Lacked the toroidal instrument container located in aft skirt of Original Soyuz.
- Lacked intermodule umbilical linking the service module to the orbital module.
- Had no backup main engine in the version flown. The sole engine was based on the Soyuz KDU-35 system. Propellant mass was only 400 kg.
- Had shorter solar arrays than Soyuz.
- Had an ablative heat shield thicker than that on the Original Soyuz to withstand atmospheric friction heating at lunar reentry velocities.
- Carried an umbrella-like high-gain antenna on its descent module.

1.4.3 L1 Mission Descriptions

Dates are launch to reentry (where applicable).

Cosmos 146 March 10-18, 1967

First flight of a Soyuz-based L1 vehicle in space. The version flown was, however, simplified, because the flight was intended primarily as a test of the Block D fourth stage of the Proton launch vehicle. The Block D engine fired twice in the course of the flight.

Cosmos 154 April 8-10, 1967

Block D could not fire, possibly because of premature ejection of its ullage motors (used to settle fuel in the stage after weightless coast in parking orbit). Because of this, Cosmos 154 failed to test the high-velocity reentry characteristics of the L1.[35]

Launch failure September 28, 1967

One of the six engines in the Proton first stage failed to operate. The emergency escape system dragged the descent module free of the errant rocket.

Launch failure November 22, 1967

One of the four engines in the second stage of the Proton failed to operate. The emergency escape system activated. The land landing rockets fired prematurely during parachute descent.

Zond 4 March 2-9, 1968

First L1 spacecraft called Zond. Zonds 1 through 3 were interplanetary probes unrelated to Soyuz. The unmanned Zond 4 spacecraft flew to lunar distance, but away from the Moon. It was lost during reentry because of an attitude control failure.[36, 37]

Launch failure April 23, 1968

Escape system triggered mistakenly during nominal Proton second stage operation.

Zond 5 September 14-21, 1968

Successfully circumnavigated the Moon, but its guidance system failed, resulting in an unplanned splashdown in the Indian Ocean. It was recovered and shipped to the Soviet Union via India.

Zond 6 November 10-17, 1968

Tested the worldwide tracking system set up for Soviet manned lunar missions and photographed the Earth. During reentry, the descent module depressurized.

The parachute deployed too early, and the module crashed. Film cassettes were recovered, however.

Launch failure January 20, 1969

Second and third stages of the Proton rocket performed poorly, so the vehicle had to be destroyed. The launch escape system functioned as designed.

Launch failure February 20, 1969

First N-1 rocket (figure 1-13) flight test; N-1 number 31 carried a simplified L1 on what was to have been a lunar flyby mission. The engine control system incorrectly shut down two of the 30 NK-15 engines in the rocket's first stage before it cleared the tower. Excessive vibration ruptured lines in engine number 12. At 55 sec, a fire started in the first stage. It burned through the engine control system cables at 69 sec, shorting out the system and shutting down the first-stage engines. Still afire, N-1 number 31 fell to Earth 50 km downrange, exploding on impact. The simplified L1 descent module ejected and landed safely.

Launch failure July 3, 1969

Launched on the second N-1 rocket to fly (number 51). Less than a second after liftoff, a loose metallic object caught in the oxidizer pump of the number 8 engine of the N-1 first stage. The engine exploded, damaging the first stage cable runs and several adjacent engines. A fire broke out, and the rocket fell back onto and destroyed its launch pad. The simplified L1 payload ejected using the launch escape system.

Zond 7 August 7-14, 1969

Most successful of the L1 flights. Its Proton launch vehicle performed nominally. Zond 7 photographed the lunar farside from 2000 km altitude, performed a skip reentry, and landed safely in the recovery area in the Soviet Union.

Zond 8 October 20-27, 1970

Mishin claims that its ballistic reentry and splashdown in the Indian Ocean were planned.[38] Afanaseyev and other sources state that Zond 8 suffered control problems.[39] It shot photos of the farside of the Moon on October 24 during flyby at 1200 km altitude.

1.5 L2 (Lunar Orbit Module): Lunar Mission Command Ship (1971-1974)

No L2 (figure 1-11) ever reached orbit. The spacecraft was meant to play the equivalent role of the U.S. manned lunar program's Apollo CSM. An L2 is on display at the Moscow Aviation Institute. For an L2/CSM comparison, see figure 4-3. Figure 1-12 depicts the Soviet manned lunar landing profile.

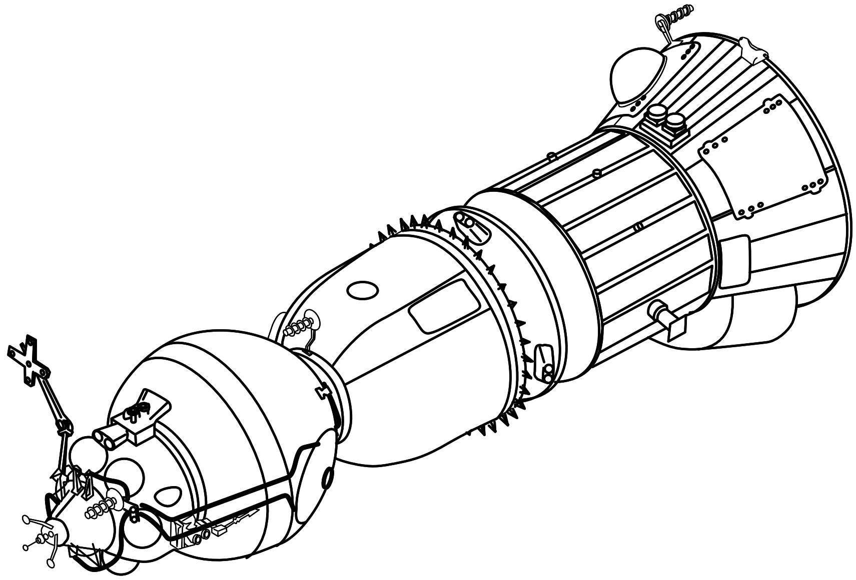

Figure 1-11. L2 (Lunar Orbit Module). At the front of the spacecraft (left) is the Aktiv unit of the lunar mission Kontakt docking system.

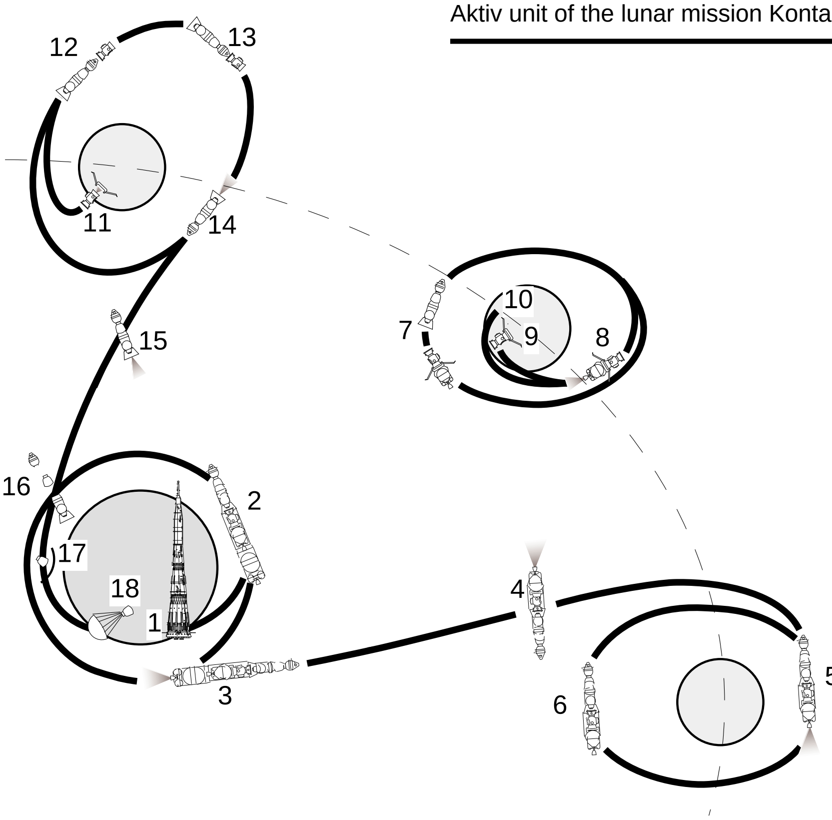

Figure 1-12. N-1/L3 lunar mission profile. 1. N-1 rocket liftoff. 2. LRS Earth orbit insertion. 3. LRS translunar injection using Block G rocket stage. Block G separates. 4. Midcourse correction using Block D rocket stage. 5. Lunar orbital insertion using Block D rocket stage. 6. Single cosmonaut transfers from L2 to L3 by EVA. 7. L3 lunar lander and Block D rocket stage separate from L2 Lunar Orbit Module. 8. Deorbit burn and powered descent using Block D rocket stage. Expended Block D rocket stage separates from the L3 1 to 3 km above the lunar surface. L3 continues powered descent using its own main or backup rocket motor. 9. L3 touchdown on Moon. 10. Expended Block D rocket stage crashes on Moon. 11. L3 liftoff using same engines used for final descent. Legs are left on Moon. 12. L2 rendezvous and docking with L3. 13. Cosmonaut transfers from L3 to L2 by EVA. L3 discarded. 14. Trans-Earth insertion burn using L2 main engine. 15. Midcourse correction using L2 main engine. 16. Orbital module and service module discarded. 17. Descent module reentry. 18. Parachute descent and touchdown on land.

1.5.1 L2 Specifications

Launch weight	14,500 kg (estimated)
Launch vehicle	N-1
Length	12 m (estimated)
Diameter of living module	2.3 m
Diameter of descent module	2.2 m
Diameter of service module	2.2 m
Maximum diameter (across aft frustum)	3.5 m (estimated)
Habitable volume	9 m^3 (estimated)
Number of crew	2

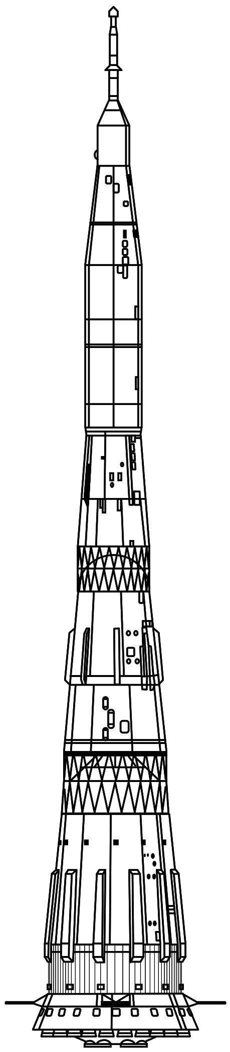

Figure 1-13. N-1 rocket configured for lunar flight. The basic rocket consisted of the Block A first stage, the Block B second stage, and the Block V third stage. All stages burned liquid oxygen and kerosene. For lunar missions the LRS was added. The N-1 would have delivered about 100,000 kg to low-Earth orbit. (For a comparison with the U.S. Saturn V rocket, see figure 4-1).

1.5.2 L2 Notable Features

- Flight-test version, dubbed T1K, was to have been launched on a Proton rocket. However, the T1K flight-test program was cancelled in favor of all-up testing on the N-1 rocket (figure 1-13).[40] Similarly, in 1965, the Apollo program opted for unmanned all-up testing.
- Launched atop an N-1 rocket with a L3 lunar lander and the Block G and Block D rocket stages. Together they formed the lunar rocket system (LRS) (figure 1-14).
- Long service module contained a large spherical propellant tank divided by a membrane into oxidizer and fuel sections. It provided propellant for a main propulsion system different from the Original Soyuz design. The L2 main engines were not used until after the L3 and D unit separated from the L2 in lunar orbit. The propulsion system provided ΔV for trans-Earth insertion and course corrections during return to Earth.
- Had enlarged conical skirt at service module aft.
- Carried a spring-loaded probe docking system, called Aktiv ("active"), which was designed to penetrate and grip a "honeycomb" drogue docking fixture on the L3. Together they were called

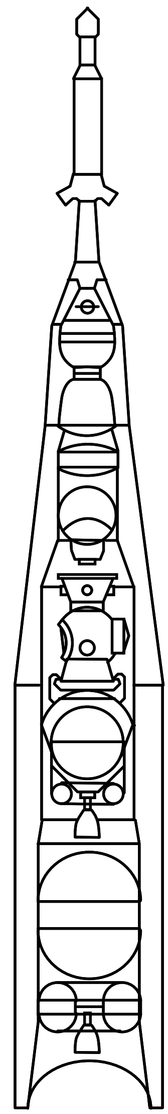

Figure 1-14. Lunar rocket system. Consisted of (bottom to top) the Block G and Block D rocket stages, the L3 lander, and the L2 command ship.

Kontakt (figure 1-15). The docking system was to be used only once during the mission, after the L3 had completed its lunar landing mission and returned to orbit. Little docking accuracy was required to link the spacecraft firmly enough to let the moonwalking cosmonaut return to the L2 by EVA.

- Made no provision for internal crew transfer after docking.
- Orbital module had an EVA hatch larger than the one on the Original Soyuz.
- Electronics more complex than those on the Original Soyuz, in keeping with its more demanding mission.
- Oxygen/hydrogen fuel cells and batteries replaced the solar arrays of the Original Soyuz.
- Descent module had a heat shield thicker than that of the Original Soyuz, permitting it to withstand reentry at lunar return speeds.

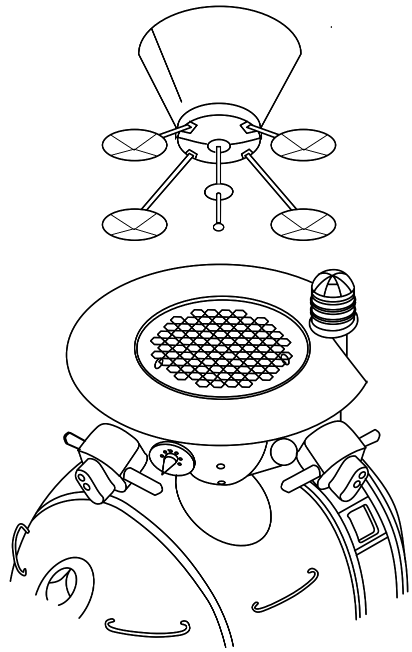

Figure 1-15. Kontakt docking system. Never used in space, the system was designed for the Soviet lunar program. The Aktiv unit (top) was located at the front of the L2, while the passive unit was located on top of the L3 lander.

1.5.3 L2 Mission Descriptions

None of the planned L2 missions reached orbit.

Launch failure June 27, 1971

The launch shroud of the third N-1 to be launched (number 61) covered L2 and L3 test articles, and was topped by a dummy launch escape system. Immediately after liftoff, eddies developed in the exhaust streams of the 30 NK-15 engines in the N-1 first stage; this, coupled with roll control and aerodynamic inadequacies, allowed the rocket to roll about its long axis. At 48 sec, the rocket began to disintegrate under the torque generated by the roll. The top part of the N-1, including the test articles, fell off. It crashed near the N-1 launch pad, while the lower part of the rocket flew on. At 51 sec, the engine control system automatically shut down the first stage engines. The lower stages impacted 20 km downrange and exploded, gouging a crater 30 m wide.

Launch failure November 23, 1972

The launch shroud of the fourth N-1 to fly (number 71) contained an L3 mockup and a prototype L2. Ninety sec into the flight, the six central engines in the first stage shut down as planned. At 104 sec, lines leading into the deactivated engines burst under pressure from backed-up kerosene fuel. Kerosene spilled on the still-hot engines. The last N-1 to fly exploded 107-110 sec after liftoff, just 40 sec before planned first-stage separation. Another account traces this failure to a foreign object in the number 4 engine oxidizer pump, making it a near-replay of the failure which destroyed N-1 number 51 in July 1969. The launch escape system plucked the descent and orbit modules of the L2 free of the N-1. This L2 was the last Soyuz variant to launch on a rocket other than the Soyuz launcher.

