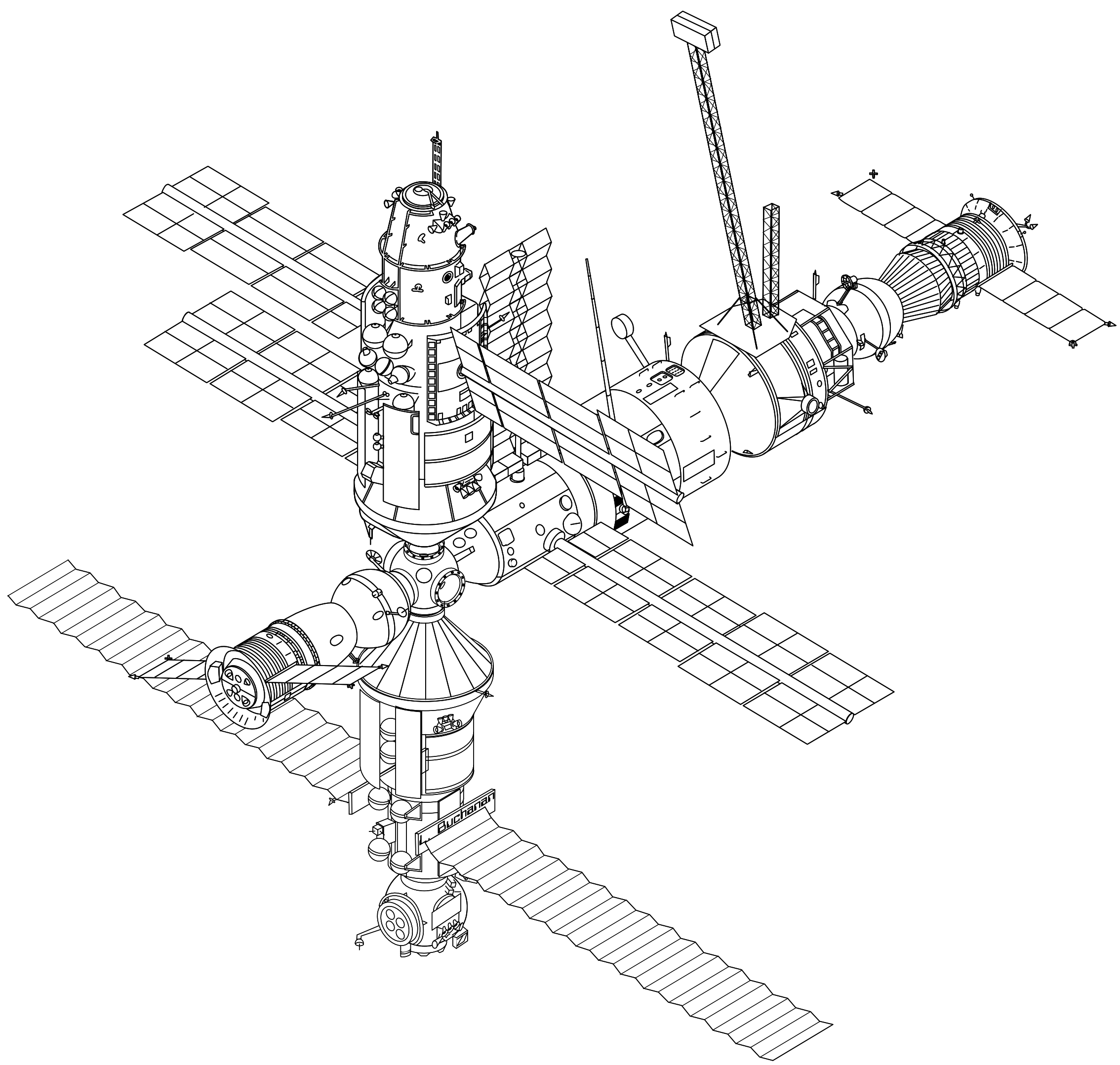
NASA RP 1357

Mir Hardware Heritage

David S. F. Portree



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Mir Hardware Heritage

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Preface

This document was prepared by the Information Services Division, Information Systems Directorate, NASA Johnson Space Center, in response to the many requests for information on Soviet/Russian spaceflight received by the Scientific and Technical Information Center in the division's Information Management Branch. We hope this document will be helpful to anyone interested in Soviet/Russian spaceflight. In particular, we hope it will provide new insights to persons working on the Shuttle-Mir missions and International Space Station Alpha.

As a look at the sources listed at the end of each part will show, this work is based primarily on Russian sources, usually in English translation. Unfortunately, these sources often conflict. In this work preference is given to sources which contain abundant details, verifiable or otherwise; are corroborated in whole or in part by at least one other Russian source; and are the product of persons or organizations that can be expected to have intimate knowledge of the hardware and events described.

This is an exciting time to study Soviet/Russian spaceflight. New light is thrown regularly on mysteries decades old. But there has not yet been time to tell all the old secrets. Because of this, new revelations still occur frequently. Most of this work will likely remain an accurate account; however, specific interpretations and details will as likely prove inaccurate as new information is revealed. So it is with any book on Soviet/Russian spaceflight written in this time of transition.

Some readers may note what they perceive to be an undue emphasis on Soviet/Russian mission and hardware anomalies. This is partly a result of the document's focus, which is, after all, on Soviet/Russian hardware history. (The reader will note that, where appropriate, U.S. anomalies are mentioned as well.) In addition, in the Soviet era, anomalies were often the chief (or only) way new information about secret hardware emerged. All countries have had their share of problems on the space frontier. Mention of anomalies in this document should not be construed as criticism of hardware or management in any country.

This document is an updated and corrected edition of document JSC 26770 (October 1994). New material updates the Soyuz-TM, Progress-M, Mir Career, and Comparative Chronology sections to November 15, 1994. Sundry corrections and additions have been made at the suggestion of readers of the JSC edition or on the basis of information unavailable when the JSC edition was written. Readers should also note the addition of an index.

Acknowledgments

The author gratefully acknowledges the assistance rendered by Joseph P. Loftus, Jr., NASA Johnson Space Center (JSC); Mark Severance, JSC; Nicholas Johnson, Kaman Sciences; Sergei Krikalev, Russian cosmonaut; Doug Ward, JSC; James Nise, JSC; Andrew Petro, JSC; Clarke Covington, JSC; Donald Kessler, JSC; David Lamar, JSC; John P. McManamen, JSC; Jonathon McDowell, Harvard-Smithsonian Center for Astrophysics; Terry Sutton, Lockheed; James Oberg; Phillip Clark; Rex Hall; Dennis Newkirk; and the staff of the Press Office of Sotheby's of New York. Several of the illustrations in this report are based on previous depictions of the hardware by Daniel James Gauthier, Robert Sweeney, David Woods, Charles Vick, and Ralph Gibbons. The author also acknowledges the assistance of the publications staff, information specialists, and library technicians of the JSC Information Services Division, Information Systems Directorate. Any errors remain the responsibility of the author.

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Acronyms and Abbreviations

This list includes Russian acronyms transliterated into English. English language explanations or translations are given in place of Russian. For example, in the entry TsUP below, TsUP is the transliterated acronym for the Russian phrase transliterated *Tsentr Upravlyeniya Polyotom*, but the English-language translation "Flight Control Center" is given.

Altair/SR . . . . Altair/satellite relay
APAS . . . . androgynous peripheral assembly system
ARIS . . . . X-ray sensor on ASPG-M platform
ASAT . . . . antisatellite
ASPG-M . . . . independently stabilized platform on Kvant 2
ASTP . . . . Apollo-Soyuz Test Project

Block D . . . . Proton fourth stage; LRS second stage
Block G . . . . LRS first stage
BST-1M . . . . multispectral telescope
BTSVK . . . . computer used in Soyuz-T spacecraft

C . . . . Cosmos
CANEX . . . . Canadian Experiments
CSM . . . . command and service module

D-module . . . . augmentation module
DOS . . . . long-duration orbital station

ECOR-A . . . . synthetic aperture radar system used on Almaz radar satellite
ERA . . . . French experimental structure deployed on Mir's exterior
ESA . . . . European Space Agency
EURECA . . . . European Retrievable Carrier
EVA . . . . extravehicular activity

F . . . . Ferry
FGB . . . . functional cargo module
FSM . . . . functional service module

HEXE . . . . high-energy X-ray experiment

ICBM . . . . intercontinental ballistic missile
ITSK . . . . infrared telescope
ITS-7D . . . . infrared spectrometer on ASPG-M platform

JSC . . . . Johnson Space Center

K . . . . Kvant
KAP-350 . . . . Earth-resources camera
KATE . . . . multispectral camera
KB . . . . design bureau
KF . . . . Kvant with FSM
KDU . . . . integrated propulsion system
Kr . . . . Kristall
KRT-10 . . . . radio telescope deployed from Salyut 6
KTDU . . . . various Soyuz and Salyut main propulsion systems

LAGEOS . . . . Laser Geodynamic Satellite
L/D . . . . lift-to-drag ratio
LDEF . . . . long-duration exposure facility
LM . . . . Lunar Module
LRS . . . . Lunar Rocket System

M . . . . modified
MKF-6M . . . . East German multispectral camera
MKF-6MA . . . . East German multispectral camera
MKF-6M2 . . . . East German multispectral camera
MMU . . . . manned maneuvering unit
MT . . . . Moscow time

N_2O_4 . . . . nitrogen tetroxide
NA . . . . not applicable
NASA . . . . National Aeronautics and Space Administration
NPO . . . . scientific production association

ODU . . . . integrated propulsion system
OKB . . . . special design bureau
Orlan-DMA . . . . advanced spacesuit
OST-1 . . . . solar telescope

P . . . . Progress

RKK . . . . Russian Space Corporation
RT-4 . . . . X-ray telescope

SAR . . . . Synthetic Aperature Radar
SDI . . . . Strategic Defense Initiative
SDRN . . . . Satellite Data Relay Network
SOUD . . . . orientation and motion control system
SPARTAN . . . . Shuttle-Pointed Autonomous Research Tool for Astronomy
SRB . . . . solid rocket booster
STS . . . . Space Transportation System

T . . . . Transport
TBS . . . . Tokyo Broadcasting System
TDRS . . . . Tracking and Data Relay Satellite
TKS . . . . transport logistics spacecraft
T1K . . . . unflown, unmanned test version of Soviet L2 spacecraft
T2K . . . . unmanned test version of Soviet L3 spacecraft
TM . . . . Transport Modified
TsUP . . . . Flight Control Center
TTM . . . . wide-angle shadow-mask X-ray camera
TV . . . . television

UDMH . . . . unsymmetrical dimethyl hydrazine
URI . . . . universal tool for welding, soldering, cutting metal
UT . . . . Universal time

VDU . . . . auxiliary thruster unit attached to Sofora girder on Mir
VEP . . . . instrument for monitoring Mir internal conditions

YMK . . . . manned maneuvering unit

Introduction

The purpose of this document is to describe concisely what is known in the West about the heritage of the major hardware elements associated with the Mir space station complex. These are

- The Mir base block, launched in 1986
- The modules added to the base block in 1987, 1989, and 1990
- The Soyuz-TM crew transports and Progress-M supply ships, which first appeared in 1986 and 1989, respectively.

This work is divided into four parts. Part 1, "Soyuz," examines the Soyuz spacecraft and its derivatives, including those used in the abandoned manned lunar landing program. Part 2, "Almaz, Salyut, and Mir," looks at the Almaz and Long-Duration Orbital Station (Russians acronym DOS) space stations. The major portion of Part 2 is devoted to the three DOS multiport stations, Salyut 6, Salyut 7, and Mir. Part 3, covering the "Space Station Modules," describes their surprisingly convoluted heritage, with particular attention given to the Mir modules Kvant, Kvant 2, and Kristall. Part 4 is a chronology comparing U.S. and Soviet/Russian manned spaceflight developments in context. It begins with the first manned spaceflight, but attempts completeness only from 1970 to its conclusion (November 1994).

All times and dates are in Universal time (UT) unless otherwise stated. The sources for times and dates were the *Satellite Situation Report*, NASA Goddard Space Flight Center, Vol. 34, No. 1, March 31, 1994; *TRW Space Log 1957-1991*, TRW, 1992; *TRW Space Log 1992*, TRW, 1993; *TRW Space Log 1993*, TRW, 1994; Jonathan McDowell, Harvard-Smithsonian Center for Astrophysics.

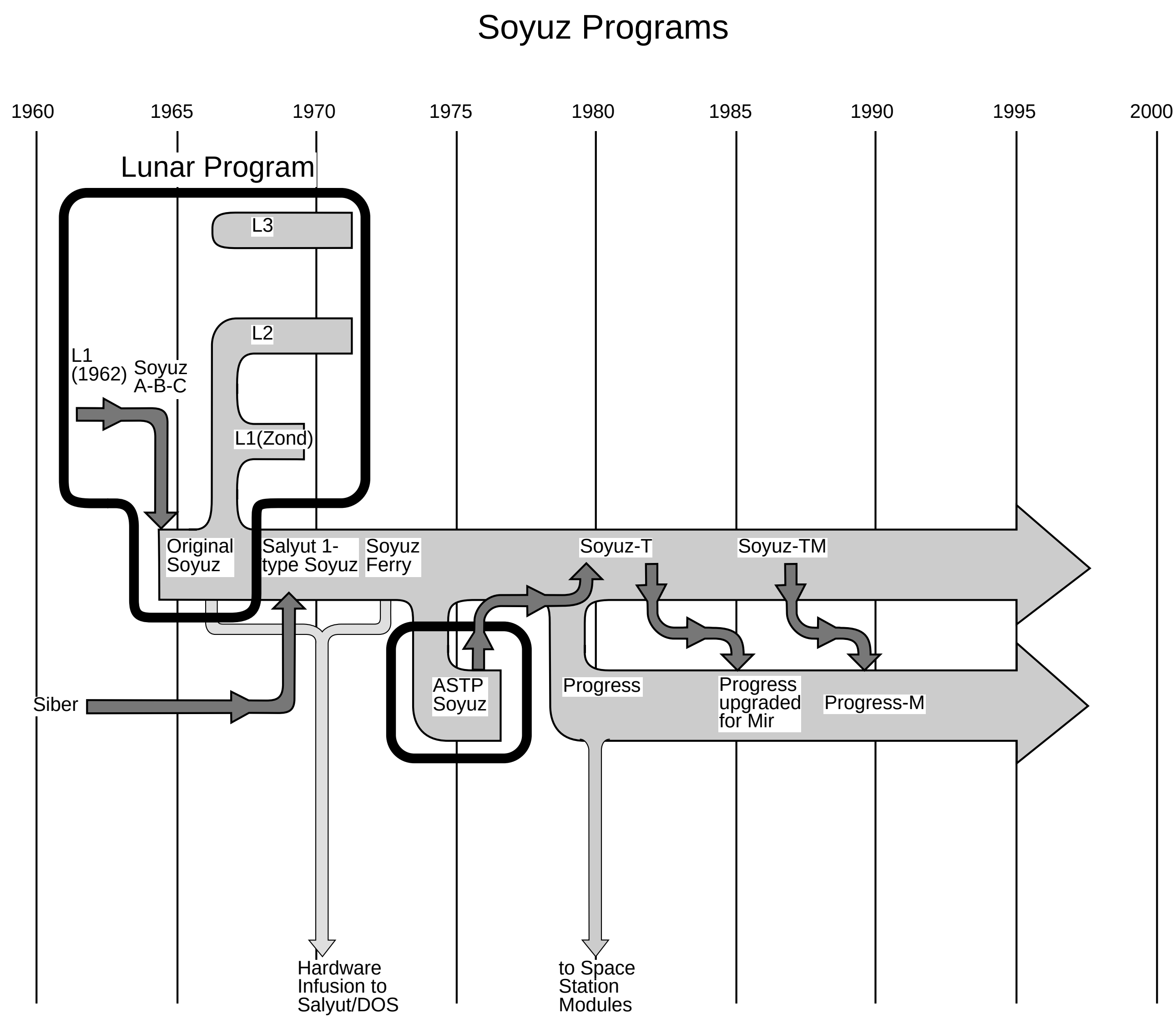

Figure 1-1. Soyuz evolution. The light gray arrows trace the evolution of flown spacecraft. The dark gray arrows show influence of concepts and flown spacecraft on other concepts and flown spacecraft. Broad black lines enclose distinct programs. The stippled and light gray arrows pointing downward, off the chart, connect to the Space Station chart (figure 2-1) and the Station Modules and Tug Programs chart (figure 3-1), respectively.

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,

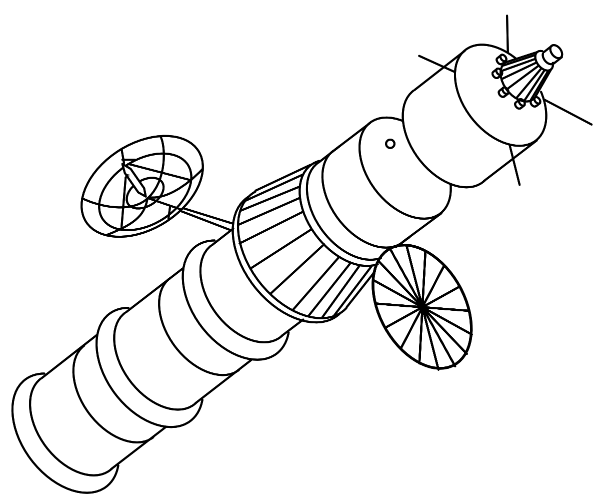

Figure 1-2. L1 Soyuz manned circumlunar concept (1962). Should not be confused with the L1 (Zond) spacecraft (figure 1-9). The cone at the front (right) of the L1 Soyuz is an attitude control module; behind it are cylindrical orbital and descent modules, and a frustum-shaped service module. The round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

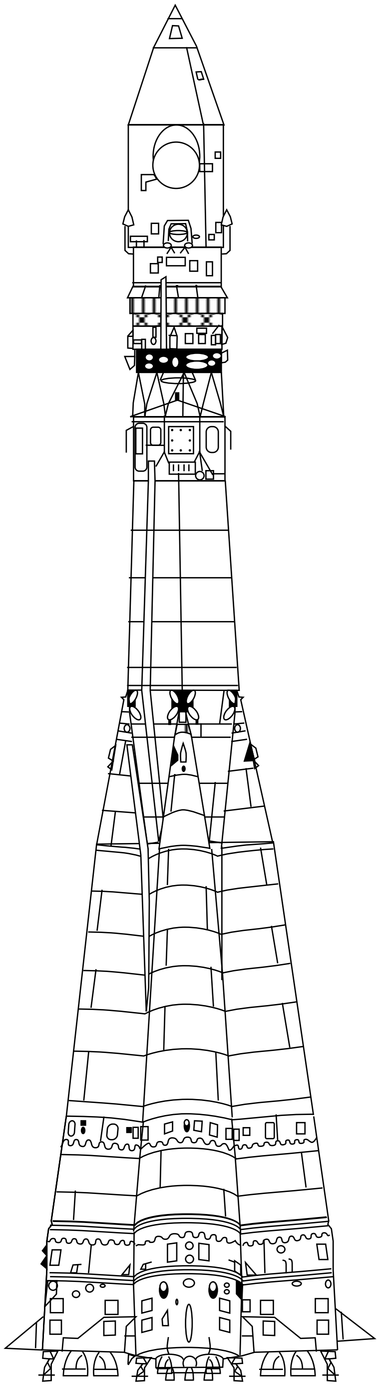

Figure 1-3. Vostok rocket. This is a two-and-a-half-stage derivative of the one-and-a-half-stage rocket which launched Sputnik 1 (1957). Its original ancestor was the SS-6 “Sapwood” ICBM. It served as the basis for the Soyuz launcher (figure 1-7), in service today. Weight of payload launched to 200-km,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

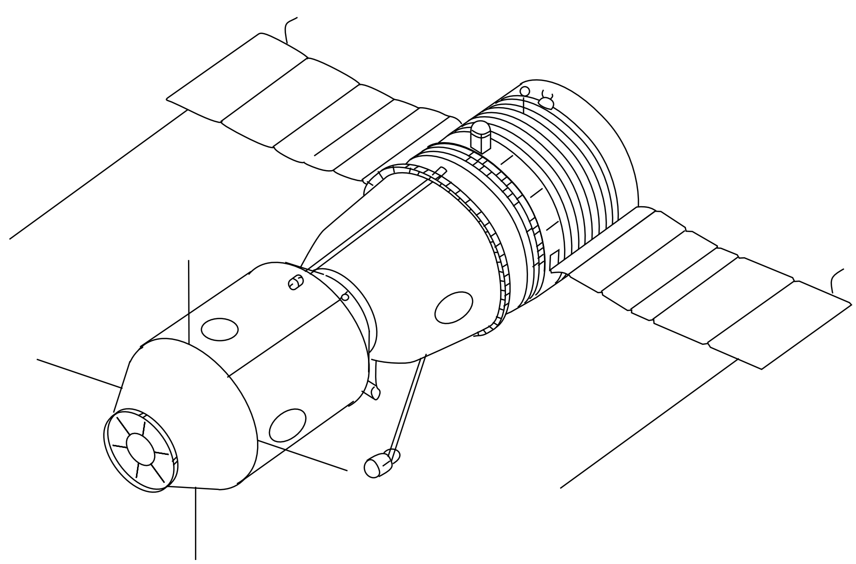

Figure 1-4. Soyuz-A manned spacecraft concept (1963). It was to have been part of the Soyuz A-B-C circumlunar complex.

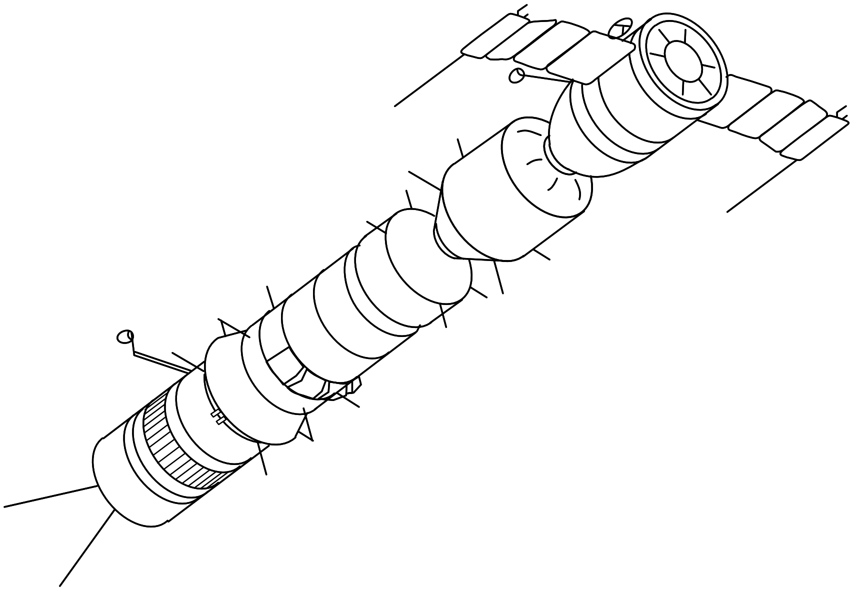

Figure 1-5. Soyuz A-B-C circumlunar concept. The drawing shows Soyuz-A (right), Soyuz-B booster, and Soyuz-C tanker with twin whip antennae (left).

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.

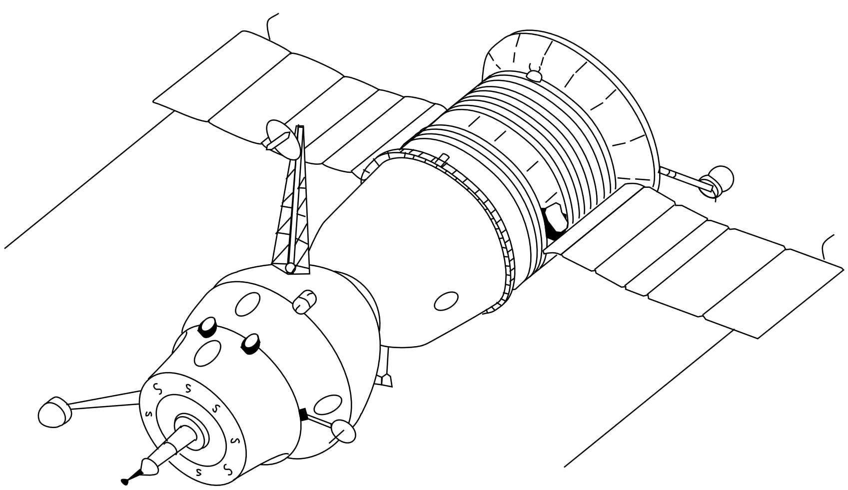

Figure 1-6. Original Soyuz spacecraft.

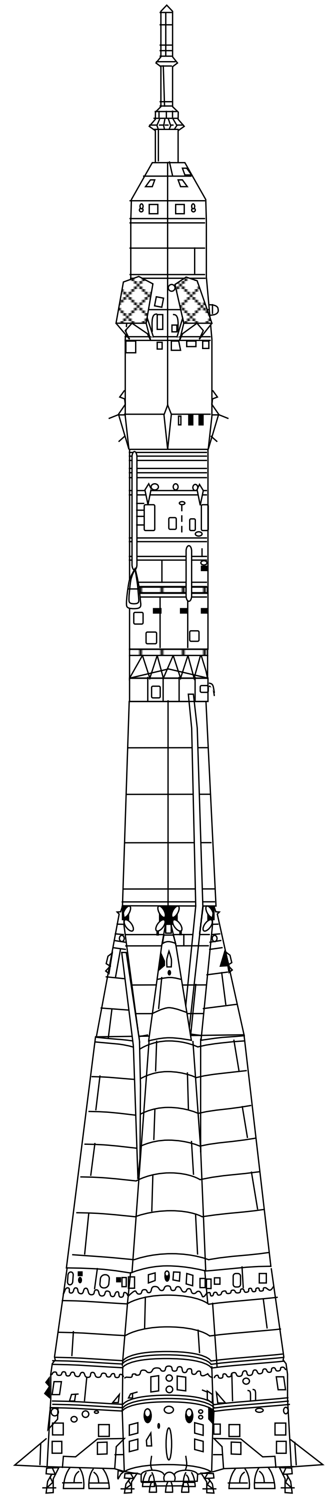

Figure 1-7. Soyuz rocket. With more than 1000 launches to its credit since 1963, the two-and-a-half-stage Soyuz rocket has flown more than any other. Propellants are liquid oxygen and kerosene. Weight of payload launched to 200-km, 51° circular orbit is 7000 kg.

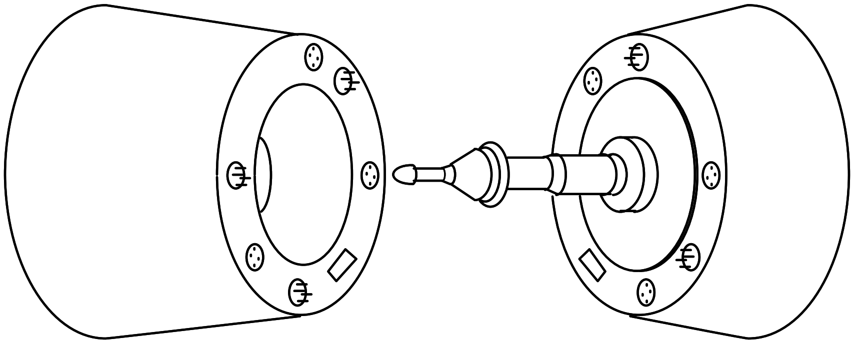

Figure 1-8. Original Soyuz probe and drogue docking system. The active unit (right) consisted of a probe and latches; the passive unit, a receiving cone, socket, and catches. The passive unit's frustum was longer than the active unit's because it was designed to accept the probe. The probe acted as a 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.

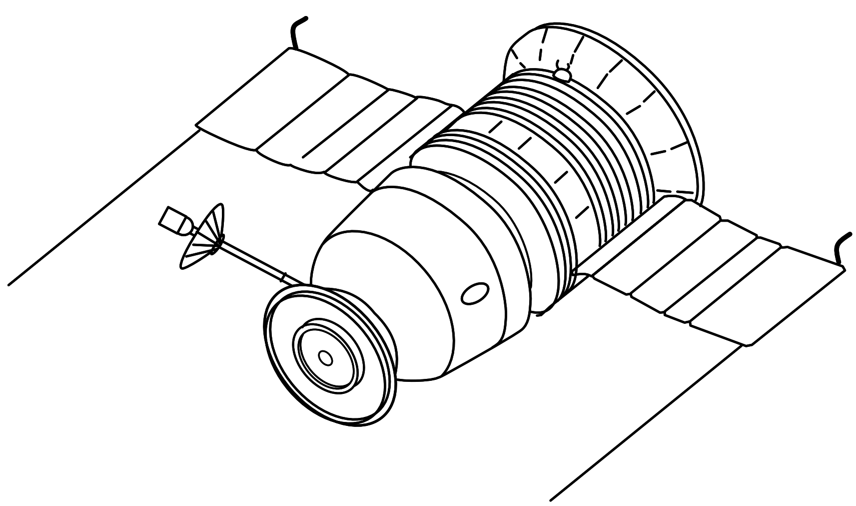

Figure 1-9. L1 (Zond) circumlunar spacecraft.

1.4.1 L1 Specifications

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.

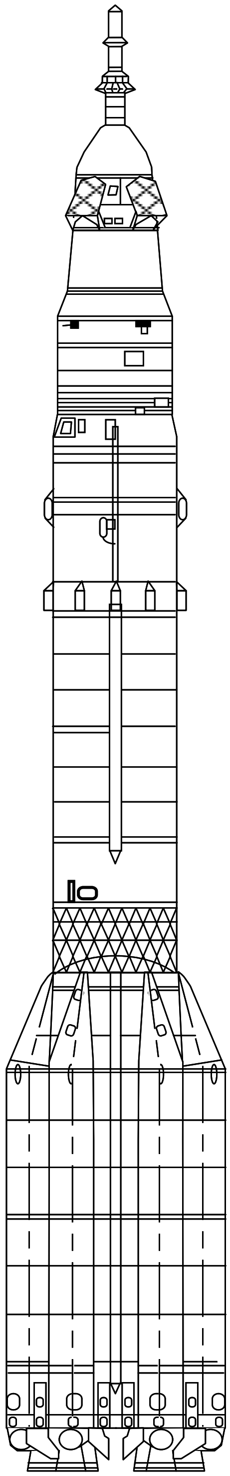

Figure 1-10. Proton configured for L1 (Zond). Note the modified Soyuz shroud (top).

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.

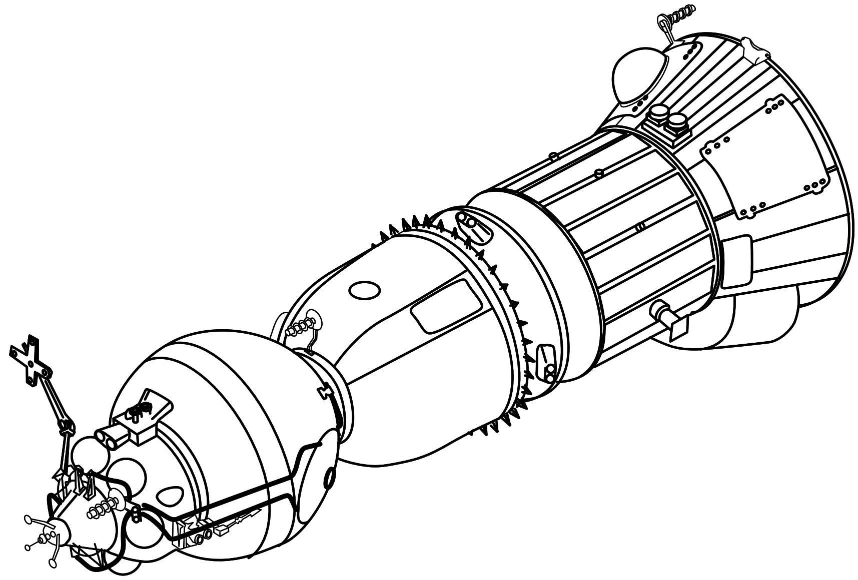

Figure 1-11. L2 (Lunar Orbit Module). At the front of the spacecraft (left) is the Aktiv unit of the lunar mission Kontakt docking system.

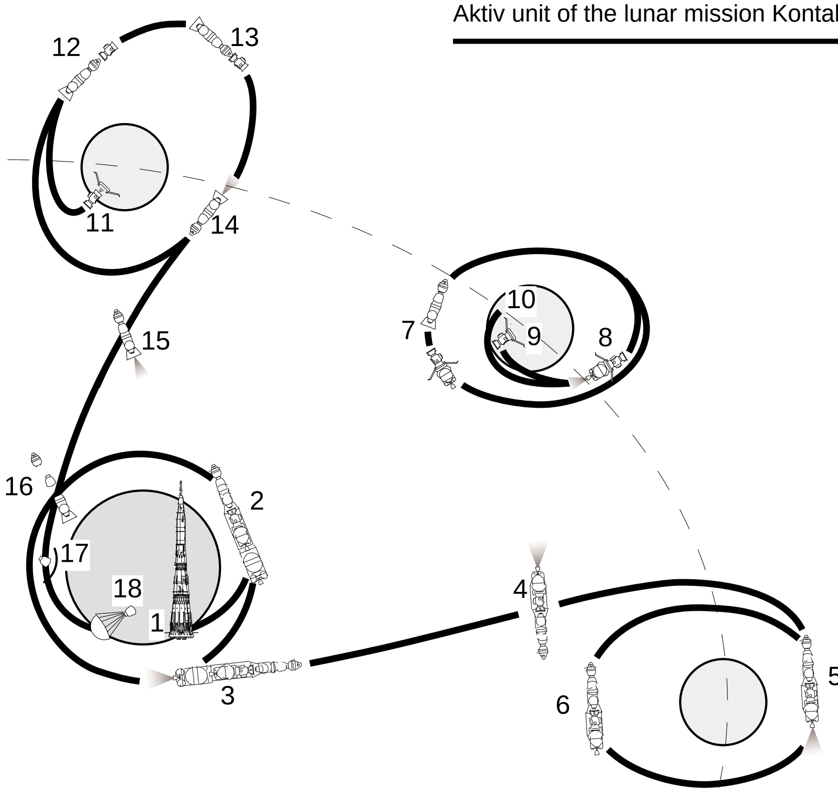

Figure 1-12. N-1/L3 lunar mission profile. 1. N-1 rocket liftoff. 2. LRS Earth orbit insertion. 3. LRS translunar injection using Block G rocket stage. Block G separates. 4. Midcourse correction using Block D rocket stage. 5. Lunar orbital insertion using Block D rocket stage. 6. Single cosmonaut transfers 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

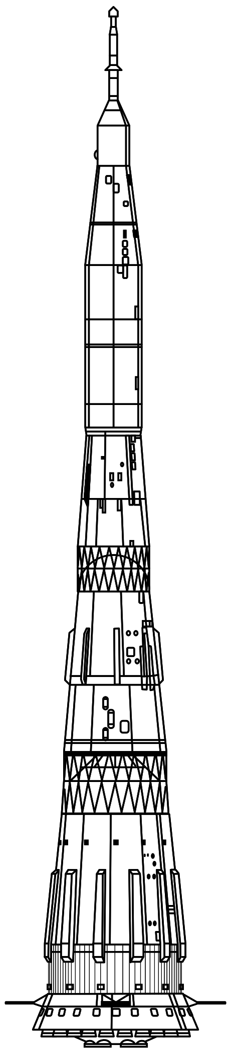

Figure 1-13. N-1 rocket configured for lunar flight. The basic rocket consisted of the Block A first stage, the Block B second stage, and the Block V third stage. All stages burned liquid oxygen and kerosene. For lunar missions the LRS was added. The N-1 would have delivered about 100,000 kg to low-Earth 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

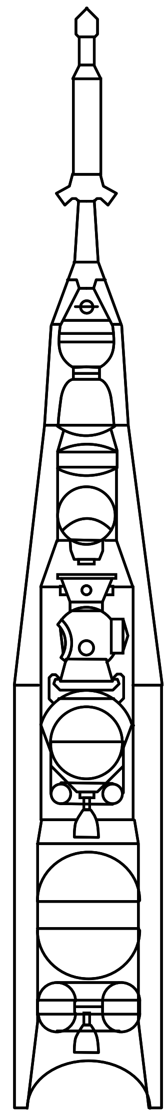

Figure 1-14. Lunar rocket system. Consisted of (bottom to top) the Block G and Block D rocket stages, the L3 lander, and the L2 command ship.