Scheduled launch August 1974

The fifth N-1 flight (scheduled for August 1974) would have carried fully operational L2 and L3 vehicles on an unmanned rehearsal of a manned lunar mission, but the flight was postponed, then cancelled, along with the N-1 project.

1.6 L3: Lunar Lander (1970-1974)

The L3 (figure 1-16) was successfully tested in simplified form in Earth orbit, but the failure of the N1 rocket program prevented it from reaching the Moon. It was designed to deliver a single cosmonaut to the lunar surface. L3 landers and associated hardware are on display in several locations in Russia: the Moscow Aviation Institute, Mozhalsk Military Institute in St. Petersburg, NPO Energia in Moscow, Kaliningrad Technical Institute, and NPO Yuzhnoye in Dnyepetrovsk. For a comparison of the L3 with the Apollo LM, see figure 4-2.

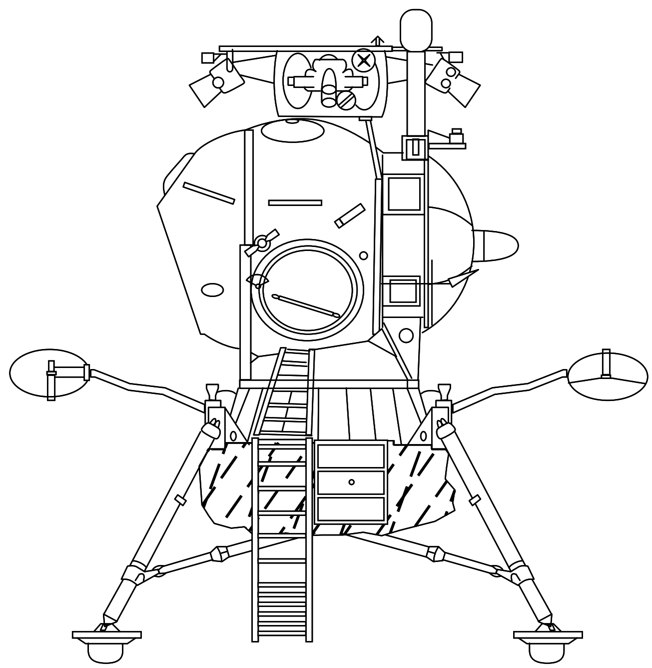

Figure 1-16. L3 lunar lander. The flat, downward-facing face (left) of the ovoid pressure cabin holds the round viewport (not visible). The Kontakt system passive unit is at cabin top, and two landing radar booms extend at left and right. Nozzles of two solid-fueled hold-down rockets are visible at the tops of the legs, near the bases of the radar booms.

1.6.1 L3 Specifications

Launch weight	5500 kg
Launch vehicle	Soyuz; N-1
Height	5.2 m
Diameter of habitable module	2.3 m by 3 m
Span across deployed landing gear	4.5 m (estimated)
Habitable volume	about 4 m^3 (estimated)
Number of crew	1

1.6.2 L3 Notable Features

- Not a Soyuz derivative per se, though it was developed as part of the same program which produced the Soyuz-derived L1 and L2 vehicles. L3 was to have been used with the L2 vehicle.
- Flight-test version of the L3 was called T2K. It was launched for Earth-orbital tests on a modified Soyuz rocket with an enlarged ("large caliber") launch shroud.[42] T2K had its landing legs replaced by two units for returning systems telemetry to Earth.
- For lunar landing missions, was to be launched on a three-stage N-1 rocket, within a shroud, as part of the LRS. The LRS consisted of Block D and Block G rocket stages, the L3 lunar lander, and the L2 command ship.
- The Block D stage carried out midcourse corrections en route to the Moon and braked the L2 and L3 into lunar orbit. After lunar orbit insertion, a single cosmonaut exited the L2 through the hatch in its living module, traversed the length of the L2 with the aid of a mechanical arm, and entered the L3 through a port in the shroud enclosing it. The shroud then fell away as the Block D and L3 separated from the L2.
- Restartable rocket motor on the Block D provided most of the ΔV for powered descent to the lunar surface. The Block D was to be depleted and discarded about 1 to 3 km above the surface. After it was discarded, the Block D crashed on the lunar surface a short distance from the L3 touchdown point.
- Had one single-nozzle main engine on its longitudinal axis, one two-nozzle backup engine, and four verniers. The lozenge-shaped propulsion unit was dubbed the Ye unit. Loaded with N_2O_4 and UDMH propellants, the Ye unit weighed approximately 2250 kg (half the weight of the L3). N_2O_4 was stored in a toroidal tank surrounding the engine units. This fuel load gave the L3 about 1 min of flight time before it began to cut into its ascent reserves.
- Control system was the first in the Soviet program based on an onboard computer. Inputs were derived from a three-axis gyro-stabilized platform, landing radar, and a collimating sight. The cosmonaut would use the sight to spot the selected landing site, then input the coordinates to the computer. Computer commands were verified using Sun and planet sensors.
- Two 40-kg thrusters gave pitch control; two more gave yaw control; and four 10-kg thrusters gave roll control. The system was exactly duplicated on a separate control circuit to provide redundancy.[43]
- Lone cosmonaut stood before a large, round, downward-angled window; controlled flight manually using a control panel located to the right of the window and control sticks. A smaller window faced upward to provide visibility during docking.
- Cabin atmosphere was oxygen/nitrogen at 560 mm/Hg, with slightly less nitrogen than the terrestrial mix normally used in Soviet spacecraft.[44]
- Relied on five chemical batteries for its electricity. Two were located on the ascent portion of

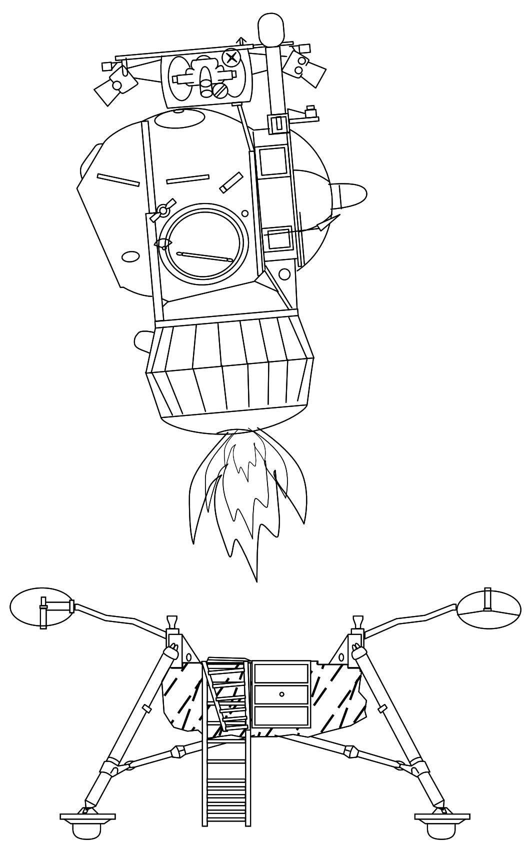

Figure 1-17. L3 ascent.

the spacecraft and three were left behind on the Moon.

- Four solid rocket hold-down motors, with upward-pointing nozzles, were fired at touchdown to help ensure that the L3 would not tumble on contact with the irregular lunar surface.[45]
- Landing gear designed to contend with a lateral velocity of 1 m/sec at touchdown on hard soil with a 20° slope.
- Cg adjustments possible by redistribution of water in the tanks of the evaporator cooling system.[46]
- Had an oval hatch designed to accomodate the cosmonaut's special Krechet lunar space suit.[47, 48]
- Left only its landing legs, landing radar, and a few other components behind on the Moon. Unlike the Apollo LM, which used separate descent and ascent propulsion systems, the L3 used the same main propulsion system for final descent and ascent. At liftoff from the lunar surface both the main and backup propulsion systems were activated. If both systems were found to be operating normally, the backup system was then shut down (figure 1-17).[49]
- L3 drogue docking unit extremely simple and tolerant of misalignment. It was a 100-cm aluminum plate, containing 108 recessed hexagons, each 6 cm in diameter. In the nominal mission it would be used only after the L3 ascended from the lunar surface. The L2's docking probe (Aktiv unit) had only to enter one of the hexagons to create a connection firm enough to allow the L3 cosmonaut to complete a space walk back to the L2 spacecraft. A flat aluminum apron protected the top of the L3 from damage in the event of gross misalignment by the L2. The combined L2/L3 docking system was called Kontakt.[50, 51]

1.6.3 L3 Mission Descriptions

Dates are launch to approximate end of maneuvers. Current status is given in the text.

Cosmos 379 November 24, 1970-about December 1, 1970

The first L3 test flight (in T2K form) in Earth orbit simulated propulsion system operations of a nominal lunar landing mission. Cosmos 379 entered a 192 to 232 km orbit. Three days later it fired its motor to simulate hover and touchdown, in the process increasing its apogee to 1210 km. After a simulated stay on the Moon, it increased its speed by 1.5 km/sec, simulating ascent to lunar orbit. Final apogee was 14,035 km. The spacecraft reentered on September 21, 1983.

Cosmos 398 February 26, 1971-about March 3, 1971

This T2K flight successfully tested L3 contingency modes. It was in a 1811 km by 185 km orbit as of March 31, 1994.

Launch failure June 27, 1971

The third flight of the N-1 rocket carried mockup L2 and L3 vehicles. They crashed near the launch pad when the N-1 broke apart (see section 1.5.3).

Cosmos 434 August 12, 1971-about August 18, 1971

The final test of the L3 in unmanned T2K form was as successful as the first two. The flight was a test of L3 contingency modes. Cosmos 434 performed the longest burn of the three T2K tests. It finished in a 186 km by 11,804 km orbit. The imminent decay from orbit of Cosmos 434 in 1980-1981 raised fears that it might carry nuclear fuel. These fears were lent urgency by memories of the recent reentry of the Soviet Cosmos 954 nuclear-powered surveillance satellite over Canada (1977) and of Skylab over Australia (1979). Cosmos 434 burned up over Australia on August 22, 1981. To allay fears of a nuclear catastrophe, representatives of the Soviet Foreign Ministry in Australia admitted that Cosmos 434 was an "experiment unit of a lunar cabin," or lunar lander.[53]

Launch failure November 23, 1972

Failure of the first stage of the fourth and last N-1 rocket to fly consumed an L3 test article (see section 1.5.3).

1.7 Salyut 1-Type Soyuz (1971)

The Salyut 1-type Soyuz (figure 1-18) was the Original Soyuz with a new docking system. Its second manned flight (Soyuz 11, 1971) ended in disaster, forcing a redesign.

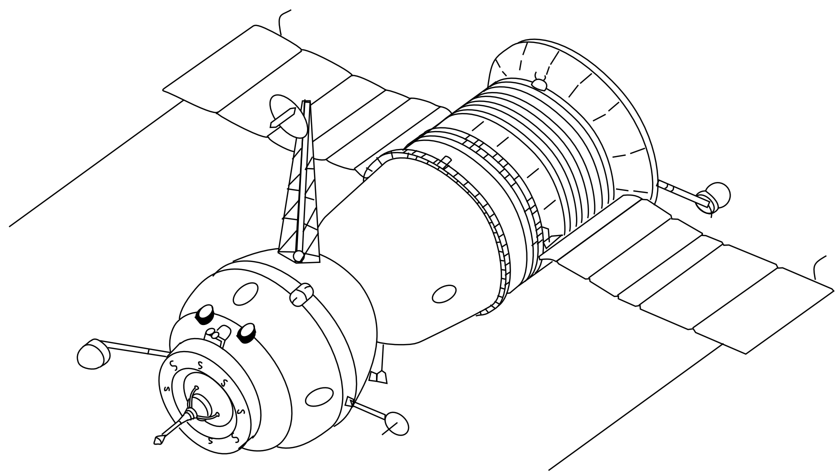

Figure 1-18. Salyut 1-type Soyuz. This was the Original Soyuz upgraded for Salyut space stations. The probe and drogue docking system (left) permitted internal transfer of cosmonauts from the Soyuz to the station.

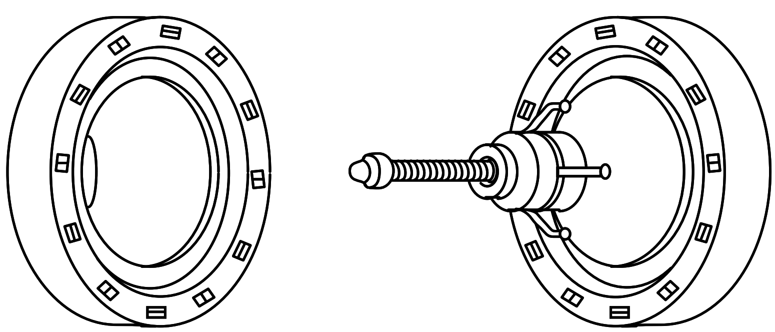

Figure 1-19. Soyuz internal transfer docking unit. This system is used today for docking spacecraft to Mir. The active craft inserts its probe into the space station receiving cone. The probe tip catches on latches in the socket at the apex of the cone. Motors then draw the two spacecraft together. Latches in the docking collars catch, and motors close them. Fluid, gas, and electrical connections are established through the collars. After the cosmonauts are certain the seal is airtight, they remove the probe and drogue units, forming a tunnel between spacecraft and station. At undocking, four spring push rods drive the spacecraft apart. If the latches fail to retract, the spacecraft can fire pyrotechnic bolts to detach from the station.

1.7.1 Salyut 1-Type Soyuz Specifications

Launch weight	about 6800 kg
Length	about 7.5 m
Span across solar arrays	10 m
Diameter of habitable modules	2.2 m
Maximum diameter	2.72 m
Habitable volume	about 10 m^3
Number of crew	3

1.7.2 Salyut 1-Type Soyuz Notable Features

- Carried three crew, who did not wear space suits during flight.
- Equipped with a probe and drogue docking system permitting internal crew transfer (figure 1-19).
- Carried solar arrays which could be tied into the Salyut 1 power system, increasing the amount of energy available to space station systems.
- Lacked the toroidal tank or pressurized instrument compartment in the aft skirt of the Original Soyuz spacecraft.
- Orbital module was shortened to 2.65 m in length (from about 4 m) by deletion of the external crew transfer docking system probe and frustum, and a docking system for internal crew transfer was added.

1.7.3 Salyut 1-Type Soyuz Mission Descriptions

For information on Salyut operations during these Soyuz missions, see section 2.2.3. Dates are launch to landing.

Soyuz 10 April 22-24, 1971

Vladimir Shatalov, Alexei Yeliseyev, Nikolai Rukavishnikov
Crew code name—Granit

Carried three crew to Salyut 1, the first space station, in April 1971. A fault in the docking unit prevented them from entering the station.

Soyuz 11 June 6-29, 1971

Georgi Dobrovolski, Vladislav Volkov, Viktor Patseyev
Crew code name—Yantar

Docked successfully with Salyut 1 on June 7, 1971. On June 27 the three-person Soyuz 11 crew reactivated Soyuz 11 and began packing experiment results for return to Earth. At 1828 UT, June 29, they undocked. They wore hooded flight suits which protected them against the descent module's chill, but not against depressurization. The Yantars fired their Soyuz main engine to deorbit. Explosive bolts for separating the orbital and service modules from the descent module then fired simultaneously, rather than sequentially as planned. The abnormally violent separation jarred loose a 1-mm pressure equalization seal in the descent module which was normally pyrotechnically released at lower altitude. The atmosphere in the descent module vented into space within 30 sec. The crew rapidly lost consciousness and died. The descent module landed automatically in Kazakhstan without additional incident at 2317 UT.[54]

1.8 Soyuz Ferry (1973-1981)

The Soyuz Ferry (figure 1-20) replaced the Salyut 1-type Soyuz. It transported crews of two cosmonauts to Salyut 3, Salyut 4, Salyut 5, and Salyut 6.