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.

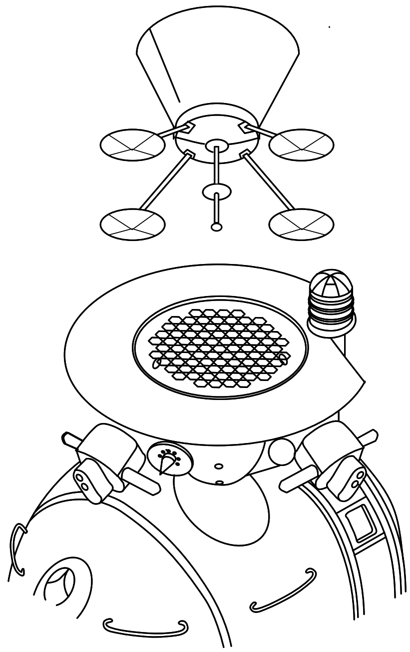

Figure 1-15. Kontakt docking system. Never used in space, the system was designed for the Soviet lunar program. The Aktiv unit (top) was located at the front of the L2, while the passive unit was located on top of the L3 lander.

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.

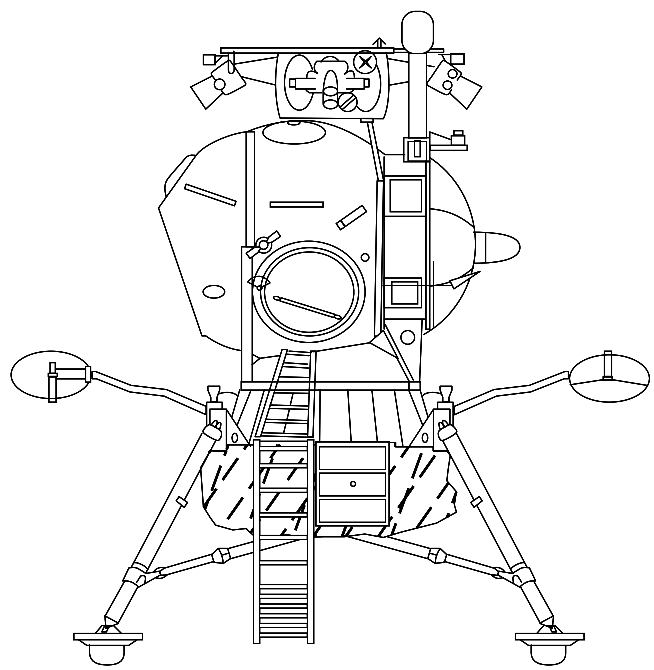

Figure 1-16. L3 lunar lander. The flat, downward-facing face (left) of the ovoid pressure cabin holds the round viewport (not visible). The Kontakt system passive unit is at cabin top, and two landing radar booms extend at left and right. Nozzles of two solid-fueled hold-down rockets are visible at the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

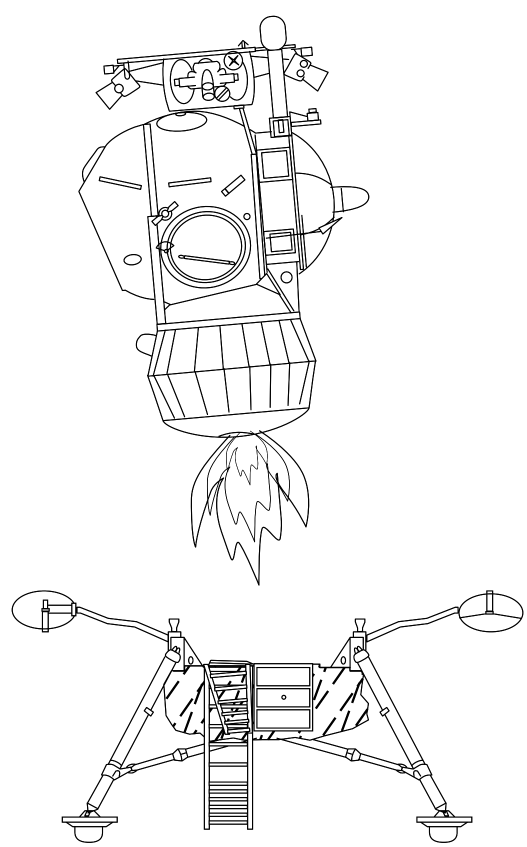

Figure 1-17. L3 ascent.

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.

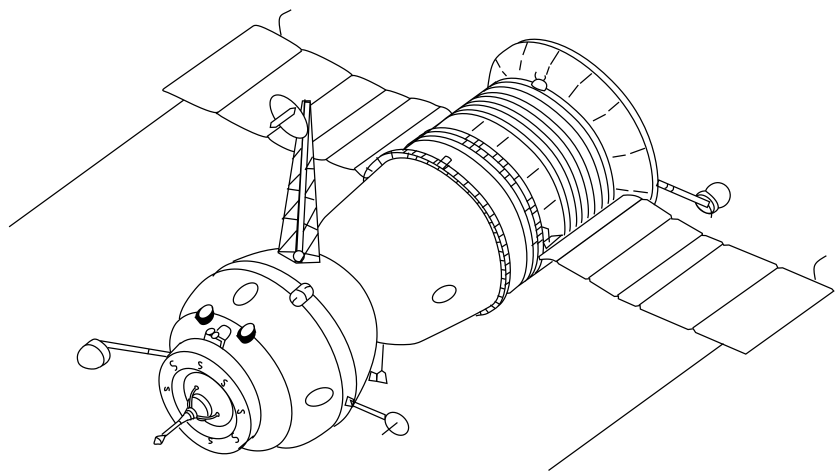

Figure 1-18. Salyut 1-type Soyuz. This was the Original Soyuz upgraded for Salyut space stations. The probe and drogue docking system (left) permitted internal transfer of cosmonauts from the Soyuz to the station.

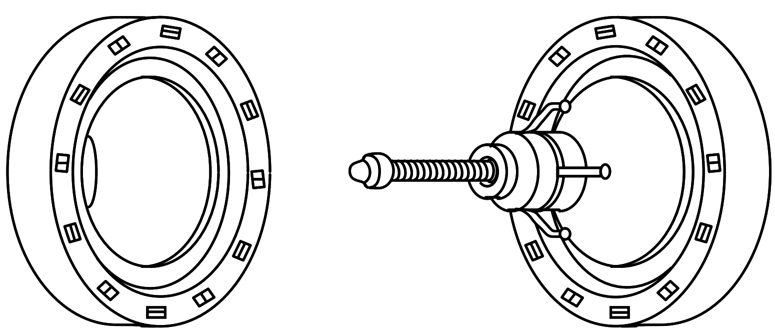

Figure 1-19. Soyuz internal transfer docking unit. This system is used today for docking spacecraft to Mir. The active craft inserts its probe into the space station receiving cone. The probe tip catches on latches in the socket at the apex of the cone. Motors then draw the two spacecraft together. Latches 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.

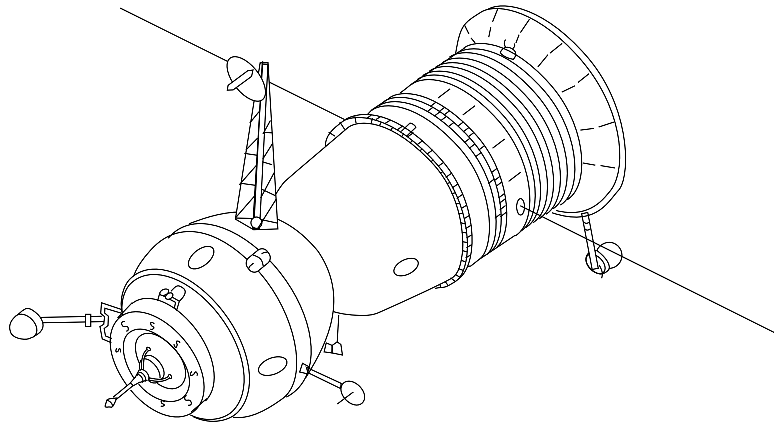

Figure 1-20. Soyuz Ferry.

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.

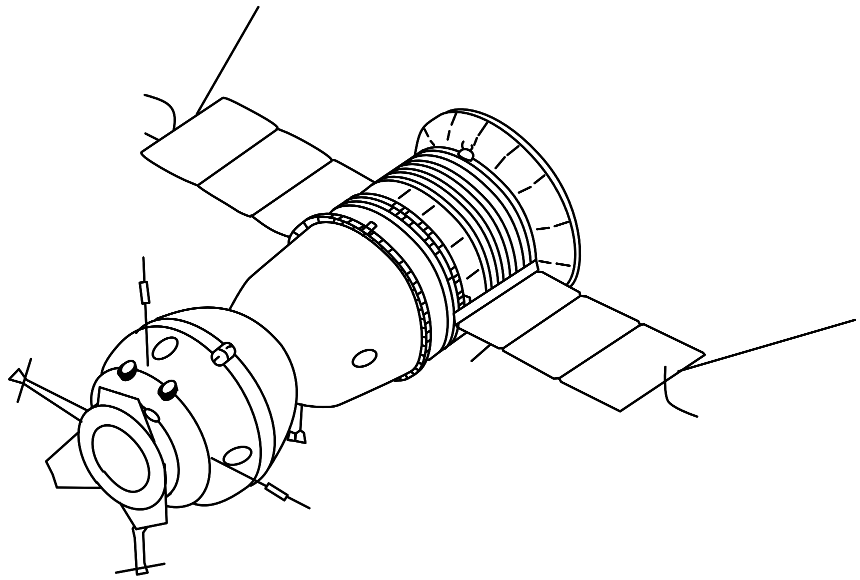

Figure 1-21. Apollo-Soyuz Test Project (ASTP) Soyuz. The APAS-75 docking unit is located at left.

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.

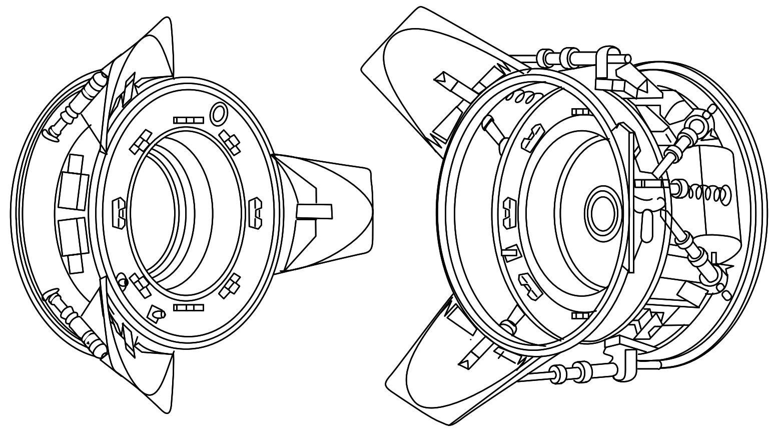

Figure 1-22. APAS-75 docking unit. Unlike previous docking systems, both units could assume the active or passive roles as required. For docking, the spade-shaped guides of the extended active unit (right) and the retracted passive unit (left) interacted for gross alignment. The ring holding the guides 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.

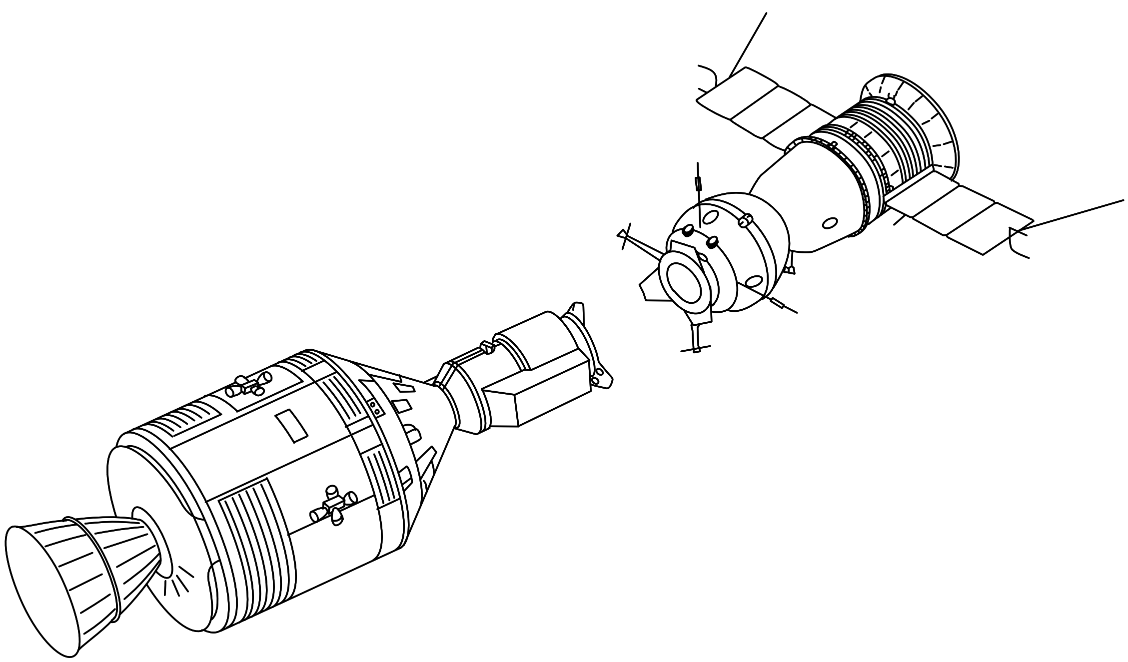

Figure 1-23. Apollo and Soyuz join in space. Note the docking module (DM) attached to Apollo's nose. The DM was stored for launch within a shroud between the CSM and the S-IVB second stage of the Apollo Saturn IB launch vehicle. In orbit the Apollo inserted its probe unit into the standard Apollo drogue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

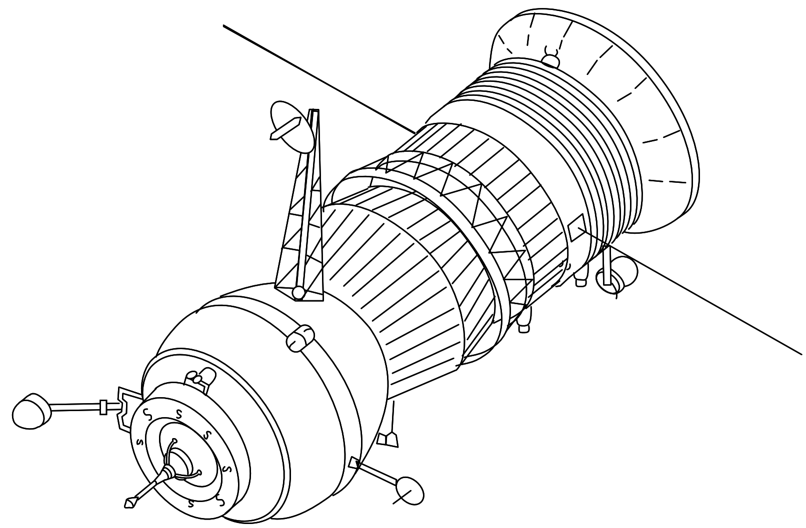

Figure 1-24. Progress logistics resupply spacecraft. It consists of the dry cargo module (left); the tanker compartment (center); and a stretched service module (right).

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]

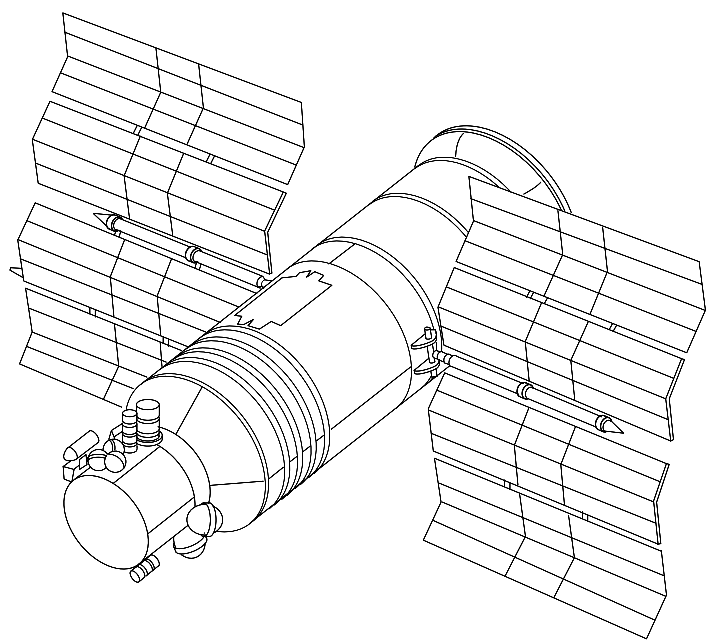

Figure 1-25. Progress-based Gamma astrophysical research satellite.

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.

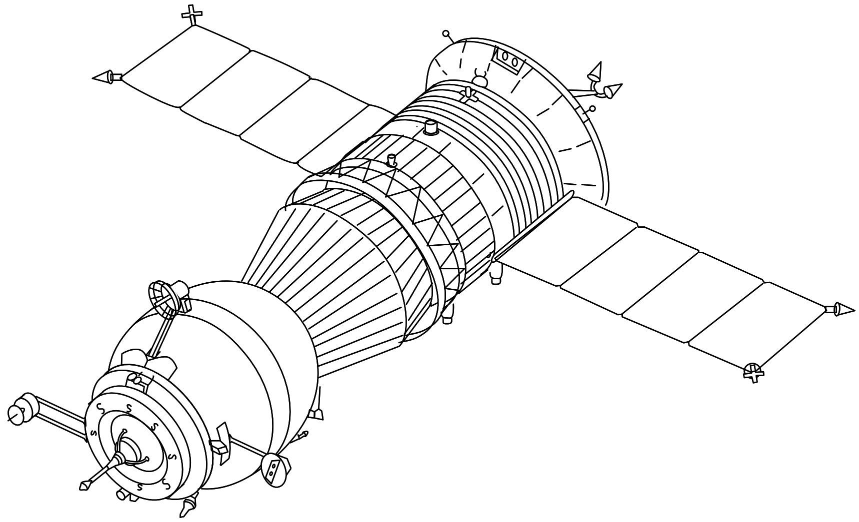

Figure 1-26. Progress-M logistics resupply spacecraft.

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.

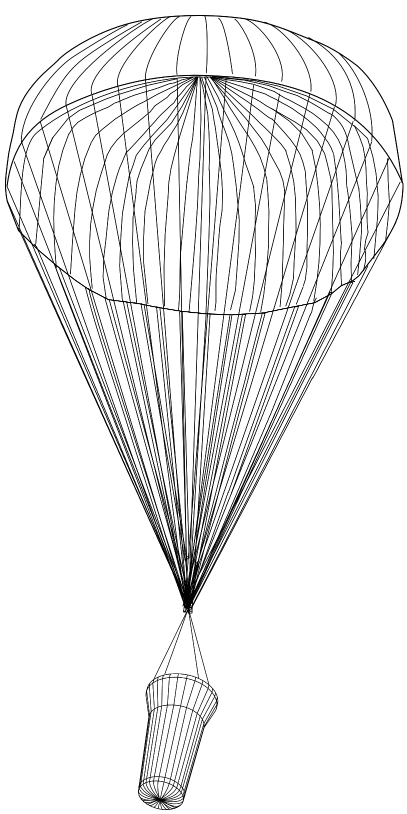

Figure 1-27. Ballistic return capsule (Raduga) during final descent to Earth.

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.

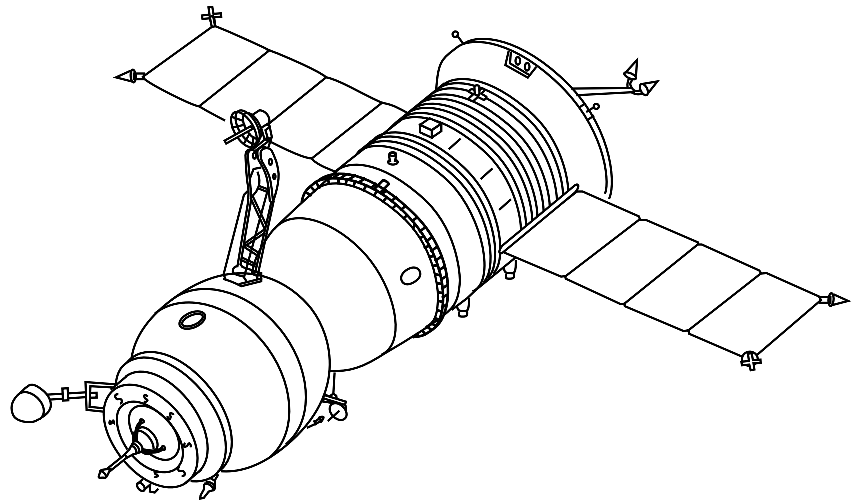

Figure 1-28. Soyuz-T spacecraft.

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.

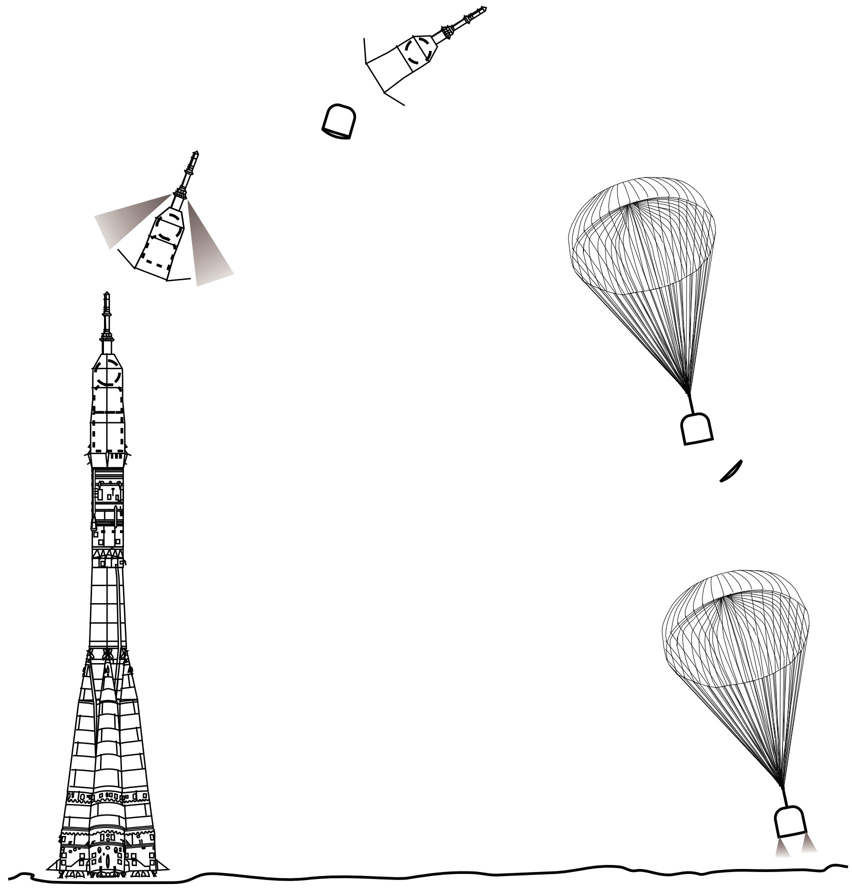

Figure 1-29. Soyuz launch pad abort sequence. The modules of the Soyuz spacecraft are shown beneath the launch shroud by dashed lines. Note the separation plane between the Soyuz descent and service modules.

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 rendezvous 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.

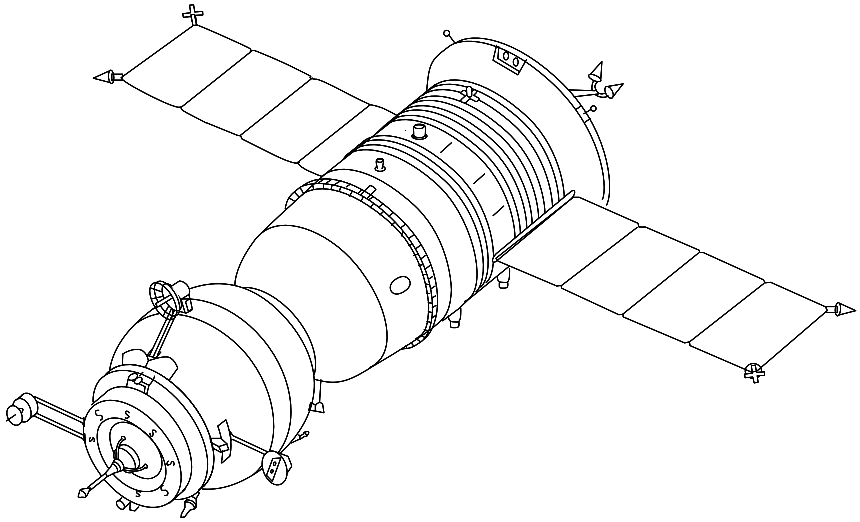

Figure 1-30. Soyuz-TM spacecraft. Compare the antennae on the orbital module to those on Soyuz-T. Differences reflect the change from the Igla rendezvous system used on Soyuz-T to the Kurs rendezvous system used on Soyuz-TM.

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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76. Nicholas Johnson, *Soviet Year in Space: 1989*, Teledyne Brown Engineering, 1990, p. 96.

77. P. N. Polezhayev and V. P. Poluektov, "The Space Program: Space-based Gamma Observatory," *Zemlya i Vselennaya*, No. 3, May-June 1991, pp. 2-9. Translated in *JPRS Report, Science & Technology, Central Eurasia, Space*, January 27, 1992 (JPRS-USP-92-001), p. 2-4.

78. Payson, June 28, 1993, p. 13.

79. *Technical Report: Russian Segment Systems Requirements Review in Support of International Space Station Alpha*, Russian Space Agency-NPO Energia, December 1993, p. 42.

80. Pierre Langereux, "New Revelations on the Soyuz-T Vehicle," *Air & Cosmos* , No. 800, February 16, 1980, pp. 50-51. Translated in *JPRS Report, JPRS L/9058, USSR Report, Space*, April 28, 1980, p. 2.

81. Yuri Malyshev, "Evolution of the Soyuz Spacecraft," *Aviatsiya i Kosmonavtika*, No. 10, 1980, pp. 38-39. Translated in *USSR Report*, *Space*, No. 9, March 2, 1981 (JPRS 77488), p. 11.

82. Langereux, p. 1.

83. Nicholas Johnson, *The Soviet Year in Space: 1983*, Teledyne Brown Engineering, 1984, p. 44.

84. Interview, David S. F. Portree with Sergei Krikalev, February 28, 1994.

85. Vadim Chernobrov, "Collision in Space," *Rossiyskiye* Vesti, January 21, 1994, p. 8. Translated in *JPRS Report, Science & Technology, Central Eurasia*, March 22, 1994 (JPRS-USP-94-003), pp. 1-2.

86. Debra D. Faktor and Daniel Van Hulle, *ANSER Moscow Office Report, #79*, May 13, 1994, pp. 2-5. Report incorporates TsUP-provided information "for completeness."

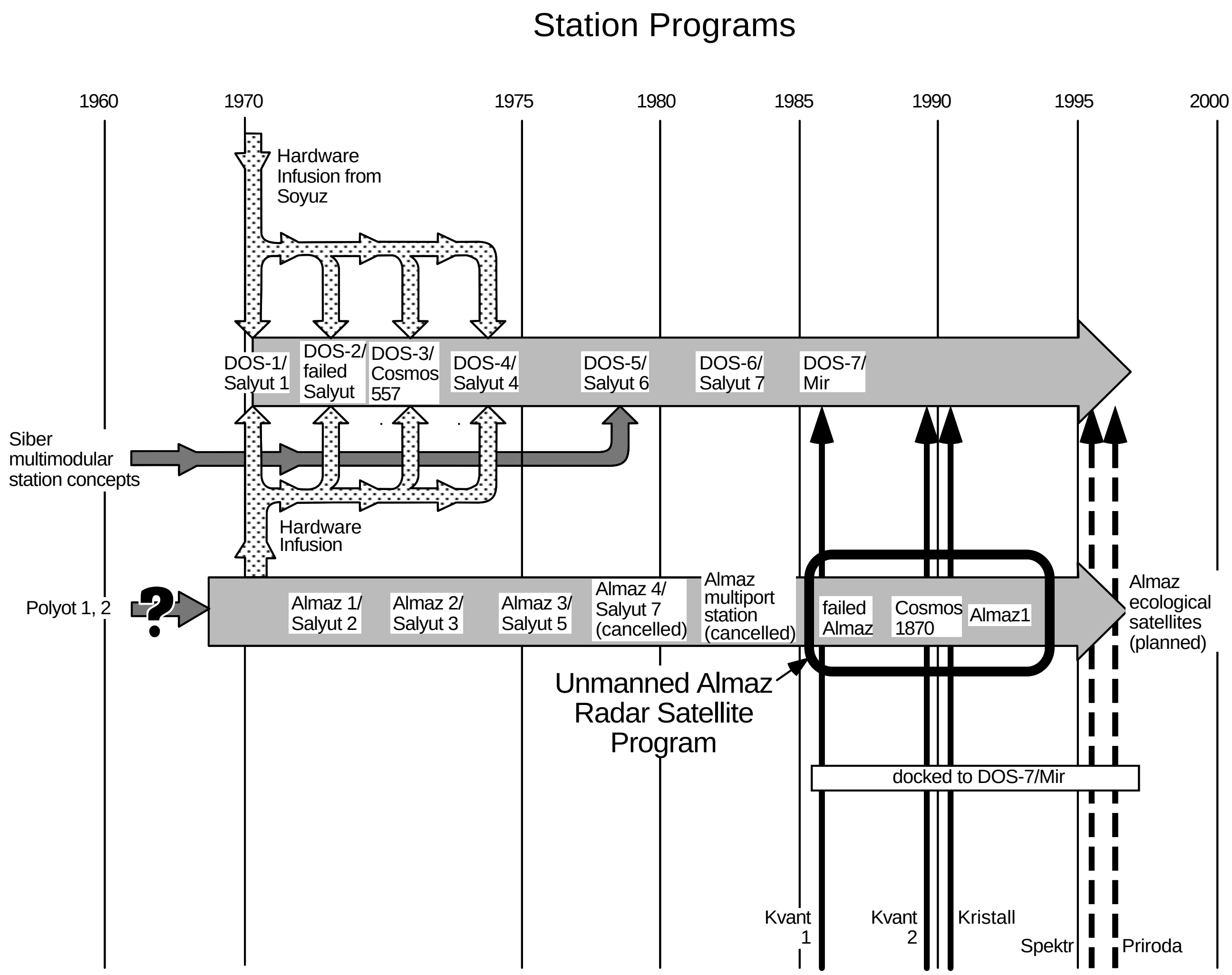


Figure 2-1. Station evolution. The chart above summarizes the development of the Soviet/Russian space stations and derivatives. Light gray arrows trace the evolution of space stations and satellites derived from space station hardware. Dark gray arrows trace the influence of concepts on later flown hardware. 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).

Part 2 Almaz, Salyut, and Mir

2.1 Overview

Figure 2-1 is a space station family tree depicting the evolutionary relationships described in this section.

2.1.1 Early Concepts (1903, 1962)

The space station concept is very old in Russia. Space pioneer Konstantin Tsiolkovskii wrote about space stations as early as 1903.[1] The first space station event relevant to this discussion occurred in March 1962, when Sergei Korolev's OKB-1 design bureau (ancestor of RKK Energia–until recently, NPO Energia) produced a report called "Complex for the Assembly of Space Vehicles in Artificial Earth Satellite Orbit (the Soyuz)." The report was largely concerned with assembly in Earth orbit of a vehicle for circumlunar flight, but also described a small station made up of independently launched modules. Three cosmonauts were to reach the station aboard a manned transport spacecraft called Siber (or Sever) ("north"), shown in figure 2-2. They would live in a habitation module and observe Earth from a "science-package" module. Korolev's Vostok rocket (a converted ICBM) was tapped to launch both Siber and the station modules. In 1965, Korolev proposed a 90-ton space station to be launched by the N-1 rocket. It was to have had a docking module with ports for four Soyuz spacecraft.[2, 3]

2.1.2 Almaz: Conception (1964-1967)

However, the Korolev organization was preoccupied with preparing the Soviet entry in the Moon race with the United States. The task of developing the first space station fell to V. N. Chelomei's OKB-52 organization (ancestor of NPO Mashinostroyeniye).[4] On October 12, 1964, Chelomei called upon his staff to develop a military station for two to three cosmonauts, with a design life of 1 to 2 years. They designed an integrated system: a single-launch space station dubbed Almaz ("diamond") and a Transport Logistics Spacecraft (Russian acronym TKS) for reaching it (see section 3.3). Chelomei's three-stage Proton booster would launch them both. Almaz was to be equipped with a crew capsule, radar remote-sensing apparatus for imaging the Earth's surface, cameras, two reentry capsules for returning data to Earth, and an antiaircraft cannon to defend against American attack.[5] An interdepartmental commission approved the system in 1967. OKB-52 and its Branch No. 1 (ancestor of KB Salyut) divided responsibility for the system's components.[6]

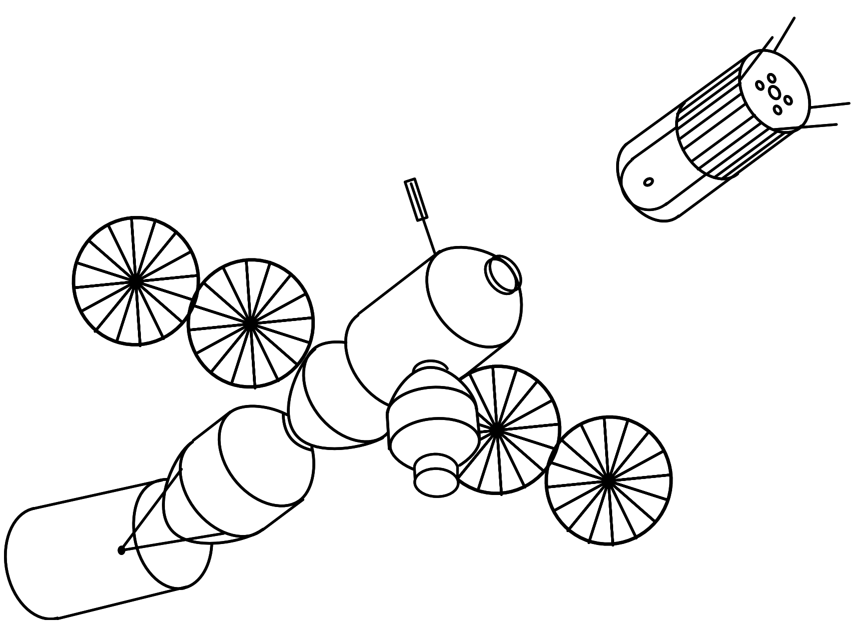


Figure 2-2. Conceptual drawing of Siber multimodule space station and Siber ferry (1962).