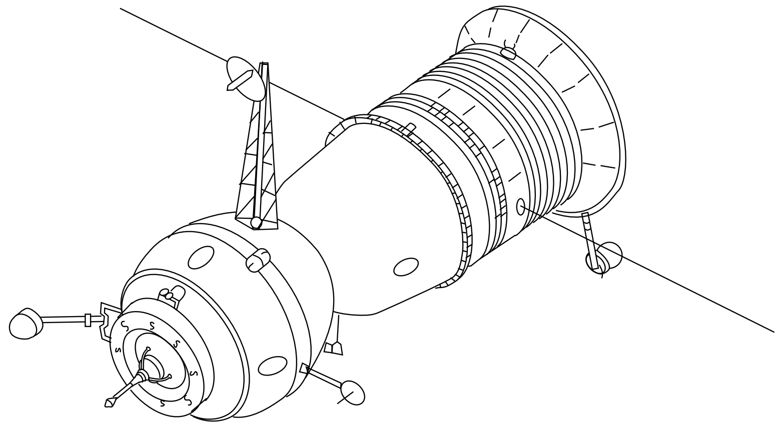

Figure 1-20. Soyuz Ferry.

1.8.1 Soyuz Ferry Specifications

Launch weight	6800 kg
Launch vehicle	Soyuz
Length	about 7.5 m
Diameter of habitable modules	2.2 m
Maximum diameter	2.72 m
Habitable volume	9.5 m^3
Number of crew	2

1.8.2 Soyuz Ferry Notable Features

- Space and weight devoted to a third crewman on the Original Soyuz was devoted to life support equipment designed to supply two crewmen in space suits.
- Deletion of solar arrays.
- Addition of batteries. These were lighter than solar arrays, permitting more cargo to be carried. The batteries restricted the Soyuz Ferry to only 2 days of autonomous flight.
- Igla (“needle”) automatic rendezvous and docking system.
- Whip antennas were relocated from the leading edges of the solar arrays to the sides of the service module.

1.8.3 Soyuz Ferry Detailed Description

Soyuz designer Konstantin Feoktistov provided a detailed description of the Soyuz Ferry near the end of its career in a brochure published in Moscow in 1980.[55] Many of the Soyuz Ferry attributes he described, listed below, apply equally to other versions of Soyuz.

Descent capsule L/D ratio of 0.2-0.3 permitted a landing site to be targeted within several kilometers. Nominal descent deceleration load was 3-4 g’s. The descent capsule had three windows. The central window was fitted with a “viewer and orientation device” for “triaxial orientation using the horizon and features on Earth over which the spacecraft passed.” The device also served as a periscope during rendezvous and docking operations, permitting the crew to see around the forward orbital module. Most of the cargo carried by a Soyuz Ferry to an orbiting Salyut space station was carried in the orbital module. A small amount was carried in the descent module.

The service module consisted of the transfer frame and the instrument-service section. The transfer frame, which joined the service module to the descent module, was unpressurized and held several docking and orientation engines (attitude control engines) and fuel tanks, purging tanks (for providing pressurant to drive propellant from the propellant tanks to the engines), the small exterior radiator for the thermal control system, and the command radio link apparatus, including a ring-shaped exterior antenna structure surrounding the forward end of the service module. The instrument-service section had electronic equipment in a lozenge-shaped pressurized container, the main propulsion system ("rendezvous-correction power plant. . . with two engines [main and backup]"), docking and orientation engines, the large hull-mounted thermal control system radiator, batteries, and orientation system sensors and antennas.

The Soyuz Ferry radio system transmitted and received voice, telemetry, television, and control command communications. Communications were relayed through ground stations and shipborne tracking stations for periods ranging from minutes to tens of minutes. If continuous telemetry were required, onboard recorders could store data for playback when the spacecraft was in range of a surface station. The Soviets also used shortwave frequencies to transmit telemetry data when out of range of a surface tracking facility.

Propulsion, orientation, radio, life support, thermal control, electrical power supply, and descent systems were automated (through program-timing devices) and could be controlled from the Flight Control Center (Russian acronym TsUP) by radio. Onboard manual controls were also available. Automatic, TsUP-operated, and onboard manual controls were all part of the onboard complex control system, which included "logical devices, commutators, the electrical automation (for connecting the electrical power supply of the instruments and systems), the control panel, and the command signal devices." While it was attached to the station, the condition of the dormant Soyuz Ferry was periodically checked by the TsUP and by the onboard crew.

The "orientation and motion control system" (Russian acronym SOUD) included "the infrared plotter of the local vertical" and ion sensors, "gyroscopic angle gauges and angular velocity gauges," the rendezvous radio system providing relative motion data during rendezvous, optical and television visual orientation instruments, "calculating and commutation instruments," and manual control and display systems.

The most complex SOUD operations involved rendezvous and docking. Feoktistov described the procedure in some detail. At Soyuz Ferry launch, the target Salyut orbited about 350 km high, in an orbit the plane of which passed through Baikonur Cosmodrome, the Soyuz Ferry launch site. Launch occurred as the station passed over the launch site. The ferry was inserted into a 190-200 km by 250-270 km orbit approximately 10,000 km behind the station. The ferry in its lower orbit caught up with the station. Up to four orbital correction burns using the main engine were made to match altitude and speed near the station. When the Soyuz closed to within 25 km of the Salyut, the automatic rendezvous phase of operations commenced. The two vehicles sensed each other and the automatic rendezvous radio equipment (the Igla system) switched on. The spacecraft maneuvered to keep their Igla antennas in line-of-sight so the Soyuz unit could obtain data on range, speed of approach, and orientation. The control computer on the Soyuz Ferry operated the main and docking and orientation engines based on the input data. The automatic rendezvous phase terminated when the distance between the Soyuz Ferry and the Salyut station dropped to 200 to 300 m. At that point the docking phase began. Automatic control could continue up to "mechanical contact of the docking units" of the two craft, or the crew could take manual control of the Soyuz and dock (Feoktistov asserted that crews were trained for manual dockings, though events seemed to indicate this was not always the case).

The main propulsion system propellant tanks used organic film (plastic?) membranes (bladders) to prevent pressurant from mixing with propellant. The system consisted of two engines (main and backup) with 400 kg of thrust each. The backup engine could fire only once, at full power. The attitude control system consisted of 14 10-kg thrust docking and orientation engines and 8 orientation engines with 1 kg of thrust each. The main propulsion system and the attitude control system did not share the same propellant supply on the Soyuz Ferry.

The launch control system controlled the descent capsule during return to Earth. Descent attitude control was provided by six engines with 15 kg of thrust each. At 12 km altitude the descent module speed was reduced to 240 m/sec. Parachutes were stored in two separate covered containers. The launch control system controlled the main and backup parachute systems and the landing solid rocket motors.

The electrical power supply was based on chemical batteries during autonomous operations. This replaced the solar arrays of earlier Soyuz versions. After docking with the Salyut, Soyuz Ferry systems operated on electricity provided by the station's solar arrays. The station also recharged the Soyuz Ferry's batteries while it was docked. Electrical connections between Salyut and Soyuz were maintained through plugs in their docking collars.

The thermal control system had two main loops and one auxiliary loop. The two main loops were connected through a liquid-liquid heat exchanger. Heat was radiated into space through radiator tubes on the outside of the instrument-service module. These gave it its characteristic ribbed appearance. The auxiliary loop connected with the Salyut thermal control system. It maintained temperature in the Soyuz Ferry crew compartment while it was docked to the station and powered down. Spacecraft surfaces not occupied by sensors, antennas, and engines (including those surfaces under the radiator panels on the service module) were covered with "packets of vacuum shielded thermal insulation."

The life support system provided life support for only a few days. It was modified from the earlier Soyuz to support space suits. Emergency supplies carried in the event that the descent module landed in an unpopulated area were also part of the life support system. While the Soyuz Ferry was docked to a Salyut, the life support system was turned off. An air duct (a rubberized fabric sleeve) was run from the Salyut through the open hatch into the Soyuz to keep its air from becoming stale.

1.8.4 Soyuz Ferry Mission Descriptions

Dates are launch to landing.

1.8.4.1 Soyuz Ferry Test Missions

Cosmos 496 June 26-July 2, 1972

Unmanned test of the redesigned Soyuz. It did not dock with a space station. Equipment for supporting two crewmen in space suits filled the space taken up by the third crewman on earlier Soyuz spacecraft. Cosmos 496 retained solar arrays.[56]

Cosmos 573 June 15-17, 1973

Unmanned test of the Soyuz Ferry without solar arrays. It did not dock with a space station.

Soyuz 12 September 27-29, 1973

Vasili Lasarev, Oleg Makarov
Crew code name—Ural

First manned Soyuz Ferry flight. Its purpose was to thoroughly test the redesigned Soyuz. It was not meant to dock with a space station.[57]

Cosmos 613 November 30, 1973-January 29, 1974

Long-duration orbital storage test of the Soyuz Ferry in preparation for long stays attached to a space station.

Soyuz 13 December 18-26, 1973

Pyotr Klimuk, Valentin Lebedev
Crew code name—Kavkaz

This was a unique mission using a Soyuz spacecraft with solar arrays. There is some question as to whether this mission should be grouped with the Soyuz Ferries. Soyuz 13 was not intended to dock with a station—no Soviet stations were available at the time of its launch, and it carried no docking apparatus.[58] Scientific instruments like those used on Soviet space stations filled its orbital module (Oazis-2 plant growth unit) and replaced its docking mechanism (Orion-2 telescope suite). Like the U.S. astronauts aboard Skylab, the Kavkaz crew observed Comet Kohoutek.[59]

1.8.4.2 Soyuz Ferry Missions to Salyut 3

For information on Salyut operations during these Soyuz missions, see section 2.4.3.

Soyuz 14 July 3-19, 1974

Pavel Popovich, Yuri Artyukhin
Crew code name—Berkut

First successful Soviet mission to a space station. It docked with Salyut 3 on July 4 and spent 16 days in space.

Soyuz 15 August 26-28, 1974

Gennadi Sarafanov, Lev Demin
Crew code name—Dunay

Failed to dock with Salyut 3 after its Igla system malfunctioned and the cosmonauts were unable to guide the spacecraft to a manual docking. Gyroscope problems nearly prevented orientation of the spacecraft for the deorbit burn. Reentry had to occur within 2 days of launch, lest Soyuz 15 exhaust its batteries. Landing occurred at night, in a lightning storm. Neither Sarafanov nor Demin flew again. This was taken to imply that they were punished for poor performance which contributed to mission failure. However, a recent Russian report vindicates the crew.[60]

1.8.4.3 Soyuz Ferry Missions to Salyut 4

For information on Salyut operations during these Soyuz missions, see section 2.5.3.

Soyuz 17 January 10-February 9, 1975

Alexei Gubarev, Georgi Grechko
Crew code name—Zenit

First to visit Salyut 4. Landed in a fierce blizzard.

"The April 5 Anomaly" April 5, 1975

Vasili Lasarev, Oleg Makarov
Crew code name—Ural

Dubbed Soyuz 18a in the West. During ascent, an electrical malfunction in the Soyuz booster prematurely fired two of the four explosive latches holding the core of the first stage and the second stage together. This severed electrical connections necessary for firing the remaining latches. The launch escape system and shroud covering the Soyuz were discarded as normal. When the core first stage burned out it could not be cast off. Second stage ignition occurred as normal, but the booster was rapidly dragged off course by the weight of the spent core first stage. When the course deviation reach 10°, the automatic safety system came into operation. It shut down the booster and separated the Soyuz. At separation the Soyuz was 180 km high and moving at 5.5 km per second. The Soyuz turned around and fired its main engine against the direction of flight to slow down, then discarded its orbital and service modules. Reentry was brutal, with the cosmonauts experiencing up to 12-18 g's. They landed unhurt, however, in the eastern U.S.S.R. The flight lasted only 21 min, but 24 hr passed before the crew could be recovered. This was the only suborbital flight of the Soviet manned space program. More importantly, it was the only downrange abort in manned spaceflight history.[61,62]

Soyuz 18 May 24-July 26, 1975

Pyotr Klimuk, Vitali Sevastyonov
Crew code name—Kavkaz

Less than two months after "the April 5 anomaly," Soyuz 18 (Soyuz 18b in the West) docked with Salyut 4. Its crew spent 62 days aboard the space station. They were in orbit while Soyuz 19 (called simply Soyuz during the mission) conducted joint operations with the U.S. Apollo spacecraft, and twice exchanged brief greetings with their colleagues.

1.8.4.4 Soyuz Ferry Missions to Salyut 5

For information on Salyut operations during these Soyuz missions, see section 2.6.3.

Soyuz 21 July 6-August 24, 1976

Boris Volynov, Vitali Zholobov
Crew code name—Baykal

Docked with Salyut 5 on July 7, 1976. The crew returned home after 49 days in space.

Soyuz 23 October 14-16, 1976

Vyacheslav Zudov, Valeri Rozhdestvenski
Crew code name—Radon

Suffered an automatic docking system malfunction during final approach to Salyut 5. The cosmonauts were ordered to return to Earth. They had less than 2 days of battery power left and had already missed the landing opportunity for that day, so they powered down systems to conserve power. A blizzard with squall force winds broke out in the landing zone, but the Soyuz capsule was designed to land in any weather. Reentry over North Africa was normal. The Soyuz 23 descent module lowered in the dark on its single red and white parachute, rocking as it encountered the high winds driving snow across the landing area. The descent module splashed down in freezing water, surrounded by ice floes, 8 km offshore in Lake Tengiz. All recovery efforts were thwarted. The cosmonauts bobbed in the capsule with systems shut off to save power. The capsule floated, and the pressure equalization valve above the waterline provided air. They ate from their supply of emergency food and donned emergency water survival suits. The next day a helicopter towed the capsule to shore with the cosmonauts still inside. They were unharmed by their ordeal.[63]

Soyuz 24 February 7-25, 1977

Viktor Gorbatko, Yuri Glazkov
Crew code name—Terek

The Tereks spent only 17 days docked to Salyut 5, which had nearly depleted its propellant supply.

1.8.4.5 Soyuz Ferry Missions to Salyut 6

For information on Salyut operations during these Soyuz missions, see section 2.7.3.

Soyuz 25 October 9-11, 1977

Vladimir Kovalyonok, Valeri Ryumin
Crew code name—Foton

Docked with Salyut 6 on October 10, 1977, but its crew was unable to complete hard dock. It was able to insert its probe into the drogue assembly, but could not secure the latches in the docking ring to create an airtight seal. After four docking attempts, Soyuz 25 backed away from the station. Three orbits later, it again failed to hard dock. Mission rules specified immediate preparations for return to Earth because of the limited lifetime of its batteries. Insufficient propellant remained for docking at the Salyut 6 aft port. Suspicion fell on the Soyuz 25 probe docking unit as the cause of the failure. Because the orbital module was discarded at reentry, it was impossible to inspect the unit to confirm that it caused the trouble.

Soyuz 26 December 10, 1977-January 16, 1978

Launch crew—Yuri Romanenko, Georgi Grechko
Crew code name—Tamyr

Landing crew—Vladimir Dzhanibekov, Oleg Makarov
Crew code name—Pamir

Docked at the aft port. Its crew inspected the front port drogue unit and found no abnormalities, increasing suspicions that the Soyuz 25 docking apparatus caused its docking failure. The Soyuz 26 crew remained aboard Salyut 6 for 96 days, surpassing the spaceflight endurance record set by the third manned Skylab mission. Their spacecraft returned to Earth before that, replaced by Soyuz 27 after about 60 days docked to Salyut 6.

Soyuz 27 January 11-March 16, 1978

Launch crew—Vladimir Dzhanibekov, Oleg Makarov
Crew code name—Pamir

Landing crew—Yuri Romanenko, Georgi Grechko
Crew code name—Tamyr

Docked with the Salyut 6 front port, confirming that the port functioned normally. This marked the first time two Soyuz craft were docked to a station at the same time. The two guest cosmonauts transferred their custom-molded couch liners from Soyuz 27 to Soyuz 26. They returned to Earth in the older craft, leaving the long-duration crew a fresh spacecraft. This was the first of many times the Soviets swapped spacecraft in orbit.

Soyuz 28 March 2-March 10, 1978

Alexei Gubarev, Vladimir Remek/Czechoslovakia
Crew code name—Zenit

Carried the first non-U.S./non-Soviet space traveler, Remek, who was also the first cosmonaut-researcher to fly as part of the international Intercosmos program.

Soyuz 29 June 15-September 3, 1978

Launch crew—Vladimir Kovalyonok, Alexandr Ivanchenkov
Crew code name—Foton

Landing crew—Valeri Bykovski, Sigmund Jähn/E. Germany
Crew code name –Yastreb

Foton crew spent 140 days on Salyut 6. The Yastrebs launched to Salyut 6 in Soyuz 31 and returned to Earth in Soyuz 29.

Soyuz 30 June 27-July 5, 1978

Pyotr Klimuk, Miroslaw Hermaszewski/Poland
Crew code name—Kavkaz

Intercosmos flight to Salyut 6.

Soyuz 31 August 26-November 2, 1978

Launch crew—Valeri Bykovski, Sigmund Jähn/E. Germany
Crew code name—Yastreb

Landing crew—Vladimir Kovalyonok, Alexandr Ivanchenkov
Crew code name—Foton

Carried first German space traveler, paired with veteran cosmonaut Bykovski (he flew solo in Vostok 5, June 1963). After the Yastrebs departed from Salyut 6 in Soyuz 29 on September 3, the Fotons transferred Soyuz 31 to the Salyut 6 front port. Moving a replacement Soyuz to the front port became standard procedure; it freed the aft port for Progress supply ships.

Soyuz 32 February 25-June 13, 1979

Launch crew—Vladimir Lyakhov, Valeri Ryumin
Crew code name—Proton

Landing crew—none

Its long-duration crew spent 175 days on Salyut 6. Less than 2 months into their stay, Soyuz 33 failed to dock because of a main engine malfunction. Soyuz 32 returned to Earth unmanned with a cargo of experiment results and equipment no longer in use after Soyuz 34 had docked unmanned with Salyut 6 to replace it.

Soyuz 33 April 10-12, 1979

Nikolai Rukavishnikov, Georgi Ivanov/Bulgaria
Crew code name—Saturn

Failed to dock with Salyut 6. Fired its main engine while closing to within 4 km of the station. The burn, the sixth of the flight, was to have lasted 6 sec, but the engine shut down after 3 sec. The Igla docking system also closed down. The Proton crew aboard Salyut 6 reported flames shooting sideways from the main engine, toward the backup engine, at the time of the shutdown. The docking was called off and the Saturns made ready to return to Earth. The backup engine fired, but did not shut off at the end of the planned 188-sec burn. Rukavishnikov, uncertain if the engine operated at the proper thrust, determined to let it burn an additional 25 sec before shutting it down manually. As a result, Soyuz 33 made a steep ballistic reentry with gravity loads up to 10 g's. Because the service module was discarded after deorbit burn, examination of the failed engine was impossible. The Soyuz 33 crew was to have traded its spacecraft for Soyuz 32.[64]

Soyuz 34 June 6-August 19, 1979

Launch crew—none

Landing crew—Vladimir Lyakhov, Valeri Ryumin
Crew code name—Proton

Launched unmanned to replace Soyuz 32 following the Soyuz 33 failure. Soyuz 34 included main engine modifications made to prevent a recurrence of the Soyuz 33 failure.[65]

Soyuz 35 April 9-June 3, 1980

Launch crew—Leonid Popov, Valeri Ryumin
Crew code name—Dneiper

Landing crew—Valeri Kubasov, Bertalan Farkas/Hungary
Crew code name—Orion

Returned to Earth carrying the crew launched on Soyuz 36.

Soyuz 36 May 26-July 31, 1980

Launch crew—Valeri Kubasov, Bertalan Farkas/Hungary
Crew code name—Orion

Landing crew—Viktor Gorbatko, Pham Tuan/Vietnam
Crew code name—Terek

Hungarian Intercosmos mission. Postponed from June 1979 after the Soyuz 33 main engine failure. Kubasov and Farkas traded their spacecraft for Soyuz 35. Soyuz 36 was later traded for Soyuz 37.

Soyuz 37 July 23-October 11, 1980

Launch crew—Viktor Gorbatko, Pham Tuan/Vietnam
Crew code name—Terek

Landing crew—Leonid Popov, Valeri Ryumin
Crew code name—Dneiper

Intercosmos mission to Salyut 6. Returned the Dneiper long-duration crew launched in Soyuz 35 to Earth.

Soyuz 38 September 18-26, 1980

Yuri Romanenko, Arnaldo Tamayo-Mendez/Cuba
Crew code name—Tamyr

Intercosmos mission to visit the Dneipers on Salyut 6.

Soyuz 39 March 22-30, 1981

Vladimir Dzhanibekov, Judgerdemidiyin Gurragcha/Mongolia
Crew code name—Pamir

Intercosmos mission to Salyut 6. The Soyuz 39 crew visited Vladimir Kovalyonok and Viktor Savinykh, who were delivered by the Soyuz-T 4 spacecraft.

Soyuz 40 May 14-22, 1981

Leonid Popov, Dmitru Prunariu/Romania
Crew code name—Dneiper

Last Soyuz Ferry flight; ended the first phase of the Intercosmos program, which concentrated on placing citizens of Soviet bloc states into space. In all, nine Intercosmos missions were launched between 1978 and 1981.[66]

1.9 ASTP Soyuz (1974-1976)

ASTP Soyuz (figure 1-21) was the Soyuz Ferry modified to carry out the specialized mission of docking with a U.S. Apollo spacecraft in Earth orbit.

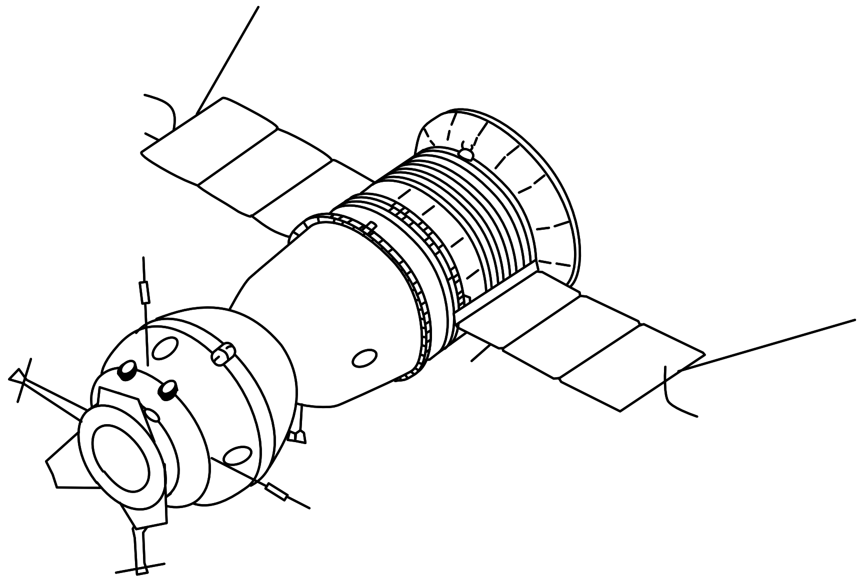

Figure 1-21. Apollo-Soyuz Test Project (ASTP) Soyuz. The APAS-75 docking unit is located at left.

1.9.1 ASTP Soyuz Specifications

Launch weight (Soyuz 19)	6680 kg
Launch weight (Soyuz 22)	6510 kg
Length (Soyuz 19)	7.48 m
Length (Soyuz 22)	7.6 m
Span across solar arrays	8.37 m
Diameter of habitable modules	2.2 m
Maximum diameter	2.72 m
Habitable volume	about 10 m^3
Number of crew	2

1.9.2 ASTP Soyuz Notable Features

Soyuz 22, the backup to the Soyuz 19 ASTP Soyuz which docked with Apollo, did not incorporate all these notable features. Some may also have been absent from the Cosmos 638 and Cosmos 672 ASTP Soyuz spacecraft; nonetheless, the ASTP Soyuz was generally associated with the following notable features:

- Advanced solar arrays.
- Modified life support systems capable of supporting four crew. This was necessary for Apollo crew visits to Soyuz, and also in the event that Soyuz had to pull away from Apollo with two Americans aboard.
- APAS-75 androgynous docking unit (figure 1-22) compatible with the unit on the docking module.

  U. S. and Soviet engineers jointly developed the system for ASTP. APAS is the acronym for the English translation, “androgynous peripheral assembly system,” and the number is the year of its first use in space.
- Modified coloration for compatibility with Apollo rendezvous sensors.
- Improved control systems.

- Docking tone ranging system and light beacons compatible with Apollo.
- Antennas and UHF air-to-air radio equipment compatible with Apollo. Also radio equipment permitting relay through the U.S. ATS-6 satellite.
- Standard Soyuz launch shroud modified to protect the outward-facing guides of the APAS-75 docking unit.

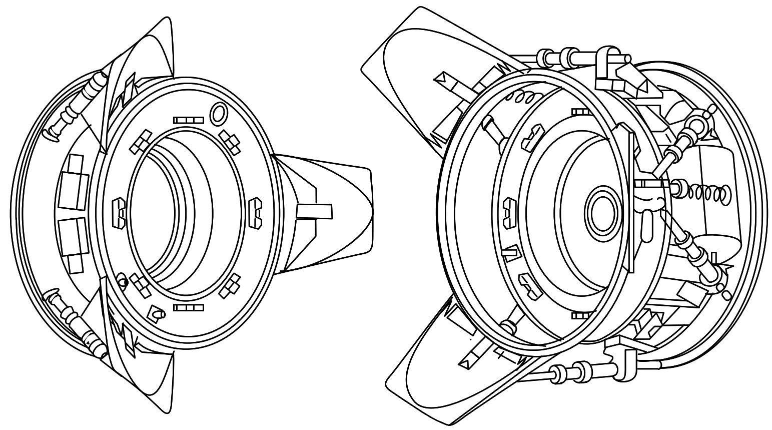

Figure 1-22. APAS-75 docking unit. Unlike previous docking systems, both units could assume the active or passive roles as required. For docking, the spade-shaped guides of the extended active unit (right) and the retracted passive unit (left) interacted for gross alignment. The ring holding the guides shifted to align the active unit latches with the passive unit catches. After these caught, shock absorbers dissipated residual impact energy in the American unit; mechanical attenuators served the same function on the the Soviet side. The active unit then retracted to bring the docking collars together. Guides and sockets in the docking collars completed alignment. Four spring push rods drove the spacecraft apart at undocking. The passive craft could play a modified active role in undocking if the active craft could not complete the standard undocking procedure. Pyrotechnic bolts provided backup.

1.9.3 ASTP Soyuz Mission Descriptions

Dates are launch to landing.

Cosmos 638 April 3-13, 1974

Unmanned test of the ASTP Soyuz. Carried APAS-75 androgynous docking system.

Cosmos 672 August 12-18, 1974

Unmanned test of the ASTP Soyuz. Carried APAS-75 androgynous docking system.

Soyuz 16 December 2-8, 1974

Anatoli Filipchenko, Nikolai Rukavishnikov
Crew code name—Buran

Manned test of the ASTP Soyuz. Carried the APAS-75 androgynous docking system.

Soyuz 19 July 15-July 21, 1975

Alexei Leonov, Valeri Kubasov
Crew code name—Soyuz

Docked with Apollo through the intermediary of a docking module using the APAS-75 unit on July 17, 1975 (figure 1-23). Soyuz 19 was officially referred to as Soyuz, just as the Apollo craft used was simply called Apollo (while some sources refer to the craft as Apollo 18, this was not the official designation). The craft undocked on July 19, redocked for 3 hours, then separated to conduct independent operations. Apollo landed after Soyuz, on July 24, 1975.

Soyuz 22 September 15-23, 1976

Valeri Bykovski, Vladimir Aksyonov
Crew code name –Yastreb

Flight of the backup ASTP Soyuz. In place of the APAS-75 androgynous docking system or other docking apparatus, it carried an East German MKF-6 camera. It operated in a 64.75° orbit to improve its abilities as an Earth observation platform.

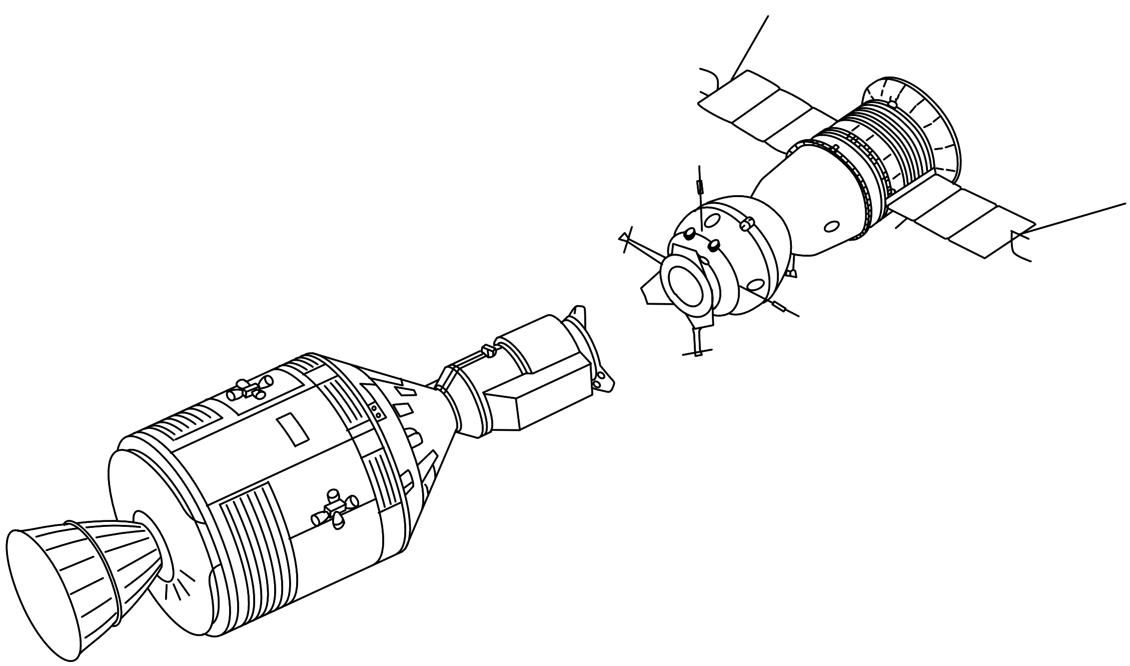

Figure 1-23. Apollo and Soyuz join in space. Note the docking module (DM) attached to Apollo's nose. The DM was stored for launch within a shroud between the CSM and the S-IVB second stage of the Apollo Saturn IB launch vehicle. In orbit the Apollo inserted its probe unit into the standard Apollo drogue unit of the docking module, extracted the DM from the S-IVB, then performed rendezvous and docking with the Soyuz spacecraft.