2.1.3 First Space Stations (1970-1974)

Work on the Almaz stations proceeded apace, but the subsystems rapidly fell behind the original schedule. In February 1970, the Soviet Ministry of General Machine Building decided to transfer Almaz hardware and plans from Chelomei's bureau to Korolev's bureau.[7] This was done in hopes it would permit the Soviet Union to launch a space station ahead of the U.S. Skylab project.[8] The transfer was less physical than administrative, because both Energia Soyuz and Mashinostroyeniye Almaz hardware were assembled in the Krunichev plant.

Using Soyuz hardware for subsystems and Almaz hardware for large components such as the hull, Korolev's bureau and OKB-52 Branch No. 1 completed the world's first space station, Long-Duration Station-1 (Russian acronym DOS-1), in just 12 months. DOS-1 was called Zarya ("dawn") 1 until shortly before its launch, when it was realized that

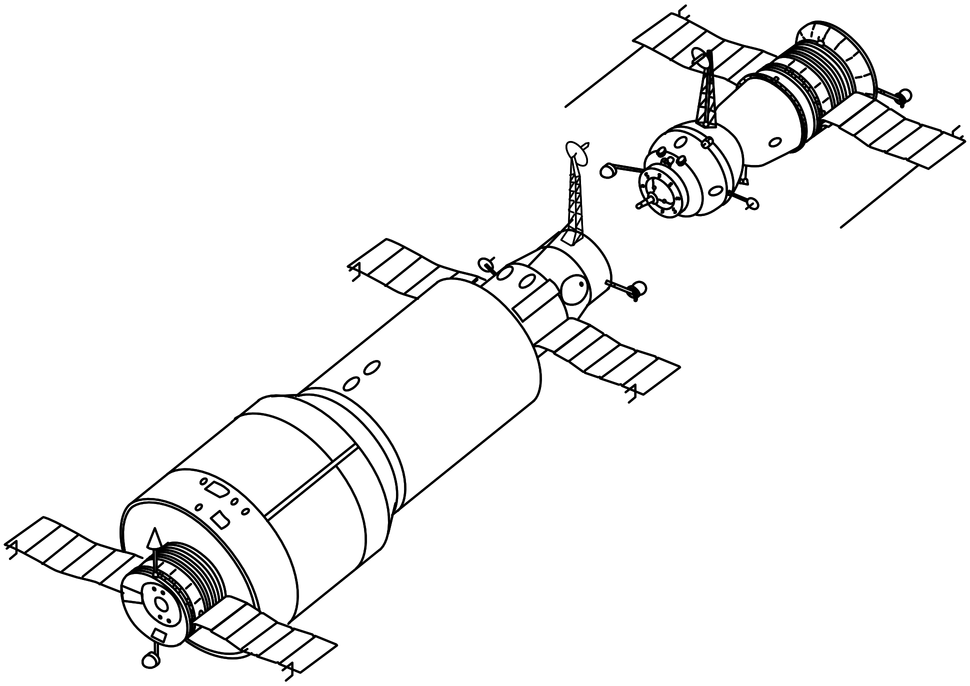


Figure 2-3. Salyut 1. Visible at the rear of the station (left) is the Soyuz-based propulsion module. A Salyut 1 Soyuz prepares to dock at the front of the station (right). Note the station's Soyuz-type solar arrays.

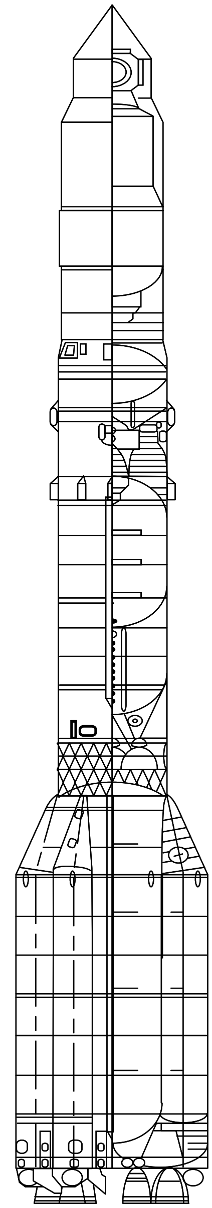


Figure 2-4. Partial cutaway of Proton configured for space station launch. The three-stage Proton rocket has launched all Soviet space stations and space station modules. Proton first flew as a two-stage vehicle in 1965. The three-stage version used to launch stations debuted in 1969 and was declared operational in 1970. All three stages burn UDMH and N_2O_4 propellants. The three-stage Proton can place 20,000 kg in a circular 185 km orbit at 51.6° of inclination.

the name would cause confusion because Zarya was the code name for the TsUP. The station was hurriedly renamed Salyut ("salute") 1 (figure 2-3).[9] A three-stage Proton rocket boosted Salyut 1 into orbit (figure 2-4). The Soyuz 11 crew, which occupied Salyut 1 in June 1971, perished during return to Earth due to a Soyuz fault. Salyut 1 was followed by three more first-generation DOS-type stations, all based on Almaz components: one which failed to reach orbit in 1972 and received no official public designation (DOS-2), Cosmos 557 (DOS-3), which failed in orbit in 1973, and Salyut 4 (DOS-4) in 1974.[10]

The first-generation stations could not be refueled, and resupply was limited to what could be carried in the Soyuz orbital module. The first-generation stations each had only a single docking port.

2.1.4 Almaz: Cancellation (1970-1980)

The Almaz program continued in modified (abbreviated) form. TKS work continued, though Soyuz spacecraft were used to ferry cosmonauts to the Almaz stations.[11] Salyut 2, Salyut 3, and Salyut 5 were the Almaz 1, Almaz 2, and Almaz 3 stations. Salyut 2/Almaz 1 failed in orbit shortly after launch. NPO Mashinostroyeniye prepared Almaz 4 for launch in 1978, and proposed a 35-ton multiport Almaz station. Launching the Almaz multiport station would have required a new launch vehicle. However, the Almaz program was cancelled shortly before Almaz 4 (it would have been Salyut 7) was set to launch. The Almaz hardware was put in storage.[12] Manned spaceflight activities became concentrated at NPO Energia in 1980. Energia worked with KB Salyut to produce additional Salyut stations.[13]

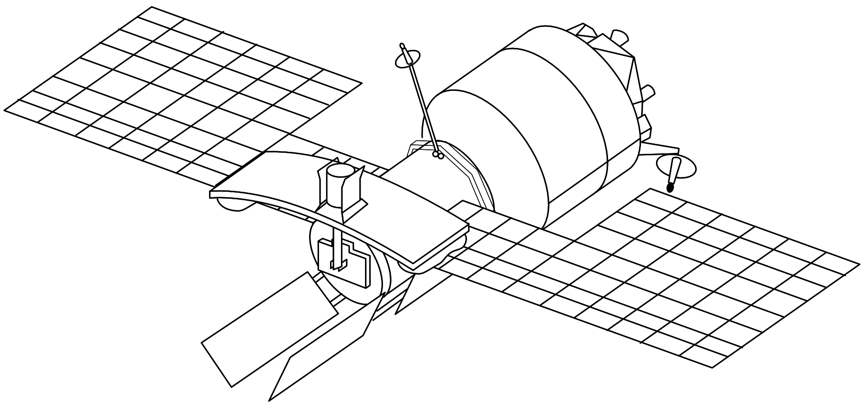


Figure 2-5. Almaz radar satellite.

2.1.5 Almaz: Conversion (1980-1993)

Mashinostroyeniye converted leftover Almaz hardware into unmanned satellites equipped with the ECOR-A Synthetic Aperture Radar (SAR) system for imaging the Earth's surface. The first such satellite was lost in 1985, after its Proton booster failed. The second, Cosmos 1870, was an experimental prototype. It operated from July 1987 to July 1989.[14] The latest satellite in the series was called Almaz 1, thereby producing confusion among persons aware of the Salyut 2/Almaz 1 space station. Almaz 1 (figure 2-5) returned images from March 1991 to October 1992.[15] In September 1992, Valentin Etkin, the chief of the Department of Applied Space Physics of the Russian Academy of Sciences Space Research Institute, described a further application of Almaz hardware. He called for a "Space Laboratory for the Study of Earth as an Ecological System" based on Almaz. The system would consist of three or four Almaz-derived satellites, each carrying 6.5 tons of scientific apparatus.[16] According to a 1993 report, the Almaz 1V radar and optical Earth observation satellite is set for launch in June-July 1996, and the Almaz 2 satellite is being designed, with launch set for 1998.[17]

2.1.6 Shuttle-Salyut (1973-1978; 1980s)

The Apollo Soyuz Test Project (ASTP) grew from and rapidly superseded joint U.S.-Soviet talks on compatibility of future spacecraft, but as early as October 1973, agreement was reached to resume the talks.[18] In January 1975, Johnson Space Center Director Christopher Kraft outlined a possible future for U.S.-Soviet space cooperation, calling for a 1980 Shuttle docking with "whatever craft the U.S.S.R. intends to fly at that time." He suggested that a joint space station program could begin in 1983, and that Soviet cosmonauts could fly as Shuttle passengers.[19]

In October 1976, Acting NASA Administrator Alan Lovelace met with Intercosmos Council chairman Boris Petrov and other Soviet officials to discuss a Shuttle docking with a Salyut space station (figure 2-6). NASA would not commit to any program ahead of the approaching U.S. Presidential elections.[20] A formal agreement creating Shuttle-Salyut working groups was signed

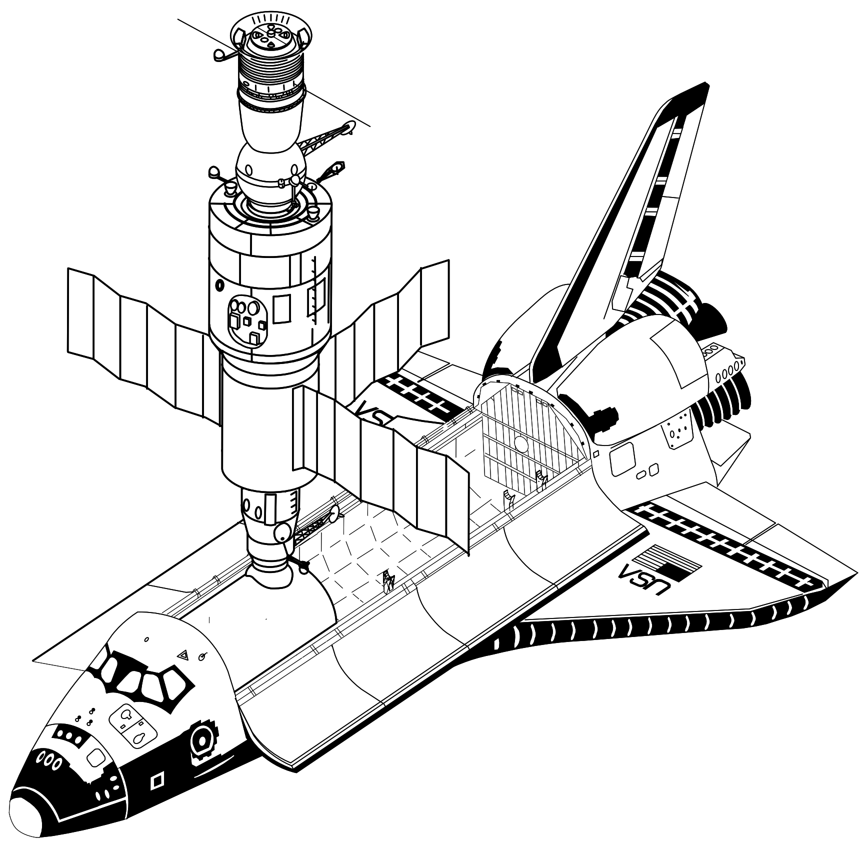


Figure 2-6. Conceptual drawing of Shuttle docked with Salyut.

between Lovelace and Anatoly Alexandrov, President of the Soviet Academy of Science, on May 11, 1977. The agreement pointed out the complimentary nature of the two countries' programs: Salyut was designed for long space stays, and Shuttle was designed for ferrying supplies and crews. The first Shuttle flight to a Soviet Salyut station was tentatively scheduled for 1981.[21]

The first Shuttle-Salyut working group meeting took place in Moscow in November 1977. However, the next meeting, set to take place in the U.S. in March-April 1978, was postponed. By late 1978, the U.S.-Soviet detente which made ASTP possible had run aground on human rights and technology transfer issues, and Shuttle-Salyut became dormant. However, occasionally during the 1980s, interest in Shuttle dockings with Soviet stations cropped up again. In 1985, the Reagan White House is said to have considered offering a Shuttle mission to aid in rescuing Salyut 7. In late 1987, NASA officials briefly considered having the Soviet shuttle dock with a U.S. station, and the U.S. Shuttle dock with Mir.[22]

2.1.7 Second-Generation Stations: Salyut 6 and Salyut 7 (1977-1986)

The second-generation stations Salyut 6 and Salyut 7 each had two docking ports. This permitted guest crews (known officially as Visiting Expeditions) to visit resident crews (known officially as Principal Expeditions). Visiting Expeditions could trade their Soyuz for the one already docked to the station, leaving a fresh vehicle for the Principal Expedition. Visiting Expeditions included cosmonauts from countries allied with or sympathetic to the Soviet Union. They were selected, trained, and flown as part of the Intercosmos program. Progress resupply craft used the aft docking port to deliver supplies to the second-generation stations.

2.1.8 Third-Generation Station: Mir (1986-present)

With Mir, the third-generation station, the Soviet space station effort has come full circle. The Korolev bureau's 1962 prospectus proposing a multimodular station reached fruition a quarter-century later, in 1987, with the permanent docking of the Kvant module to the Mir base block. In 1989-1990, the Kvant 2 and Kristall modules were added. At launch Mir was expected to be operational for 5 years. The base block is now in its ninth year. During that time it was almost always manned.

2.2 Salyut 1/DOS-1 (April 19-October 11, 1971)

Salyut 1 (figure 2-3) was the first manned space staion. Most of its main components were originally built for OKB-52's Almaz program. Many of the smaller components were borrowed from the Soyuz program.

2.2.1 Salyut 1 Specifications

Length	15.8 m
Maximum diameter	4.15 m
Habitable volume	90 m^3
Weight at launch	18,900 kg
Launch vehicle	Proton (three-stage)
Span across solar arrays	about 10 m
Area of solar arrays	28 m^2
Number of solar arrays	4
Resupply carriers	Salyut 1-type Soyuz
Number of docking ports	1
Total manned missions	2
Total long-duration manned missions	1

2.2.2 Salyut 1 Notable Features

- Attitude control and orbit maintenance provided by a modified Soyuz service module (2.17 m long by 2.2 m dia). Station main propulsion system was a slightly modified Soyuz KDU-35 system. It had one single-nozzle 417-kg thrust primary engine and one two-nozzle 411-kg thrust backup, with four 10-kg engines for attitude control.[23] The service module was attached at the aft end of the large-diameter section of the work compartment. It could not be entered by the cosmonauts.
- Two habitable compartments. In front, the transfer compartment (2 m dia by 3 m long), containing the drogue docking apparatus and an EVA hatch; aft, the work compartment, which was divided into small-diameter (2.9 m dia by 3.8 m long) and large-diameter (4.15 m dia by 4.1 m long) sections, linked by a 1.2-m-long frustum.
- Main control panel ("astropost") was a Soyuz control panel.
- Electricity provided by two pairs of Soyuz silicon photocell solar arrays.
- Electricity from the pair of solar arrays on a docked Soyuz (14 m^2 total area) augmented the station's power supply through plugs in the docking collars. Total solar array area for the Salyut 1/Soyuz 11 complex came to 42 m^2.
- Micrometeoroid detector panels built into the station's hull.
- Served as a space station engineering test bed. Cosmonauts conducted tests of the Salyut ion attitude control sensor, gyrodynes, and atmosphere, as well as tests aimed at developing new automatic docking system and antenna designs.
- Central small-diameter compartment served a wardroom function, with provisions for the cosmonauts' spare time. These included a cassette player and cassettes, a sketch pad, and a small library of books. It also held a table for dining and working.
- Equipment compartments lining the inside of the hull covered by removable panels that formed the station's interior walls. The walls each had different colors (light and dark gray, apple green, light yellow) to aid the cosmonauts in orienting themselves in weightlessness.
- Large-diameter work compartment equipped with a large conical structure housing astronomical instruments and other scientific and guidance equipment.
- Cosmonauts slept in sleeping bags attached to the walls of the large-diameter compartment, or in the orbital module of the docked Soyuz.
- Sanitation/hygiene unit located in the large-diameter section of the work compartment, within an enclosure with a ventilation system and washable walls.
- Large-diameter compartment had two refrigerators for food storage.