1.10 Progress (1975-1990)

Progress (figure 1-24) was an unmanned version of the Soyuz Ferry designed to perform logistics resupply of the Salyut 6, Salyut 7, and Mir space stations. Progress missions 1 through 12 carried supplies to Salyut 6. Missions 13 through 24 visited Salyut 7, as did the unusual Progress-related Cosmos 1669 mission. Progress missions 25 through 42 served the Mir station. The first 17 Progress missions to Mir delivered 40 tons of supplies, about double the station's launch weight. Most Progress spacecraft functioned routinely, as expected of a logistics spacecraft. No docking anomalies occurred in the 43 flights of Progress (Progress 1 through 42 plus Cosmos 1669).

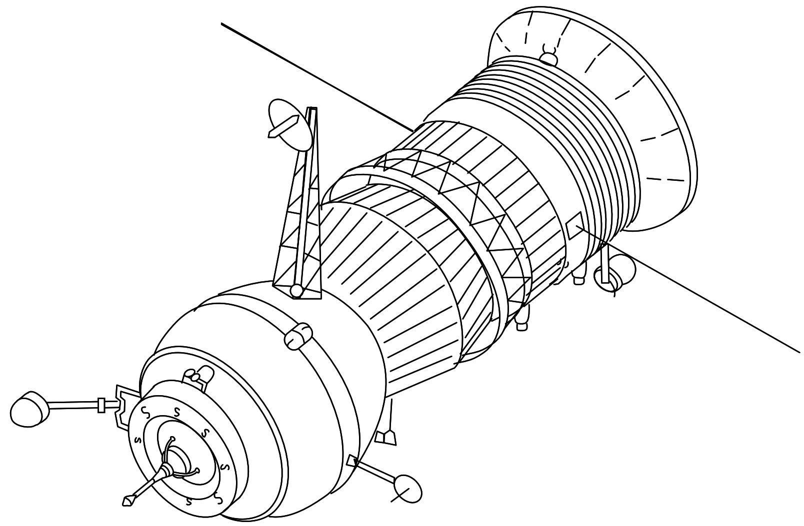

Figure 1-24. Progress logistics resupply spacecraft. It consists of the dry cargo module (left); the tanker compartment (center); and a stretched service module (right).

1.10.1 Progress Specifications

Launch weight	7020-7240 kg
Weight of cargo (Progress 1-24)	about 2300 kg
Weight of cargo (Progress 25-42)	about 2500 kg
Length	7.94 m
Diameter of cargo modules	2.2 m
Maximum diameter	2.72 m
Volume of cargo compartment	6.6 m^3

1.10.2 Progress Notable Features

- Launched on a Soyuz rocket under the same type of shroud as the Soyuz Ferry, but with no escape systems.
- Always docked with the aft port of its station target.
- Soyuz descent module replaced by tanker compartment, an assemblage of tanks in an unpressurized conical housing. The pressurized orbital module carried dry cargo. The crew could enter the orbital module to unload dry cargo, but had no access to the tanker compartment.
- No part of Progress was designed to be recovered. At the conclusion of its space station resupply mission, a Progress freighter was intentionally deorbited over the Pacific Ocean, where any pieces which survived incineration could fall harmlessly.

1.10.3 Progress Detailed Description

Spacecraft designer Konstantin Feoktistov published a brochure in 1980 in Moscow in which he described Progress in some detail.[67] A summary is given below.

Feoktistov stated that Progress constituted an alternative to building reusable ("multiple use") logistics vehicles. A reusable vehicle, he asserted, would be 1.5 to 2 times heavier empty than the equivalent expendable logistics craft. This would call for a booster nearly as large as the three-stage Proton rocket used to launch Salyut. "If we are talking about an economically effective earth-orbit-earth transport system," Feoktistov continued, "then it appears expedient to build a fully multiple use complex, not only the spaceship, but also the booster rocket." This would take too much time; therefore, "when designing the Progress spacecraft the decision was made to make it single-use and to utilize the . . . Soyuz rocket to insert it [into orbit]."

The Progress orbital module ("cargo bay") was two hemispheres welded together through the intermediary of a short cylindrical section (very similar to the Soyuz orbital module). The forward hemisphere contained the docking unit and the port connecting the orbital module to the space station. Unlike Soyuz, Progress had no hatch in the aft hemisphere. The orbital module contained a supporting framework to which large equipment (such as air regenerators) was attached. Small items were packed in bins.

The probe and drogue docking unit used on Progress resembled the Soyuz unit. The chief difference was provision of two ducted mating connectors (one each for UDMH fuel and N_2O_4 oxidizer) in the Progress docking collar for propellant transfer to corresponding connectors in the station collar. Three television cameras were carried near the docking unit.

The tanker compartment carried two tanks each of UDMH and N_20_4. Feoktistov stressed that these propellants were "chemically aggressive and poisonous to man." To avoid spillage into the pressurized volumes of the station or the supply ship, fuel lines from the unpressurized tanker compartment ran along the exterior of the Progress orbital module, through the ducts in the docking collar, then into the unpressurized section containing the main propulsion system, which was located around the intermediate compartment at the aft end of the space station. The tanker compartment also carried tanks filled with nitrogen to serve as pressurant for the fuel system and to purge it of residual propellants. This prevented propellants from spilling on the docking apparatus and being accidentally introduced into the station.

Control equipment normally located in the Soyuz orbital and descent modules was placed in the service module of the Progress spacecraft. The service module also carried equipment for controlling propellant transfer. Progress had mounted to its service module two infrared local vertical sensors (horizon sensors) and two ion sensors for its guidance system. Soyuz, by contrast, had one ion sensor and one infrared horizon sensor. Redundancy was provided because Progress was a wholly automated craft. The Progress service module was longer than the Soyuz module because of the extra equipment it carried.

1.10.4 Progress Mission Descriptions

Dates are launch to reentry.

1.10.4.1 Progress Test Mission to Salyut 4

For information on Salyut operations during this Progress-related mission, see section 2.5.3.

Soyuz 20 November 17, 1975-February 16, 1976

Speaking at Johnson Space Center in late 1974, Vladimir Shatalov, head of cosmonaut training, stated that an unmanned "cargo Soyuz" was under development.[68] Referring in 1976 to the Soyuz 20's docking with Salyut 4, former cosmonaut and Salyut designer Konstantin Feoktistov stated that "the successful link-up of the unmanned spaceship with the operating station opens up real opportunities for a more economical organization of space research. For instance, in case of necessity we could launch into orbit scientific equipment or food reserves or drinking water." Elsewhere, Feoktistov stated that Soyuz 20 "was docked with the station in order to perform long-term resource tests on the spacecraft under orbital flight conditions in the station make-up."[69] Soyuz 20 carried in its descent module biological experiments complementing those on the joint Soviet-U.S. Cosmos 782 biosatellite. These were returned to Earth for study.[70]

1.10.4.2 Progress Missions to Salyut 6

For information on Salyut operations during these Progress missions, see section 2.7.3.

Progress 1 January 20-February 8, 1978

Can be seen as a prototype for subsequent Progress missions. Progress 1 docked with the aft port of the Salyut 6 space station on January 22. The aft port carried fixtures for transferring fuel and gases from Progress to the station. The crew vented air from Progress 1's tanks into the station, and unloaded nearly 1300 kg of food, replacement parts, scientific instruments, and other supplies from the orbital module. They then worked in concert with the TsUP to pump fuel and oxidizer into Salyut 6. Propellants were pumped into each separate tank in turn. After refueling was complete, but while the Progress and station were still docked, the propellant lines linking Progress and Salyut were vented to space to prevent residual propellant from contaminating the station's docking surfaces. After that, they loaded the orbital module with refuse. On February 5 and 6, Progress 1's engine was used to make adjustments to Salyut 6's orbit. On February 6, Progress 1 backed away from Salyut 6. A deorbit burn took place over the U.S.S.R. on February 8, followed by destructive reentry over the Pacific Ocean.

Progress 2 July 7-August 4, 1978

Progress 3 August 7-23, 1978

Progress 4 October 3-26, 1978

Progress 5 March 12-April 5, 1979

Served as a receptacle for contaminated fuel from the damaged Salyut 6 propulsion system.

Progress 6 May 13-June 9, 1979

Progress 7 June 28-July 20, 1979

Delivered the KRT-10 radio telescope, which was deployed from the rear port of Salyut 6 after Progress 7 backed away. Cameras on Progress 7 televised deployment.

Progress 8 March 27-April 26, 1980

Progress 9 April 27-May 22, 1980

Before Progress 9, cosmonauts carried water into Salyut stations in 5 kg bottles. Progress 9 was the first to pump water directly into the new Rodnik system tanks aboard Salyut 6.[71]

Progress 10 June 29-July 19, 1980

Progress 11 September 28-December 11, 1980

Progress 12 January 24-March 20, 1981

1.10.4.3 Progress Missions to Salyut 7

For information on Salyut operations during these Progress missions, see section 2.8.3.

Progress 13 May 23-June 6, 1982

Progress 14 July 10-August 13, 1982

Progress 15 September 18-October 16, 1982

Progress 16 October 31-December 14, 1982

Progress 17 August 17-September 18, 1983

Progress 18 October 20-November 16, 1983

Progress 19 February 21-April 1, 1984

Progress 20 April 15-May 7, 1984

Delivered parts and tools for the Salyut 7 propulsion system repair, including some in containers attached to the outer hull of the spacecraft. In addition, Progress 20's orbital module was equipped with foot restraints on an extension to which the cosmonauts could affix themselves during the repair of Salyut 7's damaged propulsion system.

Progress 21 May 7-26, 1984

Delivered the second set of three solar array extensions to be added to attachment points provided on the existing Salyut 7 solar arrays. The first set was delivered by Cosmos 1443. The third and final set was delivered by Progress 24.

Progress 22 May 28-July 15, 1984

Progress 23 August 14-August 28, 1984

Progress 24 June 21-July 15, 1985

Delivered replacement parts which helped a repair crew rescue Salyut 7, which had lost power and frozen. See Progress 21.

Cosmos 1669 July 19-August 30, 1985

Docked with Salyut 7 on July 21. At the time of its launch, some western analysts called Cosmos 1669 a free-flying platform resembling Progress.[72] However, it is now known the spacecraft tested improvements subsequently applied to increase the cargo load of Mir's Progress spacecraft (Progress 25-42).[73] Delivered space suits to replace those damaged when Salyut 7 froze.

1.10.4.4 Progress Missions to Mir

For information on Mir operations during these Progress missions, see section 2.9.3.

Progress 25 March 19-April 21, 1986

First Progress spacecraft to dock with Mir. It was launched soon after the Mir base block because the base block carried rations for only 20 days.[74] It marked an increase in Progress launch weight to 7240 kg. Maximum cargo load increased to about 2500 kg, with up to 1400 kg in the orbital module and 1200 kg in the tankage compartment.

Progress 26 April 23-June 23, 1986

Progress 27 January 16-February 25, 1987

Progress 28 March 3-28, 1987

Delivered the usual supplies of food, water, fuel, and scientific equipment to Mir. After the space station crew filled it with refuse, it backed away and deployed a large (60 m) antenna for geophysical experiments. According to the Soviets, the assemblage was also a prototype of future space structures. A similar experiment was performed on Progress 40 (February 10-March 5, 1989).

Progress 29 April 21-May 11, 1987

First Progress to dock with the Kvant rear port.

Progress 30 May 19-July 19, 1987

Progress 31 August 3-September 23, 1987

Progress 32 September 23-November 19, 1987

Undocked on November 10 for maneuevering tests lasting 1.5 hr, then redocked. The tests were aimed at developing means of reducing propellant use during approach maneuvers. Undocked for final time November 17.

Progress 33 November 20-December 19, 1987

Progress 34 January 20-March 4, 1988

Progress 35 March 23-May 5, 1988

Progress 36 May 13-June 5, 1988

Progress 37 July 18-August 12, 1988

Progress 38 September 9-November 23, 1988

Progress 39 December 25, 1988-February 7, 1989

Greater than average solar activity hastened the decay of the Mir complex from orbit. The engine and fuel supply of this Progress were used to change Mir's orbital parameters to 340 km by 376 km, from 325 km by 353 km. According to Sergei Krikalev, onboard the station at this time, the altitude change was not noticeable from Mir's viewports.[75]

Progress 40 February 10-March 5, 1989

See Progress 28 entry.

Progress 41 March 16, 1989-April 25, 1989

Many Progress missions served a psychological purpose as well as a logistics one. Psychologists in ground control had a hand in choosing morale-boosting treats for the space station crew. In addition, Progress cargoes usually included mail from loved ones and newspapers. Progress 41 carried to Mir postcards commemorating the 30th anniversary of Luna 1 (launched January 2, 1959), the first probe to pass near the Moon. A possible main engine failure prevented Progress 41 from making the usual controlled destructive reentry at the end of its mission. It underwent uncontrolled reentry on April 25, 1989.[76]

Progress 42 May 5-May 27, 1990

Last of the old Progress resupply ships. Progress 42 was designed to interface with the Igla approach system and the Argon 16B orientation control system launched with Mir. For this reason, using the spacecraft contributed to delays in integration with the Mir complex of the new Salyut 5B orientation control computer delivered with the Kvant 2 module.

1.10.5 Progress-Derived Space Station Modules

Dates are launch to reentry.

Gamma July 11, 1990-February 28, 1992

Mir space station modules are based on TKS transport vehicles originally designed for the Almaz military space station program (see Part 3, “Space Station Modules,” and section 2.1.2). Prior to the decision to convert the TKS into space station modules, work was underway to develop Progress-derived space station modules for Mir. The first, Gamma, was launched on July 11, 1990. It flew as an independent astrophysical research satellite (figure 1-25); it was not intended to dock with a space station. The docking system which would have made it part of a multimodular space station was replaced by a housing for two telescopes in the flown version. Gamma weighed 7.32 tons, and carried 1.7 tons of scientific gear. The Gamma-1 gamma-ray telescope alone weighed 1.5 tons. The spacecraft carried solar arrays with a total area of 36.5 m^2, providing maximum power of 3.5 kW. The arrays, unlike those of Progress and Soyuz, were driven by electric motors to maintain their lock on the Sun. It was intentionally deorbited at the end of its mission. No module of this type has ever docked with Mir, though modules with similar designs have appeared in drawings of Mir’s proposed successor, Mir 2.[77, 78]

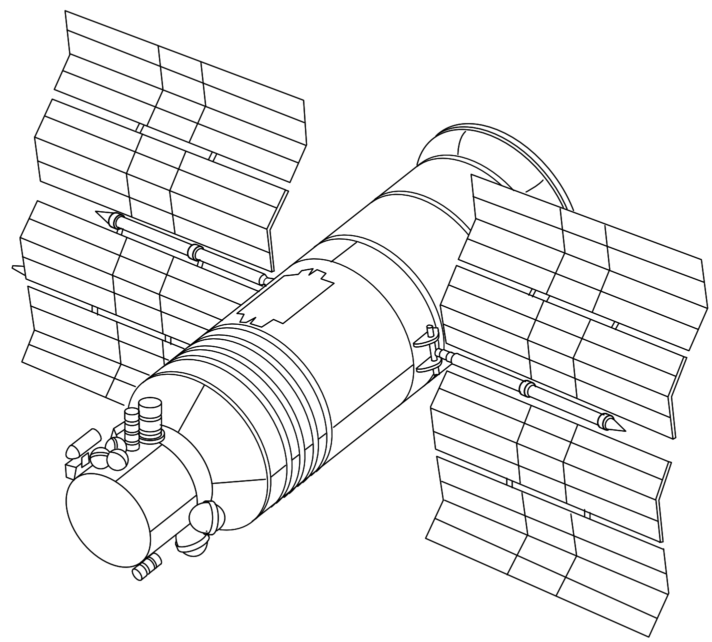

Figure 1-25. Progress-based Gamma astrophysical research satellite.