2.2.3 Salyut 1 Career

Entries below describe Salyut 1 operations during Soyuz missions to the station. For information on the Soyuz missions, see section 1.7.

Soyuz 10 April 22-24, 1971 (launch to landing)

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

Hard docked, but its crew could not enter Salyut 1.

Soyuz 11 June 7-29, 1971 (hard dock to undock)

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

The Yantars performed astronomical observations using the Orion-1 telescope, grew plants in the Oazis hydroponics unit, and conducted extensive multispectral Earth resources photography. They appeared frequently on Soviet television. On June 27, the cosmonauts photographed the in-flight explosion of the third N-1 rocket.[24] During reentry the crew died due to a Soyuz fault.

2.3 Failed Salyuts (1972-1973)

2.3.1 DOS-2 (July 29, 1972)

A year after the Soyuz 11 failure, the Soviet Union felt ready to send crews to a second DOS-type station. Like Salyut 1, its large compontents were originally built for the Almaz program. Failure of the second stage of its three-stage Proton launch vehicle prevented the station from reaching orbit. It fell into the Pacific Ocean.

2.3.2 Salyut 2/Almaz 1 (April 3-May 28, 1973)

On April 3, 1973, the day of the Salyut 2 launch, the Soviet magazine *Nauka i Zhian* published an interview with Soviet Academician Boris Petrov. In it he declared that lunar space stations would be established to act as bridgeheads for excursions to the lunar surface. He also predicted the advent of multimodular stations with crews of up to 120 people.[25] The failure of Salyut 2 a few days later must have made these goals seem distant indeed.

Salyut 2, the first Almaz station, reached orbit on April 3, 1973. Soon after, Salyut 2 lost stability and began tumbling. In 1992, Mikhail Lisun, backup cosmonaut for the Soyuz 24 flight to Almaz station Salyut 5, attributed the loss of Salyut 2 to an electrical fire, followed by depressurization.[26] Salyut 2 broke up on April 14, and all trackable pieces reentered by May 28, 1973.

2.3.3 Cosmos 557/DOS-3 (May 11-22, 1973)

The third DOS-type station reached orbit just ahead of the U.S. Skylab workshop. Like DOS-2 and Salyut 1, it was based on a hull transferred from the Almaz program in 1970. Shortly after attaining orbit, the station suffered a failure in its attitude control system ion sensors, leading to depletion of most of its attitude control fuel supply. One account states that a command to raise its orbit was sent, but the station was in the wrong attitude, so it reentered.[27]

2.4 Salyut 3/Almaz 2 (June 24, 1974-January 24, 1975)

Salyut 3 (figure 2-7) was the second Almaz station, and the first to be manned. Its mission was primarily military. For this reason, less information is available on Salyut 3 and Salyut 5 (the other successful Almaz station) than for the primarily civilian DOS-type Salyuts. Photos of the Almaz stations have surfaced only recently.

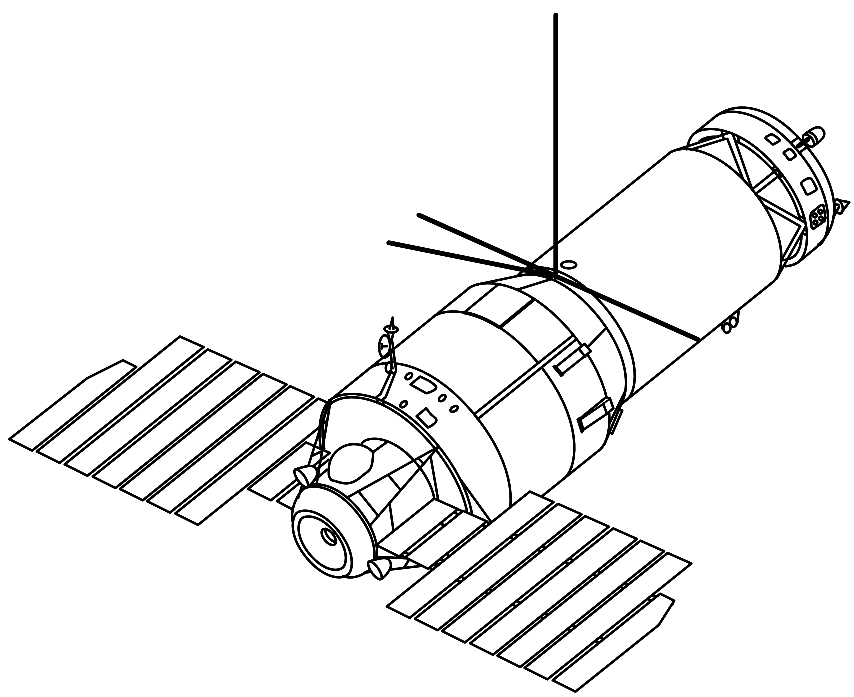


Figure 2-7. Salyut 3, the first successful Almaz space station. The drogue docking unit is at the rear of the station (left), between the two main engines.

2.4.1 Salyut 3 Specifications

Length	14.55 m
Maximum diameter	4.15 m
Habitable volume	90 m^3
Weight at launch	18,900 kg
Launch vehicle	Proton (three-stage)
Number of solar arrays	2
Resupply carriers	Soyuz Ferry
Number of docking ports	1
Total manned missions	2
Total long-duration manned missions	1
Number of main engines	2
Main engine thrust (each)	400 kg

2.4.2 Salyut 3 Notable Features

- From aft to fore, consisted of an airlock chamber, a large-diameter work compartment, and a small-diameter living compartment.
- Airlock chamber had four openings. The drogue unit of the pin and cone docking system filled the aft opening. The forward opening led into the large-diameter work compartment. On top of the airlock chamber was an EVA hatch (never used on an Almaz station). A hatch on the bottom led into the chamber from which a small Earth-return capsule could be ejected into space.[28]
- Propulsion units were located on the aft end of the large-diameter compartment, on either side of the airlock chamber. These were specialized Almaz station engines, not the modified Soyuz units used with the early DOS Salyut stations.
- Unlike the early DOS Salyuts, Almaz had solar arrays which could track on the Sun in most station attitudes.
- The large-diameter portion of the station's work compartment was dominated by the Agat Earth-observation camera, which had a 10-m focal length. This was used primarily for military reconnaissance purposes. The cosmonauts are said to have observed targets set out on the ground at Baikonur. Secondary objectives included study of water pollution, agricultural land, possible ore-bearing landforms, and oceanic ice formation.[29]
- Cosmonauts could develop film from the Agat camera on the station. Important or interesting images were printed, then scanned by a TV imaging system for broadcast to Earth.[30] The cosmonauts needed as little as 30 minutes to shoot, develop, and scan a photograph.
- Other images were packed in the small Earth-return capsule, which was then ejected from the chamber under the spherical airlock. The capsule ejected by ground command. Ejection of the capsule signaled the end of an Almaz station's usefulness. Small engines deorbited the capsule and were then discarded. The parachute of Salyut 3's capsule opened at 8.4 km altitude.
- The small-diameter living compartment was separated from the work compartment by a bank of 12 tanks for storing gas—presumably oxygen for breathing.
- Cosmonauts had one standing bunk and one foldaway bunk in the station's living section. Salyut 3 was also equipped with a shower.
- Floor was covered with Velcro to aid the cosmonauts in moving about.
- Entertainment equipment included a magnetic chess set, a small library, and a tape player with cassettes.
- Exercise equipment included a treadmill and the Pingvin exercise suit.
- Tested the Priboy water regeneration system, which condensed water from the station's atmosphere.

2.4.3 Salyut 3 Career

Entries below describe Salyut 3 operations during Soyuz missions to the station. For more information on the Soyuz missions, see section 1.8.4.2. Dates are hard dock to undock; if no hard dock achieved, launch to landing.

Soyuz 14 July 4-19, 1974

Pavel Popovich, Yuri Artyukhin
Crew code name—Berkut

The Berkuts tested the suitability of Salyut 3 as a manned military reconnaissance satellite. They also tested Almaz station systems, such as the solar arrays. The cosmonauts exercised for 2 hours each day to counter the effects of weightlessness. Because of this, they were able to climb from their Soyuz Ferry descent module without assistance at the end of their flight.

Soyuz 15 August 26-28, 1974

Gennadi Sarafanov, Lev Demin
Crew code name—Dunay

Failed to dock with Salyut 3.

2.5 Salyut 4/DOS-4 (December 26, 1974-February 2, 1977)

2.5.1 Salyut 4 Specifications

Length	15.8 m
Maximum diameter	4.15 m
Habitable volume	90 m^3
Weight at launch	18,900 kg
Launch vehicle	Proton (three-stage)
Orbital inclination	51.6°
Area of solar arrays	60 m^2
Number of solar arrays	3
Electricity production	4 kW
Resupply carriers	Soyuz Ferry
Number of docking ports	1
Total manned missions	3
Total unmanned missions	1
Total long-duration manned missions	2

2.5.2 Salyut 4 Notable Features

- Structural layout very similar to that of Salyut 1. That is, it had a single docking port leading into a transfer compartment, a work compartment divided into small-diameter and large-diameter sections, and a propulsion and service module based on the Soyuz service module (figure 2-8). It was the last of four DOS-type stations based on hulls from the Almaz program.
- Stroka teleprinter allowed the TsUP to send hardcopy instructions to the Salyut 4 cosmonauts.
- Raketa (“rocket”) vacuum cleaner in transfer compartment.
- Rubberized fabric sleeve in the transfer compartment for providing ventilation to docked Soyuz Ferries.
- Cosmonauts spent a great deal of time conducting astrophysics observations. The large-diameter work compartment was dominated by a conical structure housing, among other things, the OST-1 25-cm solar telescope. It was equipped with a spectrograph and a diffraction spectrometer. The cosmonauts could recoat the mirror by remote control using the Zentis system. The solar telescope lacked a solar events alarm (as had Skylab) to alert the cosmonauts to valuable observation opportunities. The conical housing also held the Filin and RT-4 X-ray telescopes and the ITSK infrared telescope.[31]
- Cosmonauts also spent a great deal of time on experiments with application to closed-cycle life support systems. They cultivated peas and onions in the Oazis plant growth unit. They again tested a water regeneration system, which condensed about a liter of water from the station’s air each day. The Priboy water regeneration system was first tested on Salyut 3.
- Meteoroid measurement system with 4 m^2 of detectors built into the hull.
- Solar arrays larger than the Soyuz-based arrays on Salyut 1/DOS-1. Salyut 4 had three steerable arrays with a combined surface area greater than the four nonsteerable arrays on Salyut 1.
- Exercise equipment included a treadmill (flown on previous stations) and a bicycle ergometer (flown for the first time on Salyut 4). The bicycle ergometer generated electricity which was stored for use by the station.[32]
- Used Delta orientation/navigation system; also tested the Kaskad orientation/navigation system.
- For observing Earth, carried the KATE-140 and KATE-500 multispectral cameras, Spektru upper atmosphere analyzer, and other instruments.

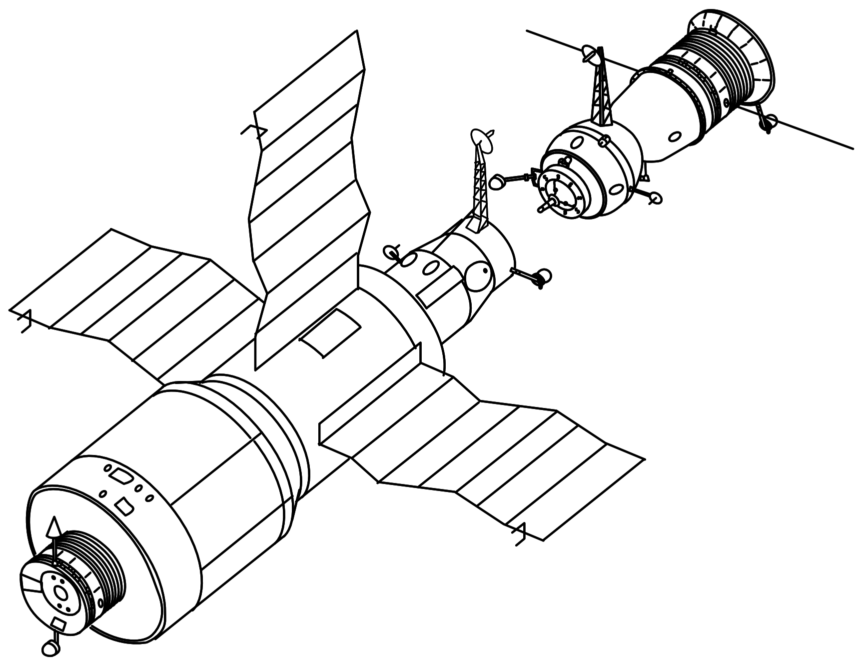


Figure 2-8. Salyut 4, the second DOS station to be manned.

2.5.3 Salyut 4 Career

Entries below describe Salyut 4 operations during Soyuz missions to the station. For more information on the Soyuz missions, see sections 1.8.4.3 and 1.10.4.1. Dates are hard dock to undock; if no hard dock achieved, launch to landing.

Soyuz 17 January 12-February 9, 1975

Alexei Gubarev, Georgi Grechko
Crew code name—Zenit

When Soyuz 17 docked, Salyut 4 was in an unusually high circular orbit at 350 km. Astrophysics was a major component of their mission (hence the high altitude). The Zenits discovered that the main mirror of the solar telescope had been ruined by direct exposure to sunlight when the pointing system failed. They resurfaced the mirror and worked out a way of pointing the telescope using a stethoscope, stopwatch, and the noises the moving mirror made in its casing.[33]

"The April 5 Anomaly" April 5, 1975

Vasili Lazerev, Oleg Makarov
Crew code name—Ural

Failed to dock with Salyut 4 due to a catastrophic Soyuz booster failure during ascent to orbit.

Soyuz 18 May 26-July 26, 1975

Pyotr Klimuk, Vitali Sevastyanov
Crew code name—Kavkaz

The Kavkaz crew carried out 90 scientific and engineering experiments, continuing the work of the Soyuz 17 crew. During their stay, they conducted two communications sessions with the ASTP Soyuz (Soyuz 19) crew.

Soyuz 20 November 17, 1975-February 16, 1976

First spacecraft to dock unmanned with a Salyut station. Carried life sciences experiments, qualified Soyuz for long-duration flights attached to a station, and served as proof-of-concept mission for Progress development.

2.6 Salyut 5/Almaz 3 (June 22, 1976-August 8, 1977)

Salyut 5 was the third Almaz station. Like Salyut 3/Almaz 2 (figure 2-7), which it closely resembled, its aims were primarily military.

2.6.1 Salyut 5 Specifications

Length	14.55 m
Maximum diameter	4.15 m
Habitable volume	100 m^3
Weight at launch	19,000 kg
Launch vehicle	Proton (three-stage)
Orbital inclination	51.6°
Number of solar arrays	2
Resupply carriers	Soyuz Ferry
Number of docking ports	1
Total manned missions	3
Total long-duration missions	2

2.6.2. Salyut 5 Notable Features

- Consisted of a spherical transfer module with four hatches, a large-diameter work compartment and a small-diameter living compartment.
- As with Salyut 3, the large Agat Earth-observation camera dominated the floor of the large-diameter work compartment. Agat images were used to compile maps; analyze tectonic structures; seek out oil, gas, and ore deposits; survey the sites of planned hydroelectric facilities; study formation of storms; and spot forest fires.[34] These activities were in addition to the station's primary Earth-observation objectives, which were military.

2.6.3 Salyut 5 Career

Entries below describe Salyut 5 operations during Soyuz missions to the station. For more information on the Soyuz missions, see section 1.8.4.4. Dates are hard dock to undock; if no hard dock achieved, launch to landing.

Soyuz 21 July 7-August 24, 1976

Boris Volynov, Vitali Zholobov
Crew code name—Baykal

The Salyut 5 crew's stay coincided with the start of the Siber military exercise in Siberia. The cosmonauts observed the exercise as part of an assessment of the station's military surveillance capabilities. They conducted only a few scientific experiments–these included first use of the Kristall furnace for crystal growth. Engineering experiments included propellant transfer system tests with implications for future Progress freighter operations. The Soyuz 21 crew seems to have left the station suddenly, ahead of their scheduled departure date. This has been attributed to a fire, an environmental control system failure, and to health problems caused by fumes from chemicals used to develop film from the station's surveillance cameras.

Soyuz 23 October 14-16, 1976

Vyacheslav Zudov, Valeri Rozhdestvenski
Crew code name—Radon

Failed to dock with Salyut 5.

Soyuz 24 February 8-25, 1977

Viktor Gorbatko, Yuri Glazkov
Crew code name—Terek

The cosmonauts entered the station wearing breathing masks, apparently because of the problems encountered on Soyuz 21, but the air proved safe to breathe. The main purpose of their mission seems to have been to tie up loose ends generated by the precipitous departure of the Soyuz 21 crew. They loaded the Salyut 5 Earth-return capsule with samples and film. It detached the day after their departure from the station, on February 26, and was recovered. The Soyuz 24 crew conducted Earth observation and materials sciences experiments. They also conducted an air replacement engineering experiment with implications for future Progress freighter operations. Air was released from the forward end of the station while simultaneously being replaced from storage tanks in the Soyuz 24 orbital module.

2.7 Salyut 6/DOS-5 (September 29, 1977-July 29, 1982)

Salyut 6 (figure 2-9) was the first second-generation DOS-type Salyut space station.

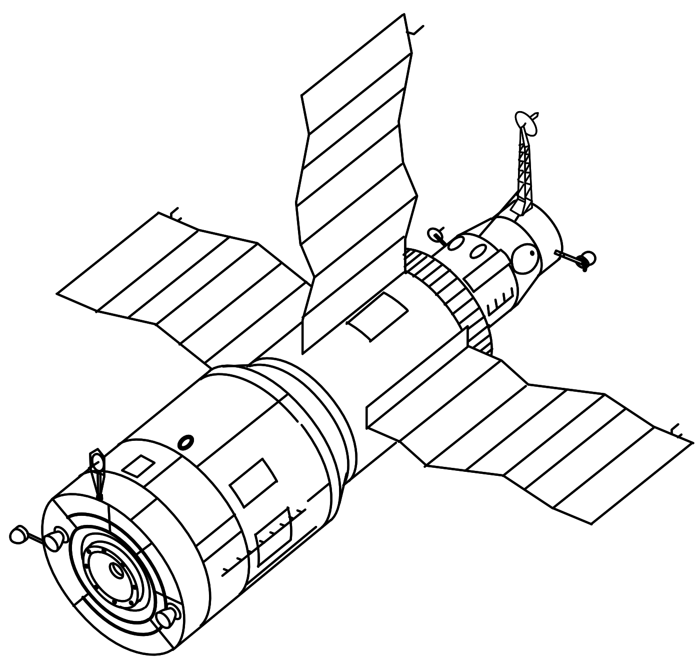


Figure 2-9. Salyut 6, the third DOS station to be manned. Addition of the aft port (left) forced redesign of the main propulsion system.

2.7.1 Salyut 6 Specifications

Length	15.8 m
Maximum diameter	4.15 m
Habitable volume	90 m^3
Weight at launch	19,824 kg
Launch vehicle	Proton (three-stage)
Orbital inclination	51.6°
Span across solar arrays	17 m
Area of solar arrays	51 m^2
Number of solar arrays	3
Electricity available	4-5 kW
Resupply carriers	Soyuz Ferry, Soyuz-T, Progress, TKS
Number of docking ports	2
Total manned missions	18
Total unmanned missions	13
Total long-duration missions	6
Number of main engines	2
Main engine thrust (each)	300 kg

2.7.2 Salyut 6 Notable Features

- Most notable single feature was aft docking port that permitted dockings by Visiting Expeditions and resupply by Progress freighters. Aft port equipped with the Igla approach system. Docking collar contained ports for transfer of propellants and pressurant from a docked Progress to Salyut 6's tanks. The aft port was connected to the large-diameter work compartment through a small intermediate compartment.
- Large-diameter compartment longer than the one on the first-generation Salyut 1 and Salyut 4 stations (6 m vs 4.1 m). Omission of the Soyuz-based propulsion module used on the first-generation stations meant total station length did not change.
- As with the earlier Salyuts, Salyut 6's large-diameter work compartment was dominated by a conical housing for scientific equipment. For Salyut 6 it contained astronomical equipment, including the BST-1M multispectral telescope and the Yelena gamma-ray telescope.
- Had three sets of large solar arrays–one set on either side of the hull, and one on top. The arrays were equipped with motors and sun-sensors for automatic Sun tracking. Communications antennas were located on the ends of the solar arrays. Radio signals from the antennas and electricity generated by the arrays passed through "rotating connections" at the bases of the arrays to enter Salyut 6. Salyut 4 also had steerable arrays, though their functional details may have differed from those on Salyut 6. There was no fourth array opposite the array on top because it would have interfered with the instruments projecting from the conical scientific instrument compartment, which opened to space on that side (the bottom) of the station.[35]
- Guidance and control systems concentrated in the Orientation and Motion Control System of the Station (Russian acronym SOUD). It included gyroscopes, ion sensors, solar sensors, star sensors, a sextant, manual controls, the Kaskad orientation system, and "the radio rendezvous equipment which jointly with the radio equipment of the transport ship provides for measuring the relative parameters of motion." Rendezvous and docking was the SOUD's most complicated operating mode. The system had several layers of redundancy.[36]
- Attitude control and main propulsion systems were brought together in Salyut 6 to form the Integrated Propulsion System (Russian acronym ODU). Both attitude control and main propulsion engines drew on the same supply of N_2O_4 and UDMH propellants. The two main engines each had 300 kg of thrust. The 32 attitude control engines each had 14 kg of thrust.[37]
- To permit changeout and addition of scientific gear, extra electrical outlets for new scientific equipment were provided within Salyut 6's pressurized compartments.

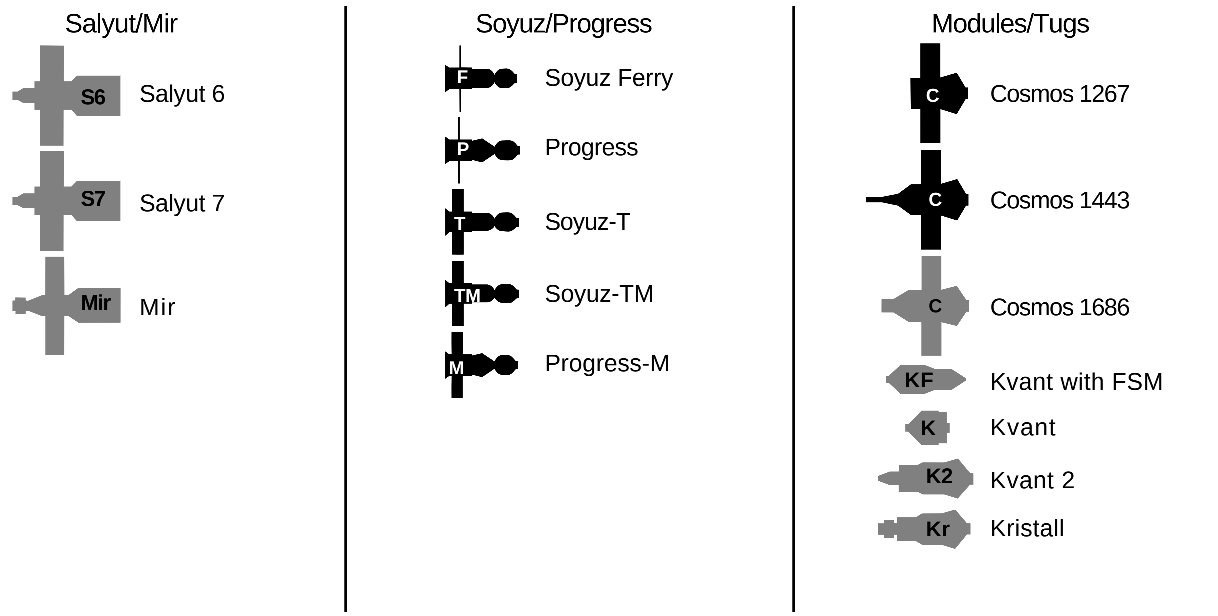
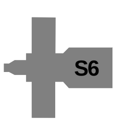


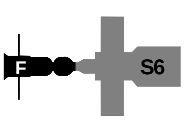
Figure 2-10. Key to icons. Salyut 6 and Salyut 7 each had two docking ports; the Mir base block has two docking ports and four berthing ports. Multiple docking ports mean continual configuration changes as spacecraft come and go and modules are added. The icons shown here are combined in sections 2.7.3, 2.8.3, and 2.9.3 to depict the changing configurations of the three multimodular stations throughout their careers (1977-1994). The icons and icon combinations are strictly representative, and do not depict the true orientation of solar arrays or true relative sizes.

2.7.3 Salyut 6 Career

Changes in the configuration of the Salyut 6 station included dockings by Soyuz Ferry, Soyuz-T, Progress, and the Cosmos 1267 FGB, as well as Soyuz transfers from port to port. The icons on the following pages depict these changes. Aligned horizontally with each icon are names (arranged to match icon positions) of spacecraft and station modules depicted and the inclusive dates of the configuration. Port transfers are shown by flipping the Salyut icon and leaving the Soyuz icon in place because it was Salyut 6 that rotated during port transfers. The text blocks below the icons cover important hardware-related events, such as anomalies and EVAs. Refer to figure 2-10 for key to icons. For more information on Soyuz Ferry, Soyuz-T, and Progress vehicles mentioned, see sections 1.8.4.5, 1.12.3.2, and 1.10.4.2. For Cosmos 1267 FGB information, see section 3.3.4.

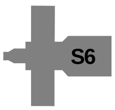


Salyut 6 September 29-October 10, 1977



Soyuz 25 • Salyut 6 October 10, 1977

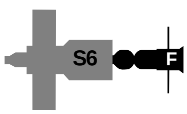
Unsuccessful Soyuz 25 docking. Soyuz 25 achieved soft dock with the new Salyut 6 station, inserting its probe apparatus into the conical drogue of the Salyut 6 front port. Hard docking involved retracting the probe to pull the station and spacecraft docking collars together. However, the docking collars would not latch. Cosmonauts Vladimir Kovalyonok and Valeri Ryumin had to return to Earth before their ferry's batteries became depleted. Engineers theorized that the Salyut 6 forward port might have been damaged during ascent, or that the Soyuz 25 docking unit was at fault. If the latter was true (and they could not be certain, because the docking unit was discarded before reentry, along with the Soyuz 25 orbital module), then it was possible that the several hard docking attempts had damaged the Salyut 6 forward port, making it unfit for future dockings.[38]



Salyut 6 October 10-December 11, 1977

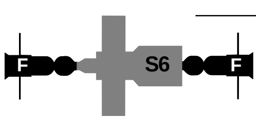
2.7.3.1 Salyut 6 Principal Expedition 1

Yuri Romanenko, Georgi Grechko
Crew code name—Tamyr
Launched in **Soyuz 26**, December 10, 1977
Landed in **Soyuz 27**, March 16, 1978
96 days in space



Salyut 6 • Soyuz 26 December 11, 1977-January 11, 1978

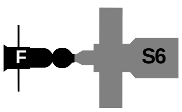
Soyuz 26 docks at aft port, EVA inspection of front port. The Tamyrs docked with the station's aft port because of the Soyuz 25 failure. On December 20 they conducted the first EVA from a Salyut space station. They depressurized the forward transfer compartment and opened the forward docking port. Grechko and Romanenko inspected the forward docking port drogue and docking collar. They beamed color TV images of the unit to the TsUP in Moscow. Grechko reported, "All of the docking equipment—lamps, electric sockets, latches—all is in fine order." The spacewalk lasted about 20 min, and depressurization lasted about 90 min. They repressurized the transfer compartment from storage tanks—a procedure first tested by the Soyuz 24 crew on Salyut 5 in February 1977. Their inspection confirmed that the Soyuz 25 spacecraft docking unit was at fault in its failure to hard dock, and that its docking attempts had left the Salyut 6 front port undamaged. During this period, the Tamyrs extensively tested the Salyut 6's Delta automatic navigational system. On December 29 the Soyuz 26 main engine raised Salyut 6's orbit. Because Soyuz 26 was at the aft port, Salyut 6's own engines could not be used to raise its orbit.[39, 40]



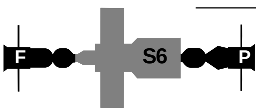
Soyuz 27 • Salyut 6 • Soyuz 26 January 11-16, 1978

Soyuz 27 arrives at Salyut 6. The Soviets hurried to take advantage of the undamaged Salyut 6 forward port. Soyuz 27 docked without incident at the front port carrying cosmonauts Oleg Makarov and Vladimir Dzhanibekov, who formed the first Visiting Expedition crew in the Soviet space station program (or, for that matter, in any space station program). For the docking, the Tamyrs withdrew to their Soyuz 26 spacecraft and sealed the hatch into Salyut 6 behind them. This was done in the event of a depressurization emergency associated with the docking of Soyuz 27. There was also some concern that stresses and vibrations produced when the 7-ton Soyuz 27 spacecraft contacted the front port might transmit through Salyut 6, forcibly uncoupling Soyuz 26 from the rear port.

Rezonans and first spacecraft swap. The Soyuz 27-Salyut 6-Soyuz 26 combination massed about 33,000 kg and featured seven compartments: two descent modules, two orbital modules, the transfer compartment, the work compartment, and the small aft intermediate compartment. The four cosmonauts conducted many experiments, including Rezonans, which was designed to determine if resonant frequencies might threaten the structural integrity of the three-spacecraft combination. The experiment called for the cosmonauts to jump around Salyut 6 on command from the TsUP. The guest crew spent 5 days on Salyut 6, then returned to Earth in Soyuz 26, leaving the fresh Soyuz 27 spacecraft for the Tamyrs. This was the first of many such spacecraft swaps.

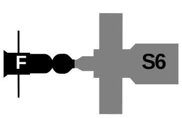


Soyuz 27 • Salyut 6 January 16-22, 1978

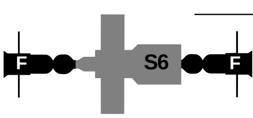


Soyuz 27 • Salyut 6 • Progress 1 January 22-February 6, 1978

Progress 1 refuels Salyut 6. The first Progress delivered what would become the standard manifest of food, air, water, and fuel. According to Sergei Krikalev, in Progress' early days the cosmonauts rushed to unload delivered supplies and reload the Progress with waste. By the time he flew for the first time (to Mir, in 1988), this procedure had been modified to let Progress serve as a kind of storage room while docked. The Progress was retained for as long as possible (until the next Progress was needed and ready for launch), and cargo was removed gradually, as needed. For this purpose, cargo was loaded so that it could be taken out in order of anticipated need. Center-of-gravity and volume limitations sometimes compromised this, however.[41] For this first Progress refueling operation, the Tamyrs fastidiously inspected Salyut 6's fuel lines for leaks for several days. Fuel and oxidizer were transferred February 2-3. On February 5 nitrogen from Progress 1 purged the lines so they would not spill toxic propellant onto the docking drogue when the supply ship undocked.

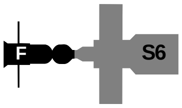


Soyuz 27 • Salyut 6 February 6-March 3, 1978

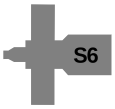


Soyuz 27 • Salyut 6 • Soyuz 28 March 3-10, 1978

First Intercosmos mission. Alexei Gubarev and Vladimir Remek formed the Zenit Visiting Expedition. Vladimir Remek, a Czech, was the first non-U.S./non-Soviet space traveler. He flew as part of Intercosmos, a program of cooperative space activities between the Soviet Union and other countries (especially those in the eastern bloc). Remek's experiment program touched on life sciences, materials processing, and upper atmosphere research.



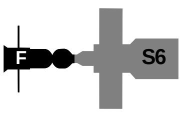
Soyuz 27 • Salyut 6 March 10-16, 1978



Salyut 6 March 16-June 16, 1978

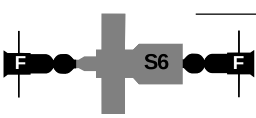
2.7.3.2 Salyut 6 Principal Expedition 2

Vladimir Kovalyonok, Alexandr Ivanchenkov
Crew code name—Foton
Launched in **Soyuz 29**, June 15, 1978
Landed in **Soyuz 31**, November 2, 1978
140 days in space



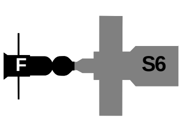
Soyuz 29 • Salyut 6 June 16-29, 1978

The Fotons start work aboard Salyut 6. Upon arriving at Salyut 6, Kovalyonok and Ivanchenkov switched on the station's air regenerators and thermal regulation system, and activated the water recycling system to reprocess water left aboard by the Tamyrs. De-mothballing Salyut 6 occurred simultaneously with the crew's adaptation to weightlessness, and required about one week. On June 19 Salyut 6 was in a 368 km by 338 km orbit. Onboard temperature was 20°C, and air pressure was 750 mm/Hg. Soon after this, Kovalyonok and Ivanchenkov performed maintenance on the station's airlock, installed equipment they brought with them in Soyuz 29's orbital module, and tested the station's Kaskad orientation system. The station operated in gravity-gradient stabilized mode June 24-26 to avoid attitude control system engine firings which could cause interference with a 3-day smelting experiment using the Splav-01 furnace. The previous crew installed the furnace in the intermediate compartment so it could operate in vacuum.[42]

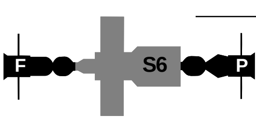


Soyuz 29 • Salyut 6 • Soyuz 30 June 29-July 5, 1978

Poland in space. Miroslaw Hermaszewski, the second Intercosmos cosmonaut, flew to Salyut 6 with Pyotr Klimuk. His experiment program stressed life sciences, Earth observations, and study of the aurora borealis.