1.11 Progress-M (1989-Present)

Progress-M (figure 1-26) is the Progress logistics resupply spacecraft upgraded by incorporating Soyuz-TM technology and other improvements.

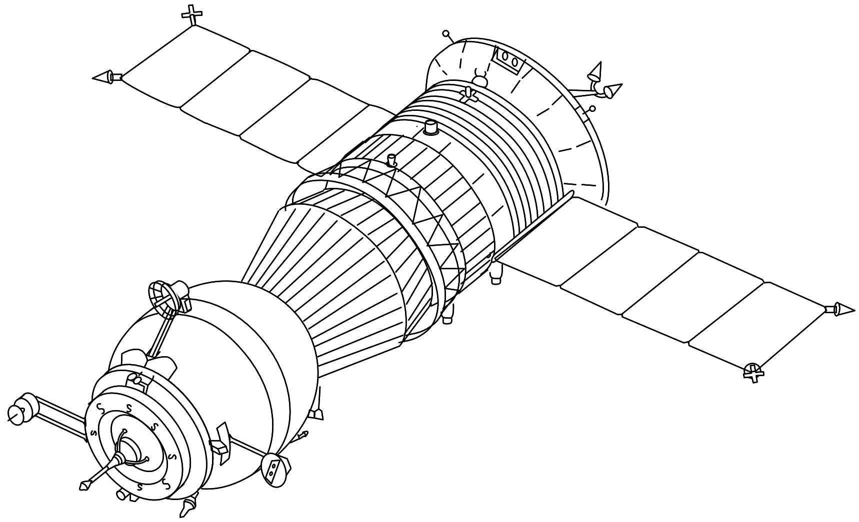

Figure 1-26. Progress-M logistics resupply spacecraft.

1.11.1 Progress-M Specifications[79]

Launch weight	7130 kg
Weight of cargo (maximum)	2600 kg (maximum)
Weight of dry cargo (maximum)	1500 kg (maximum)
Weight of liquid and gaseous cargo (maximum)	1540 kg* (maximum)
Length	7.23 m
Span across solar arrays	10.6 m
Volume of dry cargo compartment	7.6 m^3
Diameter of cargo modules	2.2 m
Maximum diameter	2.72 m

*Includes 200 kg of propellant transferred to Mir from Progress-M propulsion system.

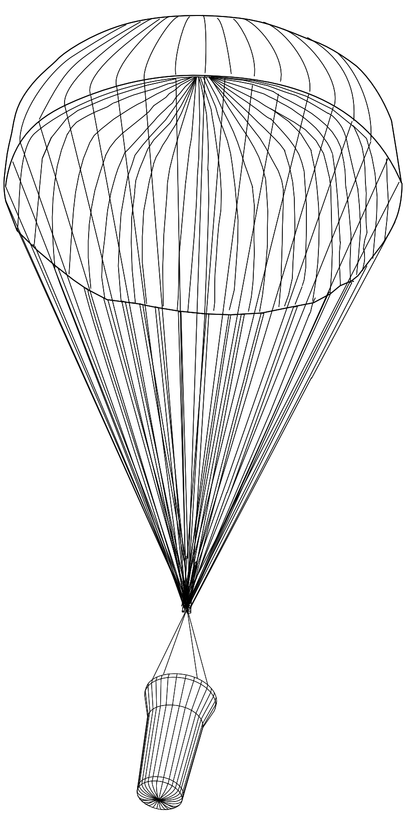

Figure 1-27. Ballistic return capsule (Raduga) during final descent to Earth.

1.11.2 Progress-M Notable Features

- Independent flight time of up to 30 days (10 times longer than the Progress 1 through 42 spacecraft).
- Increased cargo load delivered to Mir (on average, about 100 kg greater than carried by Progress 25 through 42).
- Return payload capability when equipped with Raduga ("rainbow") ballistic return capsule (figure 1-27). The Russians use this capsule to return small, valuable payloads from Mir. It was named Raduga largely for marketing purposes. The capsule is carried in the Progress-M dry cargo compartment. At the beginning of Raduga's return to Earth, the Progress-M completes its deorbit burn. At an altitude of about 120 km, the capsule separates. The Progress-M undergoes destructive reentry, while the capsule makes an intact reentry, with landing and recovery in central Asia. Raduga is used to return up to 150 kg of payloads to Earth two or three times each year. Each Raduga capsule is about 1.5 m long, is 60 cm in diameter, and weighs about 350 kg empty. Use of the Raduga

ballistic return capsule lowers Progress-M cargo capacity by about 100 kg, to a maximum of about 2400 kg. Progress-M 5 carried the first Raduga capsule.
- Ability to dock and transfer propellant at the Mir front port.
- Ability to transfer excess propellant (up to 200 kg) in Progress-M service module to Mir, or transfer propellant from Mir to Progress-M service module.
- Kurs rendezvous and docking system (same as Soyuz-TM).
- Solar arrays like those on Soyuz-TM. While docked, its solar arrays augment Mir's electrical supply.

1.11.3 Progress-M Mission Descriptions

All Progress-M resupply ships docked with Mir. For information on Mir operations during these Progresss missions, see sections 2.9.3.5 through 2.9.3.18. Dates are launch to reentry.

Progress-M 1 August 23-December 1, 1989

First Progress-type vehicle to dock at the front port of a Soviet space station.

Progress-M 2 December 20, 1989-February 9, 1990

Delivered to Mir a protein crystal growth experiment built by Payload Systems, Inc., a private U.S. firm.

Progress-M 3 February 28-April 28, 1990

Progress-M 4 August 15-September 20, 1990

After unloading its cargo and loading the cargo compartment with refuse, the Mir cosmonauts installed on Progress-M 4's docking unit a device for producing plasma. After undocking from Mir's front port, Progress-M 4 spent 3 days releasing plasma, while the cosmonauts on Mir observed and recorded.

Progress-M 5 September 27-November 28, 1990

First Progress-M equipped with a Raduga payload return capsule.

Progress-M 6 January 14-March 15, 1991

Progress-M 7 March 19-May 7, 1991

The ability to dock at the front port stood it in good stead when damage to the Kurs antenna at the Mir aft port prevented it from docking there. After Soyuz-TM 11 was moved manually to the rear port, the Progress-M 7 spacecraft moved to the front port and docked there instead. Its Raduga recoverable capsule was lost during reentry.

Progress-M 8 May 30-August 16, 1991

Deployed a balloon for experiments after undocking.

Progress-M 9 August 20-September 30, 1991

Launched without incident during the coup d'etat against Mikhail Gorbachev's government. Returned Raduga capsule.

Progress-M 10 October 17, 1991-January 20, 1992

Docking was delayed 2 days from October 19 by a rendezvous software problem. Docking occurred October 21. Returned Raduga capsule.

Progress-M 11 January 25-March 13, 1992

Returned Raduga capsule.

Progress-M 12 April 19-June 27, 1992

Progress-M 13 June 30-July 24, 1992

Docking was delayed by 2 days because of a rendezvous software problem. Docking occurred on July 4.

Progress-M 14 August 15, 1992-October 21, 1992

Featured a modified tanker compartment supporting a framework for the VDU thruster unit. Returned Raduga capsule.

Progress-M 15 October 27, 1992-February 7, 1993

Deployed Znamya ("banner"), a prototype solar reflector, from its cargo compartment after undocking in February. The solar reflector was then cast off, and Progress-M 15 was put through a series of maneuvers controlled by the cosmonauts inside Mir. A similar telerobotics control experiment used Progress-M 16. See also Progress-M 24.

Progress-M 16 February 21-March 27, 1993

Progress-M 17 March 31, 1993-March 3, 1994

The Raduga capsule launched in Progress-M 17 was transferred to Progress-M 18. Progress-M 17 remained in orbit after undocking from Mir on September 13, 1993. Its reentry point and trajectory were unprecedented in the Progress series, leading some to speculate that it had experienced an unplanned contingency. Reentry occurred off the southeast coast of South America.

Progress-M 18 May 22-July 4, 1993

Returned Progress-M 17's Raduga capsule to Earth.

Progress-M 19 August 10-October 13, 1993

Returned Raduga capsule.

Progress-M 20 October 11-November 21, 1993

Returned Raduga capsule.

Progress-M 21 January 28-March 23, 1994

Progress-M 22 March 22-May 23, 1994

Progress-M 23 May 22-July 2, 1994

Carried 2207 kg of cargo. Returned Raduga capsule.

Progress-M 24 August 25-October 5, 1994

The mission was delayed from July by funding constraints. Originally Progress-M 24 was to have been the first of two resupply craft received by Mir Principal Expedition 16, but the second Progress was cancelled to save money and its cargo combined with that of Progress-M 24 or put on Soyuz-TM 19 in place of Gennadi Strekalov. Progress-M 24 carried 230 kg of propellant, 420 kg of water, 639.3 kg of food, 276.5 kg of scientific equipment (including 140 kg of equipment critical for Euromir 94, scheduled for the following month, and 100 kg of NASA equipment), and 26 kg of documentation and "packages" (including mail and newspapers)–a total of about 2355 kg of cargo for Mir. Total launch mass was about 7100 kg. Automatic docking at the front longitudinal port was aborted on August 27. The spacecraft drifted 330 km ahead of Mir while ground controllers loaded it with new rendezvous software. During final approach on August 30, the spacecraft struck the forward docking unit two to four times. It then drifted away. Ground controllers stated that the spacecraft carried sufficient propellant for at least two more docking attempts. On September 2 Yuri Malenchenko took control of Progress-M 24 using a panel in Mir. Piloting Progress-M to a successful docking by remote control was said to be very similar to piloting Soyuz-TM. To date (November 1994) the Progress-M 24 problems have been variously attributed to software or Kurs electronics failures on Progress-M 24, or failure of control equipment in the TsUP. For additional details, see section 2.9.3.17.

Progress-M 25 November 13-

1.12 Soyuz-T (1976-1986)

Soyuz-T (figure 1-28) replaced Soyuz Ferry. The “T” stands for transport. Soyuz-T gave the Soviets the ability to launch three cosmonauts in a single spacecraft for the first time since Soyuz 11 in 1971. It was used with the Salyut 6, Salyut 7, and Mir stations.

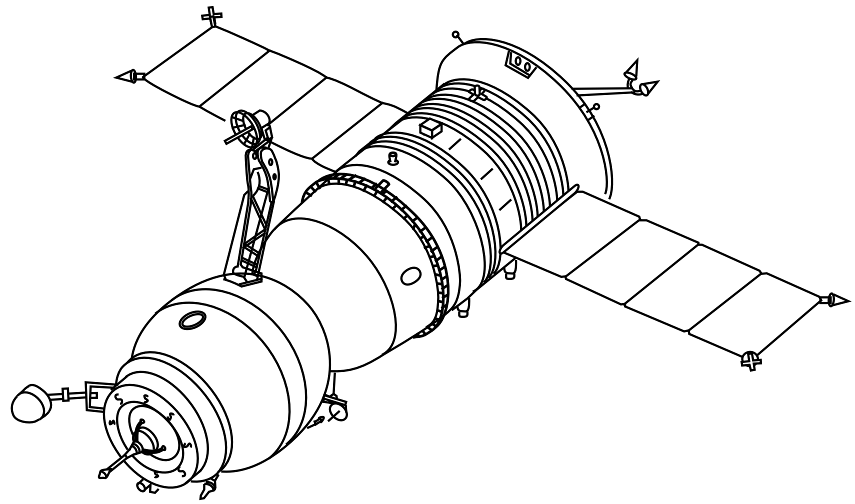

Figure 1-28. Soyuz-T spacecraft.

1.12.1 Soyuz-T Specifications

Launch weight	6850 kg
Length	6.98 m
Span across solar arrays	10.6 m
Diameter of habitable modules	2.2 m
Maximum diameter	2.72 m
Habitable volume	9.5 m^3
Number of crew	2-3

1.12.2 Soyuz-T Notable Features

- Ability to carry three crew in pressure suits, or two crew in pressure suits and 100 kg of additional cargo weight.
- Solar arrays (similar to those on the ASTP Soyuz) replaced batteries as the primary source of electrical power. These were smaller and more efficient than those used on the Original Soyuz and Salyut 1-type Soyuz.[80]
- “Unified” (integrated, or combined) propulsion system: attitude control rockets and main engines drew on the same supplies of N_2O_4 and UDMH propellants.
- Orbital module was discarded prior to deorbit burn to reduce the mass of the Soyuz-T, resulting in a 10% propellant savings. Occasionally the Soyuz-T descent and service modules detached from the orbital module while it was still attached to the Salyut. Typically the orbital module was then detached from the Salyut within a few hours.
- Igla approach system.
- Chayka flight control system featuring BTSVK digital computer. The computer, also called Argon, had 16 kilobytes of RAM. Under nominal conditions, the computer replaced the ground-based computers and ground measurement stations which had guided earlier Soyuz craft. Previous Soyuz spacecraft had relied on hard copy technical documentation carried in the descent module and data transmitted in verbal form from the TsUP analysis group. Argon prepared data which it simultaneously displayed on screens in the descent module and in the TsUP. In addition, control systems were upgraded to include integrated circuit chips, saving volume and weight.[81]
- New main engine similar to that used on Progress. Elimination of

backup engine (with KDU system, attitude thrusters can draw on main propellant supply and thereby deorbit Soyuz-T, removing the need for a separate backup main engine).

- Jettisonable covers for portholes which permitted crew to look out of the spacecraft after reentry. On earlier flights a black coating formed on the portholes during reentry and prevented crews from looking outside during descent and on the surface.
- A lighter launch escape system.
- Improved telemetry capabilities.
- More powerful land landing system solid rocket motors. This made for a gentler touchdown, important for the health and safety of the cosmonauts after a long-duration flight.
- Sufficiently different from the Soyuz Ferry that crews required more than a year of special training to be able to fly it. This accounted in part for the gradual introduction of Soyuz-T, while Soyuz Ferries continued to fly.[82]

1.12.3 Soyuz-T Mission Descriptions

Dates are launch to landing.

1.12.3.1 Soyuz-T Test Missions.

For information on Salyut operations during the Soyuz-T 1 mission, see section 2.7.3.3.

Cosmos 1001 April 4-15, 1978

Unmanned Soyuz-T test.

Cosmos 1074 January 31-April 1, 1979

Unmanned Soyuz-T test.

Soyuz-T 1 December 16, 1979-March 25, 1980

Docked unmanned with Salyut 6 on December 19, after overshooting the station on December 18.

1.12.3.2 Soyuz-T Missions to Salyut 6.

For information on Salyut operations during these Soyuz missions, see sections 2.7.3.4 through 2.7.3.6.

Soyuz-T 2 June 5-9, 1980

Yuri Malyshev, Vladimir Aksyonov
Crew code name—Yupiter

First manned Soyuz-T mission. Its crew of two took over from the Argon computer system during final approach to the station, after it committed a guidance control error.

Soyuz-T 3 November 27-December 10, 1980

Leonid Kizim, Oleg Makarov, Gennadi Strekalov
Crew code name—Mayak

First Soyuz since 1971 to carry three cosmonauts. It constituted a Salyut 6 refurbishment mission.

Soyuz-T 4 March 12-May 26, 1981

Vladimir Kovalyonok, Viktor Savinykh
Crew code name—Foton

Docking with Salyut 6 delayed after the onboard Argon computer determined it would occur outside of radio range with the TsUP. In mid-May, Kovalyonok and Savinykh replaced the Soyuz-T 4 probe with a Salyut drogue. This may have been an experiment to see if a Soyuz-T docked to a space station could act as a rescue vehicle in the event that an approaching Soyuz-T equipped with a probe experienced docking difficulties and could not return to Earth.

1.12.3.3 Soyuz-T missions to Salyut 7

For information on Salyut operations during these Soyuz missions, see section 2.8.3.

Soyuz-T 5 May 13-August 27, 1982

Launch crew—Anatoli Berezevoi, Valentin Lebedev
Crew code name—Elbrus

Landing crew—Leonid Popov, Alexandr Serebrov, Svetlana Savitskaya
Crew code name—Dneiper

First Soyuz to dock with Salyut 7.

Soyuz-T 6 June 24-July 2, 1982

Vladimir Dzhanibekov, Alexandr Ivanchenko, Jean-Loup Chretien/France
Crew code name—Pamir

Suffered Argon computer failure 900 m from Salyut 7. Commander Vladimir Dzhanibekov took manual control and docked with the station 14 minutes ahead of schedule. The skill he displayed contributed to his being tapped for the Soyuz-T 13 mission to rescue Salyut 7 in 1985. Chretien's launch marked the start of a new phase in the manned Intercosmos flights.

Soyuz-T 7 August 19-December 10, 1982

Launch crew—Leonid Popov, Alexandr Serebrov, Svetlana Savitskaya
Crew code name—Dneiper

Landing crew—Anatoli Berezevoi, Valentin Lebedev
Crew code name—Elbrus

Svetlana Savitskaya was the first woman in space since Valentina Tereshkova (who flew in 1963 on Vostok 6).

Soyuz-T 8 April 20-22, 1983

Vladimir Titov, Gennadi Strekalov, Alexandr Serebrov
Crew code name—Okean

First failure to dock at a space station since Soyuz 33 in 1979. When the launch shroud separated from the booster, it took with it the rendezvous antenna boom. The crew believed the boom remained attached to the spacecraft's orbital module, and that it had not locked into place. Accordingly, they shook the spacecraft using its attitude thrusters in an effort to rock it forward so it could lock. The abortive docking attempts consumed much propellant. To ensure that enough would remain to permit deorbit, the cosmonauts shut down the attitude control system and put Soyuz-T 8 into a spin-stabilized mode of the type used by Soyuz Ferries in the early 1970s. Landing occurred as normal.

Soyuz-T 9 June 27, 1983-November 23, 1983

Vladimir Lyakhov, Alexandr Alexandrov
Crew code name—Proton

Its mission was heavily impacted by the Soyuz-T and Soyuz booster failures which bracketed it.

Pad Abort September 26, 1983

Vladimir Titov, Gennadi Strekalov
Crew code name—Okean

Refer to figure 1-29. Shortly before liftoff fuel spilled around the base of the Soyuz launch vehicle and caught fire. Launch control activated the escape system, but the control cables had already burned. The crew could not activate or control the escape system, but 20 sec later ground control was able to activate the escape system by radio command. By this time the booster was engulfed in flames. Explosive bolts fired to separate the descent module from the service module and the upper launch shroud from the lower. Then the escape system motor fired, dragging the orbital module and descent module, encased within the upper shroud, free of the booster at 14 to 17 g's of acceleration. Acceleration lasted 5 sec. Seconds after the escape system activated, the booster exploded, destroying the launch complex (which was, incidentally, the one used to launch Sputnik 1 and Vostok 1). Four paddle-shaped stabilizers on the outside of the shroud opened. The descent module separated from the orbital module at an altitude of 650 m, and dropped free of the shroud. It discarded its heat shield, exposing the solid-fueled land landing rockets, and deployed a fast-opening emergency parachute. Landing occurred about 4 km from the launch pad. The aborted mission is often called Soyuz-T 10a in the West. This was the last failed attempt to date to reach a space station to date.[83]

Soyuz-T 10 February 8-April 11, 1984

Launch crew—Leonid Kizim, Vladimir Solovyov, Oleg Atkov
Crew code name—Mayak

Landing crew—Vladimir Dzhanibekov, Svetlana Savitskaya, Igor Volk
Crew code name—Pamir

Called Soyuz-T 10b in the West.

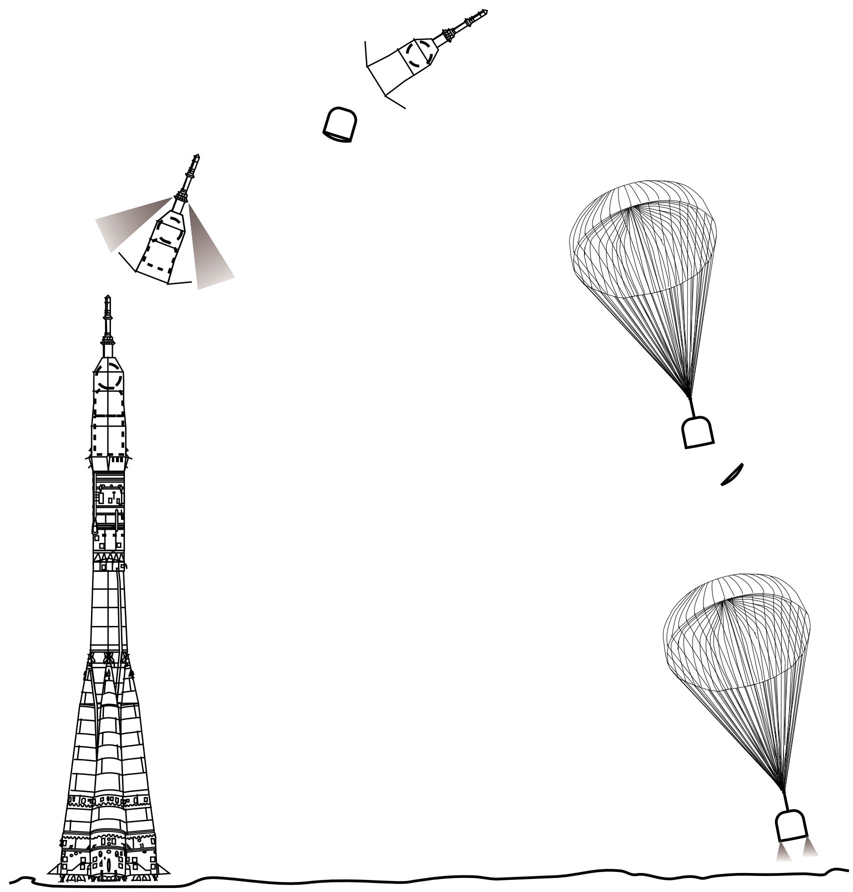

Figure 1-29. Soyuz launch pad abort sequence. The modules of the Soyuz spacecraft are shown beneath the launch shroud by dashed lines. Note the separation plane between the Soyuz descent and service modules.

Soyuz-T 11 April 3-October 2, 1984

Launch crew—Yuri Malyshev, Gennadi Strekalov, Rakesh Sharma/India
Crew code name—Yupiter

Landing crew—Leonid Kizim, Vladimir Solovyov, Oleg Atkov
Crew code name—Mayak

Carried the first Indian cosmonaut to the Salyut 7 station.

Soyuz-T 12 July 17-29, 1984

Vladimir Dzhanibekov, Svetlana Savitskaya, Igor Volk
Crew code name—Pamir

Volk was a glimpse of things which might have been: he was a Buran shuttle program pilot being flown in space to prove he would be able to pilot Buran back to Earth after an extended stay in space.

Soyuz-T 13 June 6-September 26, 1985

Launch crew—Vladimir Dzhanibekov, Viktor Savinykh
Crew code name—Pamir

Landing crew—Vladimir Dzhanibekov, Georgi Grechko
Crew code name—Pamir

Vladimir Dzhanibekov could have had no notion that he would so soon visit Salyut 7 after his Soyuz-T 12 flight. Soyuz-T 13 was the first Soyuz to dock manually with an inert Salyut. For the purpose it was slightly modified to include control levers in the descent module for proximity operations. Viktor Savinykh and Vladimir Dzhanibekov salvaged the Salyut 7 station, which had been crippled by a solar array problem (see section 2.8.3.4). Savinykh remained aloft for 169 days, returning to Earth in Soyuz-T 14; Dzhanibekov returned to Earth in Soyuz-T 13 with Grechko after spending 110 days on Salyut 7. Before deorbiting, Soyuz-T 13 spent about 30 hr conducting rendez-vous and docking tests.

Soyuz-T 14 September 17-November 21, 1985

Launch crew—Vladimir Vasyutin, Georgi Grechko, Alexander Volkov
Crew code name—Cheget

Landing crew—Vladimir Vasyutin, Viktor Savinykh, Alexandr Volkov
Crew code name—Cheget

Demonstrated the wisdom of maintaining a Soyuz at Salyut 7 as an emergency medical evacuation vehicle. Vasyutin, the mission commander, fell ill, forcing early termination of the planned 6-mo mission.

1.12.3.4 Soyuz-T Mission to Salyut 7 and Mir

For information on Salyut 7 and Mir operations during this Soyuz Mission, see sections 2.8.3.6 and 2.9.3.1

Soyuz-T 15 March 13-July 16, 1986

Leonid Kizim, Vladimir Solovyov
Crew code name—Mayak

Carried the first two cosmonauts to the Mir station. May 5-6 they transferred to Salyut 7, where they conducted two EVAs and collected experiment results, experimental apparatus, and samples of materials. They returned to Mir on June 25-26.

1.13 Soyuz-TM (1986-Present)

Soyuz-TM (figure 1-30) is an upgraded version of Soyuz-T used with the Mir space station. The "TM" in Soyuz-TM is usually translated as "transport modified," meaning that it is a further improvement of the Soyuz-T.

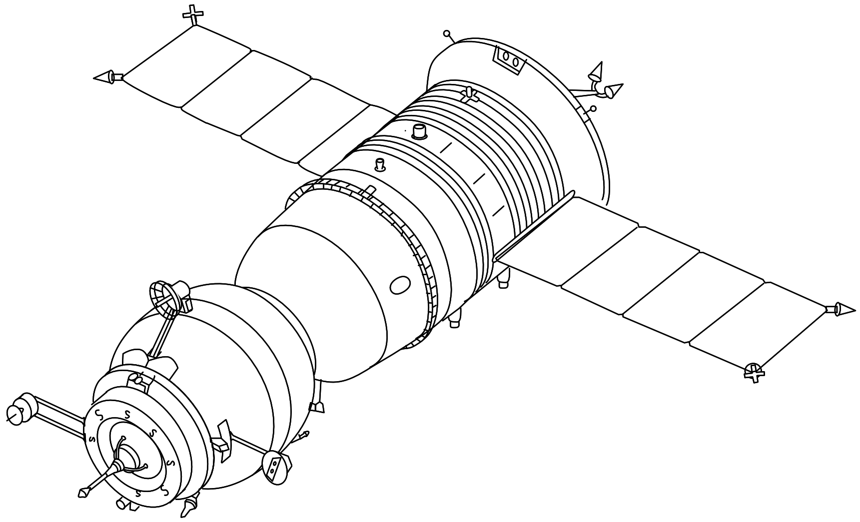

Figure 1-30. Soyuz-TM spacecraft. Compare the antennae on the orbital module to those on Soyuz-T. Differences reflect the change from the Igla rendezvous system used on Soyuz-T to the Kurs rendezvous system used on Soyuz-TM.

1.13.1 Soyuz-TM Specifications

Launch weight	7070 kg
Length	6.98 m
Span across solar arrays	10.6 m
Diameter of habitable modules	2.2 m
Maximum diameter	2.72 m
Habitable volume	9.5-10 m^3
Number of crew	2-3

1.13.2 Soyuz-TM Notable Features

- The Kurs rendezvous system, which permitted automatic dockings with an unresponsive space station, replaced the Igla system. Kurs could operate at greater distances from a station than Igla, and could lock on even if its antennas were not aligned with those on the target station; that is, the antennas were omnidirectional and did not have to be in line of sight.
- 10-kg launch and reentry pressure suits, which in an emergency can protect the wearer in open space.
- Lighter parachutes, which take up less room in the descent module and save up to 140 kg of weight.
- Launch payload increased by 200-250 kg to 51.6° orbit; return payload increased by 70-90 kg.
- Improved propellant tanks—these featured metal membranes for dividing the oxidizer from the fuel. Past Soyuz propellant systems used organic (plastic?) membranes which could leak, degrading engine performance.
- Improved communications gear—separate voice channels for each cosmonaut and improved reception quality.
- Improved landing radar altimeter.
- Lighter escape system motors.
- Triple redundant electrical systems, and redundant hydraulic systems.

1.13.3 Soyuz-TM Mission Descriptions

All Soyuz-TM spacecraft docked with Mir. For information on Mir operations during these Soyuz missions, see section 2.9.3. Dates are launch to landing.

Soyuz-TM 1 May 21-30, 1986

Unmanned Soyuz-TM test.

Soyuz-TM 2 February 5, 1987-July 30, 1987

Launch crew—Yuri Romanenko, Alexandr Laveikin
Crew code name—Tamyr

Landing crew—Alexandr Viktorenko, Alexandr Laveikin, Mohammed al Faris/ Syria
Crew code name—Vityaz

Laveikin developed heart irregularities which made necessary his early return to Earth.

Soyuz-TM 3 July 22, 1987-December 29, 1987

Launch crew—Alexandr Viktorenko, Alexander Alexandrov, Mohammed al Faris/Syria
Crew code name—Vityaz

Landing crew—Yuri Romaneko, Alexandr Alexandrov, Anatoli Levchenko
Crew code name—Tamyr

Faris was the first Syrian in space. Alexandrov was Laveikin's replacement aboard Mir, becoming Romanenko's new partner.

Soyuz-TM 4 December 21, 1987-June 17, 1988

Launch crew—Vladimir Titov, Musa Manarov, Anatoli Levchenko
Crew code name—Okean

Landing crew—Anatoli Solovyov, Viktor Savinykh, Alexandr Alexandrov/ Bulgaria
Crew code name—Rodnik

Manarov and Titov spelled Romanenko and Alexandrov. Anatoli Levchenko was a cosmonaut in the Buran shuttle program. Levchenko returned with Romanenko and Alexandrov in Soyuz-TM 3.

Soyuz-TM 5 June 7, 1988-September 7, 1988

Launch crew—Anatoli Solovyov, Viktor Savinykh, Alexandr Alexandrov/ Bulgaria
Crew code name—Rodnik

Landing crew—Alexandr Lyakhov, Abdul Ahad Mohmand/Afghanistan
Crew code name—Proton

Arrived at Mir carrying the second Bulgarian in space, Alexandrov (not to be confused with the Soviet cosmonaut of the same name). He became the first Bulgarian to reach a Soviet space station (Georgi Ivanov failed to reach Salyut 6 on Soyuz 33 in 1979—Alexandrov was his backup). Their launch had been advanced by 2 weeks late in the planning stages to improve lighting conditions for the Rozhen astronomical experiment. On September 5 cosmonauts Alexandr Lyakhov and Abdul Ahad Mohmand undocked from Mir. They jettisoned the orbital module and made ready for deorbit burn to return to Earth. However, unbeknownst to the cosmonauts or TsUP, the guidance computer was using the docking software of the Bulgarian Mir mission in June. The deorbit burn did not occur at the appointed time because the infrared horizon sensor could not confirm proper attitude. Seven minutes after the scheduled time, the sensor determined that the correct attitude had been achieved. The main engine fired, but Lyakhov shut it down after 3 sec. A second firing 3 hr later lasted only 6 sec. Lyakhov immediately attempted to manually deorbit the craft, but the computer shut down the engine after 60 sec. The cosmonauts were forced to remain in orbit a further day. Even if the main engine had permitted them to do so, they would not have been able to redock with Mir because they had discarded the docking system along with the orbital module. The cosmonauts were left for a day in the cramped quarters of the descent module with minimal food and water and no sanitary facilities. Reentry occurred as normal on September 7. After this the Soviets retained the orbital module until after deorbit burn, as they had done on the Soyuz Ferry flights.

Soyuz-TM 6 August 29-December 21, 1988

Launch crew—Alexandr Lyakhov, Valeri Polyakov, Abdul Ahad Mohmand/ Afghanistan
Crew code name—Proton

Landing crew—Vladimir Titov, Musa Manarov, Jean-Loup Chretien/France
Crew code name—Okean

Dr. Valeri Polyakov remained behind on Mir with cosmonauts Musa Manarov and Vladimir Titov when Mohmand and Lyakhov returned to Earth in Soyuz-TM 5.

Soyuz-TM 7 November 26, 1988-April 27, 1989

Launch crew—Alexandr Volkov, Sergei Krikalev, Jean-Loup Chretien/France
Crew code name—Donbass

Landing crew—Alexandr Volkov, Sergei Krikalev, Valeri Polyakov
Crew code name—Donbass

Original launch date of November 21 was moved back to permit French president Francois Mitterand to attend the launch. Arrived at the Mir station carrying a three-man crew, including French cosmonaut Chretien on his second flight into space. Titov, Manarov, and Chretien returned to Earth in Soyuz TM-6. Alexander Volkov, Sergei Krikalev, and Valeri Polyakov remained aboard Mir. On April 28, 1989, they left Mir in mothballs and returned to Earth in

Soyuz-TM 7. The Soyuz-TM land landing system is effective at reducing velocity in the vertical direction. However, according to cosmonaut Sergei Krikalev, winds at the landing site often impart considerable horizontal velocity. As a result, about 80% of all Soyuz descent modules come to rest on their sides. During the rough landing, Krikalev suffered a minor injury to his knee.[84]

Soyuz-TM 8 September 5, 1989-February 19, 1990

Alexander Viktorenko, Alexandr Serebrov
Crew code name—Vityaz

Launch vehicle was painted with advertisements. During final approach to Mir (4 m distance), the Kurs system malfunctioned, so Viktorenko took over manual control and withdrew to 20 m. He then docked manually. Spent 166 days attached to Mir.

Soyuz-TM 9 February 11-August 9, 1990

Anatoli Solovyov, Alexandr Balandin
Crew code name—Rodnik

During docking, cosmonauts aboard Mir noticed that three of the eight thermal blankets (layers of foil vacuum-shield insulation) on the descent module of the approaching Soyuz-TM 9 spacecraft had come loose from their attachments near the heat shield, yet remained attached at their top ends. The main concern was that the capsule might cool down, permitting condensation to form inside and short out its electrical systems. There was also fear that the blankets might block the infrared vertical sensor, which oriented the module for reentry. Three other areas of concern emerged: that the explosive bolts binding the service module to the descent module might fail to work after direct exposure to space, that the heat shield might be compromised by direct space exposure, and that an EVA to repair the blankets might cause additional damage. Consideration was given to flying Soyuz-TM 10 with one cosmonaut aboard as a rescue mission. During an EVA, the cosmonauts folded back two of the three blankets and left the third alone. During reentry, the cosmonauts ejected both the orbital module and the service module simultaneously in an effort to minimize the chances that a blanket could snag. Normally the orbital module went first. The descent module suffered no damage as a result of its prolonged exposure to space conditions. Reentry occurred as normal.

Soyuz-TM 10 August 1-December 10, 1990

Launch crew—Gennadi Manakov, Gennadi Strekalov
Crew code name—Elbrus

Landing crew—Gennadi Manakov, Gennadi Strekalov, Toyohiro Akiyama/ Japan
Crew code name—Elbrus

Spent 131 days attached to Mir. A camera was installed in the descent module as part of the agreement with Akiyama's network to film the reactions of the returning cosmonauts.

Soyuz-TM 11 December 2, 1990-May 26, 1991

Launch crew—Viktor Afanasyev, Musa Manarov, Toyohiro Akiyama/Japan
Crew code name—Derbent

Landing crew—Viktor Afanasyev, Musa Manarov, Helen Sharman/Britain
Crew code name—Derbent

Spent 175 days docked to Mir. Its launch shroud and Soyuz booster were painted with the Japanese flag and advertisements. A camera inside the descent module filmed the cosmonauts during ascent for Akiyama's network.

Soyuz-TM 12 May 18-October 10, 1991

Launch crew—Anatoli Artsebarksi, Sergei Krikalev, Helen Sharman/Britain
Crew code name—Ozon

Landing crew—Anatoli Artsebarski, Toktar Aubakirov/Kazakhstan, Franz Viehboeck/Austria
Crew code name—Ozon

Spent 144 days docked to Mir. While it was in orbit, the failed coup d'etat against Mikhail Gorbachev rocked the Soviet Union, setting in motion events which led to the end of the Soviet Union on January 1, 1992.

Soyuz-TM 13 October 2, 1991-March 25, 1992

Launch crew—Alexandr Volkov, Toktar Aubakirov/Kazakhstan, Franz Viehboeck/Austria
Crew code name—Donbass

Landing crew—Alexandr Volkov, Sergei Krikalev, Klaus-Dietrich Flade/Germany
Crew code name—Donbass

Spent 175 days docked to Mir. Krikalev launched from the Kazakh Soviet Socialist Republic of the Soviet Union, and landed in independent Kazakhstan.

Soyuz-TM 14 March 17-August 10, 1992

Launch crew—Alexandr Viktorenko, Alexandr Kaleri, Klaus-Dietrich Flade/Germany
Crew code name—Vityaz

Landing crew—Alexandr Viktorenko, Alexandr Kaleri, Michel Tognini/France
Crew code name—Vityaz

Suffered a landing system malfunction, causing its descent module to turn over. It came to rest upside down, trapping its occupants inside until it could be righted.

Soyuz-TM 15 July 27, 1992-February 1, 1993

Launch crew—Sergei Avdeyev, Anatoli Solovyov, Michel Tognini/France
Crew code name—Rodnik

Landing crew—Sergei Avdeyev, Anatoli Solovyov
Crew code name—Rodnik

Tognini spent 3 weeks in space as part of ongoing space cooperation between Russia and France.

Soyuz-TM 16 January 24-July 22, 1993

Launch crew—Gennadi Manakov, Alexandr Poleshchuk
Crew code name—Elbrus

Landing crew—Gennadi Manakov, Alexandr Poleschuk, Jean-Pierre Hagniere/France
Crew code name—Elbrus

First Soyuz without a probe and drogue docking system since 1976. It carried an APAS-89 androgynous docking unit (see figure 3-13) different from the APAS-75 unit (see figure 1-22) used for ASTP in 1975, yet similar in general principles. Soyuz-TM 16 used it to dock with an androgynous docking port on the Kristall module. This was a test of the docking system in preparation for dockings by space shuttles with Mir.

Soyuz-TM 17 July 1, 1993-January 14, 1994

Launch crew—Vasili Tsibliyev, Alexandr Serebrov, Jean-Pierre Haignere/France
Crew code name—Sirius

Landing crew—Vasili Tsibliyev, Alexandr Serebrov
Crew code name—Sirius

At 7:37:11 a.m. Moscow time (MT), on January 14, Soyuz-TM 17 separated from the forward port of the Mir station. At 7:43:59 a.m., the TsUP ordered Tsibliyev to steer Soyuz-TM 17 to within 15 m of the Kristall module to begin photography of the APAS-89 docking system. At 7:46:20 a.m., Tsibliyev complained that Soyuz-TM 17 was handling sluggishly. Serebrov, standing by for photography in the orbital module, then asked Tsibliyev to move the spacecraft out of the station plane because it was coming close to one of the solar arrays. In Mir, Viktor Afanasyev ordered Valeri Polyakov and Yuri Usachyov to evacuate to the Soyuz-TM 18 spacecraft. At 7:47:30 a.m., controllers in the TsUP saw the image from Soyuz-TM 17's external camera shake violently, and Serebrov reported that Soyuz-TM 17 had hit Mir. The TsUP then lost communications with Mir and Soyuz-TM 17. Intermittent communications were restored with Soyuz-TM 17 at 7:52 a.m. Voice communications with Mir were not restored until 8:02 a.m. Inspection of Soyuz-TM 17 indicated no serious damage. In this connection, the Russians revealed that they had studied contingency reentries by depressurized spacecraft in the wake of the Soyuz 11 accident. The Mir cosmonauts did not feel the impact, though the station's guidance system registered angular velocity and switched to free-flying mode. Later analysis indicated that the right side of the orbital module had struck Mir two glancing blows 2 sec apart. The impact point was on Kristall, near its connection to the Mir base block. The cause of the impact was traced to a switch error: the hand controller in the orbital module which governed braking and acceleration was switched on, disabling the equivalent hand controller (the left motion control lever) in the descent module. Tsibliyev was able to use the right lever to steer Soyuz past Mir's solar arrays, antennas, and docking ports after it became clear impact was inevitable.[85, 86]

Soyuz-TM 18 January 8-July 9, 1994

Launch crew—Viktor Afanasyev, Yuri Usachyov, Valeri Polyakov
Crew code name—Derbent

Landing crew—Viktor Afanasyev, Yuri Usachyov
Crew code name—Derbent

Afanseyev and Usachyov spent 179 days on Mir. Dr. Polyakov is slated to return to Earth on Soyuz-TM 20 in March 1995, after more than 420 days on Mir.

Soyuz-TM 19 July 1-November 4, 1994

Launch crew–Yuri Malenchenko, Talgat Musabayev/Kazakhstan
Landing crew–Yuri Malenchenko, Talgat Musabayev/Kazakhstan, Ulf Merbold/ESA
Crew code name–Agat

Commander Malenchenko and Flight Engineer Musabayev, spaceflight rookies, were to have been launched with veteran cosmonaut Gennadi Strekalov, who would have returned to Earth with Viktor Afanaseyev and Yuri Usachyov in Soyuz-TM 18 after a few days on Mir. However, cancellation of one of two Progress-M cargo ships scheduled to resupply Mir during the Agat crew's stay meant Strekalov's couch had to carry supplies. The result was an unusual all-rookie flight. Docking occurred without incident on July 3. On November 3, Musabayev, Malenchenko, and Merbold undocked in Soyuz-TM 19 and backed 190 m from Mir. They then activated the Kurs automatic approach system, which successfully redocked the spacecraft. The cosmonauts then transferred back to Mir. The test was related to the difficulties Soyuz-TM 20 and Progress-M 24 experienced during their automatic approaches. Final undocking and reentry the following day occurred without incident.

Soyuz-TM 20 October 3, 1994-

Launch crew–Alexandr Viktorenko, Yelena Kondakova, Ulf Merbold/ESA
Landing crew–
Crew code name–Vityaz

Carried 10 kg of equipment for use by Merbold in ESA's month-long Euromir 94 experiment program. During automatic approach to Mir's front port, the spacecraft yawed unexpectedly. Viktorenko completed a manual docking without additional incident.

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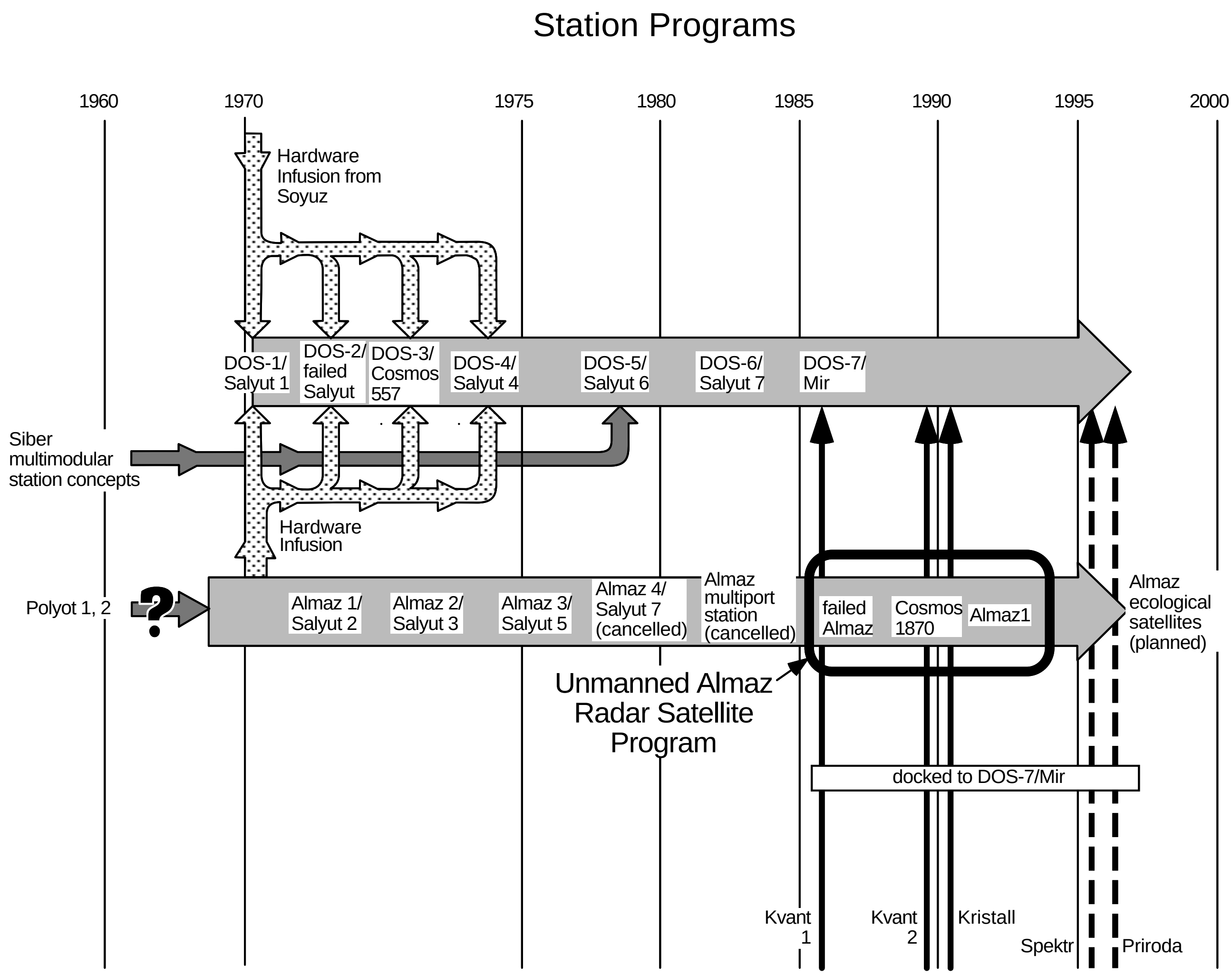

Figure 2-1. Station evolution. The chart above summarizes the development of the Soviet/Russian space stations and derivatives. Light gray arrows trace the evolution of space stations and satellites derived from space station hardware. Dark gray arrows trace the influence of concepts on later flown hardware. The stippled arrow leads from the Soyuz Programs chart (figure 1-1). Solid black arrows indicate modules joined to Mir, while dashed black arrows stand for modules to be added to Mir in the near future. These arrows lead from the Station Modules and Tug Programs chart (figure 3-1).