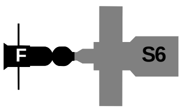


Soyuz 29 • Salyut 6 July 5-9, 1978

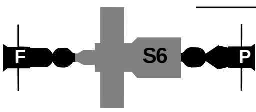


Soyuz 29 • Salyut 6 • Progress 2 July 9-August 2, 1978

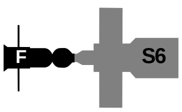
EVA and Progress 2. Progress 2 delivered, among other items, the Kristall kiln. Fuel transfer was carried out under TsUP control, leaving the cosmonauts free to do other things. On July 29, the Fotons conducted an EVA to retrieve detectors and materials samples launched attached to the Salyut 6 hull. The EVA lasted 2 hr, 5 min. Afterwards, the Fotons replenished the Salyut 6 air supply, which had been depleted by the EVA, from tanks in Progress 2. They then filled Progress 2 with trash. It separated and deorbited on command from the TsUP.[43]



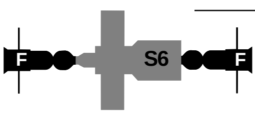
Soyuz 29 • Salyut 6 August 2-10, 1978



Soyuz 29 • Salyut 6 • Progress 3 August 10-21, 1978

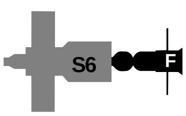


Soyuz 29 • Salyut 6 August 21-27, 1978

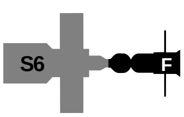


Soyuz 29 • Salyut 6 • Soyuz 31 August 27-September 3, 1978

East Germany in space. Valeri Bykovski and Sigmund Jähn of East Germany formed the Yastreb crew. Jähn's program focused on materials sciences, Earth observations, and life sciences.

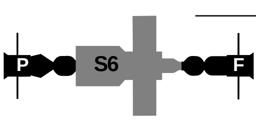


Salyut 6 • Soyuz 31 September 3-7, 1978

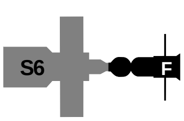


Salyut 6 • Soyuz 31 September 7-October 6, 1978

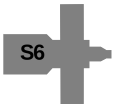
Transfer from aft port to front port. The Fotons conducted the first transfer of a Soyuz from the aft port to the front port of a space station. This became a routine procedure. They undocked Soyuz 31 and backed off to 100-200 m distance. Then the TsUP commanded Salyut 6 to rotate laterally 180°, placing the front port before the waiting Soyuz 31 spacecraft. The operation freed the aft port for additional Progress freighters.[44]



Progress 4 • Salyut 6 • Soyuz 31 October 6-24, 1978



Salyut 6 • Soyuz 31 October 24-November 2, 1978

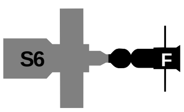


Salyut 6 November 2, 1978-February 26, 1979

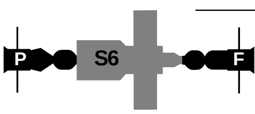
Salyut 6 propulsion system malfunction. Late in Salyut 6 Principal Expedition 2, the Fotons noted deviations in the control parameters of the fuel lines in the Salyut 6 propulsion system. During this period, analysis of readings from six sensors indicated a leak in one of three tanks in the Salyut 6 ODU. UDMH fuel had leaked into the nitrogen-pressurized bellows which pushed fuel from the tank to Salyut 6's rocket motors. It threatened to damage nonmetallic parts of a valve which lead into the "supercharging line," and to contaminate the entire propulsion system, including the attitude control system.[45, 46]

2.7.3.3 Salyut 6 Principal Expedition 3

Vladimir Lyakhov, Valeri Ryumin
Crew code name—Proton
Launched in **Soyuz 32**, February 25, 1979
Landed in **Soyuz 34**, August 19, 1979
175 days in space

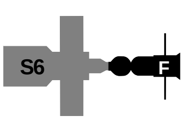


Salyut 6 • Soyuz 32 February 26-March 14, 1979



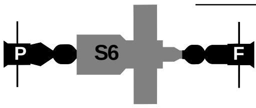
Progress 5 • Salyut 6 • Soyuz 32 March 14-April 3, 1979

Propulsion system repair. Repair procedures began on March 15. Fuel in the undamaged tanks was combined in one tank. The station was spun end over end so centrifugal force would separate UDMH fuel from the nitrogen pressurant leaked from behind the ruptured bellows in the damaged fuel tank. The fuel in the damaged tank was then pumped into the emptied good tank and into two tanks in Progress 5. The damaged tank was then sealed off and opened to space for 7 days. On March 23 the tank was closed and filled with nitrogen pressurant, then vented again. This procedure was repeated several times in order to purge the tank of residual fuel traces. In addition, the "supercharging line" was purged. On March 27 the damaged tank was purged once more, filled with nitrogen, then sealed off from the rest of the fuel system, leaving Salyut 6 with two functioning fuel tanks. The opening and closing of valves was carried out by the crew under supervision of the TsUP.[47] According to Ryumin, the operation "restored the entire system," and "the success of this operation enabled the station to fly several years beyond the end of the program."[48]

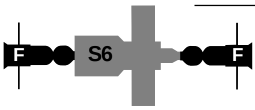


Salyut 6 • Soyuz 32 April 3-May 15, 1979

Soyuz 33 malfunction. The Protons were to receive the Saturns, Nikolai Rukavishnikov and Bulgarian Intercosmos cosmonaut Georgi Ivanov, on April 11. But Soyuz 33's main engine failed, forcing its return to Earth without docking with Salyut 6. This cast doubt on Soyuz 32's engine and the engines of other Soyuz Ferries. This in turn cast doubt on the Photons' ability to complete their mission—Soyuz 32 was nearing the end of its rated 90-day space endurance and needed to be replaced with a fresh craft.[49] The Saturns returned safely to Earth on April 12 after a ballistic reentry.[50]

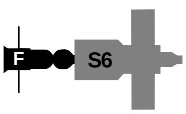


Progress 6 Salyut 6 Soyuz 32 May 15-June 8, 1979

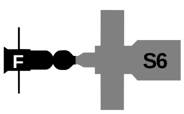


Soyuz 34 • Salyut 6 • Soyuz 32 June 8-13, 1979

Soyuz 34 replaces Soyuz 32. Progress 6 circularized Salyut 6's orbit on May 29 in preparation for the arrival of Soyuz 34. Soyuz 34 was launched unmanned to replace Soyuz 32, which had exceeded its 90-day stay limit on May 27. Arrival of Progress 34 helped ensure that Ryumin and Lyakhov would be able to complete their mission. Soyuz 34 also tested improvements to the Soyuz main engine meant to prevent recurrence of the Soyuz 33 failure. The spacecraft delivered 200 kg of cargo. Soyuz 32 returned to Earth unmanned with a cargo of experiment results and malfunctioning Salyut 6 equipment. The equipment was of interest to space station engineers.[51]

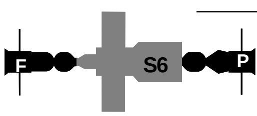


Soyuz 34 • Salyut 6 June 13-14, 1979



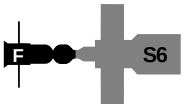
Soyuz 34 • Salyut 6 June 14-30, 1979

Port Transfer. The Soviets transferred Soyuz 34 from the aft port to the front port by rotating Salyut 6. This freed the aft port for Progress 7.



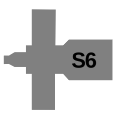
Soyuz 34 • Salyut 6 • Progress 7 June 30-July 18, 1979

KRT-10 assembly and deployment. Progress 7 delivered the 350-kg KRT-10 radio telescope. It comprised a total of seven pieces of equipment: antenna reflector, "focal container and supports," "mechanism for securing the antenna to the station," control console, "time block," and a package containing low-frequency radiometers. The Protons assembled the antenna and its support equipment in the station and Progress 7's dry cargo compartment over a 2-week period. Ryumin and Lyakhov had not seen the complete system before because the KRT-10 was still being tested and manufactured at the time they were trained to assemble it. Control panels were attached to the conical housing in the large-diameter compartment and data recorders to the station's "ceiling." A "cable entrance mechanism" was assembled in the intermediate compartment, behind the device for securing the antenna to the station, which filled the aft port. The diameter of the folded antenna was only 0.5 m. As Progress 7 backed away from the station, Ryumin commanded the antenna to unfold from the aft port. A TV camera on Progress 7 transmitted a blurry image of Salyut 6's aft port to the TsUP and the TV aboard Salyut 6 as the KRT-10 opened to its full 10-m diameter.[52, 53, 54]

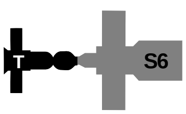


Soyuz 34 • Salyut 6 July 18-August 19, 1979

Emergency EVA to remove KRT-10. On August 9 the KRT-10 antenna failed to separate from Salyut 6. Examination through the aft-facing ports indicated that the antenna was snared on the aft docking target. This prevented further Progress dockings and interfered with the engines. The Protons attempted to free the antenna by rocking the station. After considering abandoning Salyut 6 —according to Ryumin, its primary mission was complete—crew and TsUP agreed to attempt an EVA to remove the antenna. Ryumin and Lyakhov performed the 83-min EVA on August 15. With difficulty Ryumin deployed a folded handrail, then clambered over the hull to the rear of the station. He found that the KRT-10's ribs had torn the station's insulation. As Ryumin cut cables the KRT-10 oscillated back and forth, threatening to strike him. Ryumin carried a 1.5-m barbed pole to push the antenna away after he finished cutting it away from Salyut 6. Once the antenna was discarded, the Protons inspected the exterior of Salyut 6. They found that portions of its insulation had broken off or become discolored. They also retrieved samples of materials that had been exposed to space conditions on Salyut 6's hull, and a portion of the micrometeoroid detector.[55, 56]

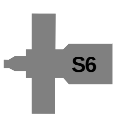


Salyut 6 August 19-December 19, 1979

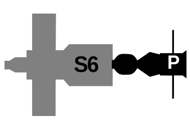


Soyuz-T 1 • Salyut 6 December 19, 1979-March 23, 1980

Soyuz-T 1. This improved version of Soyuz was test-flown unmanned to Salyut 6. It remained docked to the unmanned station, powered down, for 95 days, then returned to Earth.[57, 58]



Salyut 6 March 23-29, 1980

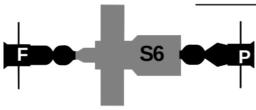


Salyut 6 • Progress 8 March 29-April 10, 1980

For Icon Key, see page 76

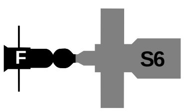
2.7.3.4 Salyut 6 Principal Expedition 4

Leonid Popov, Valeri Ryumin
Crew code name—Dneiper
Launched in **Soyuz 35**, April 9, 1980
Landed in **Soyuz 37**, October 11, 1980
185 days in space

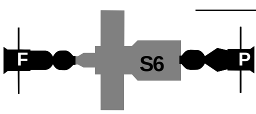


Soyuz 35 • Salyut 6 • Progress 8 April 10-25, 1980

Ryumin again in orbit. Valentin Lebedev was scheduled to be Leonid Popov's flight engineer, but he required an operation after injuring his knee while working out on a trampoline. Ryumin, of the last crew to visit Salyut 6, was called in to fill his place. Upon entering Salyut 6, Ryumin noted that the two viewports in the transfer compartment had lost their transparency. The windows also had many chips in them caused by micrometeoroids and orbital debris.[59] The cosmonauts replaced components of the attitude control system and life support system, installed a new caution and warning system, synchronized the station's clocks with those in the TsUP, added an 80-kg storage battery, and replaced air from tanks in Progress 8.

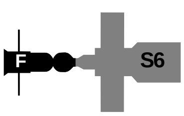


Soyuz 35 • Salyut 6 April 25-29, 1980

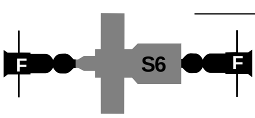


Soyuz 35 • Salyut 6 • Progress 9 April 29-May 20, 1980

Progress 9 pumps water. Before Progress 9, Salyut 6 crewmen had to transfer water into the station in 5-kg containers. Progress 9 featured the Rodnik system, by which crewmen ran a pipe to the station's tanks. The cargo ship transferred 180 kg of water in this manner.

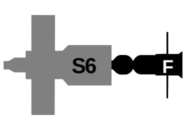


Soyuz 35 • Salyut 6 May 20-27, 1980

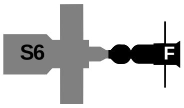


Soyuz 35 • Salyut 6 • Soyuz 36 May 27-June 3, 1980

Hungary in space. Valeri Kubasov and Bertalan Farkas formed the Orion Visiting Expedition crew. Hungary's experiments were in the areas of materials processing, Earth observation, and life sciences.

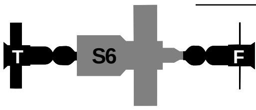


Salyut 6 • Soyuz 36 June 3-4, 1980



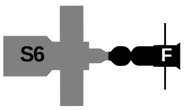
Salyut 6 • Soyuz 36 June 4-6, 1980

Port Transfer. Soyuz 36 was repositioned by rotating Salyut 6, freeing the aft port for Soyuz-T 2.



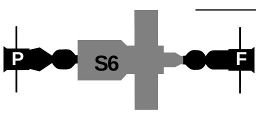
Soyuz-T 2 • Salyut 6 • Soyuz 36 June 6-9, 19

Soyuz-T 2. This was a manned test flight of the successor to the Soyuz Ferry, the Soyuz-T. Cosmonauts Yuri Malyshev and Vladimir Aksyonov spent only 2 days on Salyut 6 with the Dneiper resident crew.

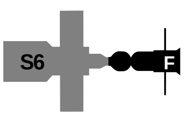


Salyut 6 • Soyuz 36 June 9-July 1, 1980

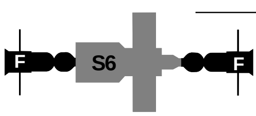
Running track breaks. Popov and Ryumin relied heavily on the running track and bicycle ergometer to maintain their fitness so they could return safely to Earth after their prolonged stay in weightlessness. On June 15 their running track broke, but the cosmonauts avoided repairing it for several days, because "it meant unscrewing a lot of bolts and would take a lot of time to repair." However, doctors on the ground ordered them to increase their level of exercise, so they had to repair the track.[60] Also at about this time, the cosmonauts repaired the Kaskad attitude control system, in the process expending a large amount of fuel.



Progress 10 • Salyut 6 • Soyuz 36 July 1-17, 1980

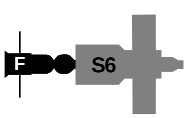


Salyut 6 • Soyuz 36 July 17-24, 1980

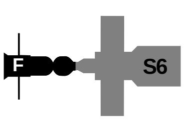


Soyuz 37 • Salyut 6 • Soyuz 36 July 24-31, 1980

Vietnam in space. Viktor Gorbatko and Pham Tuan of Vietnam arrived aboard Salyut 6 in Soyuz 37, and returned to Earth in Soyuz 36. Tuan's 30 experiments involved observing Vietnam from space, life sciences (including tests of growth of Vietnamese azolla water ferns, with application to future closed-loop life support systems), and materials processing.



Soyuz 37 • Salyut 6 July 31-August 1, 1980



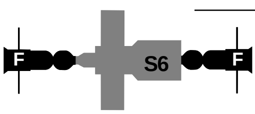
Soyuz 37 • Salyut 6 August 1-September 19, 1980

Port Transfer. Soyuz 37 was repositioned by rotating Salyut 6, freeing the aft port for Soyuz 38.

For Icon Key, see page 76

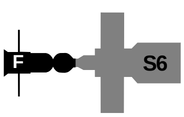
Microgravity at night. Ryumin noted in his diary on August 16 that every night before going to sleep the crew activated the Kristall or Splav-01 materials processing furnaces. This was done to reduce the level of disturbance caused by crew movements around the station, improving its microgravity conditions for materials processing.[61] Ryumin also commented that Splav and Kristall could not be used at the same time, because they each placed a heavy load on the Salyut 6 power supply. Previous expeditions had operated the furnaces for a maximum of 10-12 hr at a time, but for Salyut 6 Principal Expedition 4, longer melts, of 120 hr and 60 hr, were carried out. The products of these melts were large crystals.[62]

Fuel conservation and problems with showers. On September 10 Ryumin wrote in his diary that the experiments requiring that Salyut 6 be maneuvered at a cost in fuel were complete, so the station was in a gravity-gradient stabilization mode at least until the next Progress arrived. In this mode it pointed the aft end of the Soyuz 37 spacecraft toward the Earth. This made Earth observations convenient, as most of the windows not blocked by equipment were located in the transfer compartment and pointed toward Earth. Ryumin also noted that he and Lyakhov had decided to postpone their monthly shower. “When you begin to think of all the preparatory operations you have to do, and then how many post-shower operations you have to perform, the desire to take a shower diminishes. You have to heat the water, in batches, no less. You have to get the shower chamber, set up the water collectors, attach the vacuum cleaner . . . it takes nearly the entire day just for that shower,” he complained.[63]

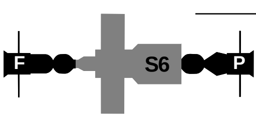


Soyuz 37 • Salyut 6 • Soyuz 38 — September 19-26, 1980

Cuban in Space. The Soyuz 38 docking occurred in darkness. As the spacecraft approached Salyut 6, the Dneipers could see only its “headlights.” Ryumin filmed ignition and operation of the transport’s main engine.[64] Arnaldo Tamayo-Mendez of Cuba and Soviet cosmonaut Yuri Romanenko docked without incident.

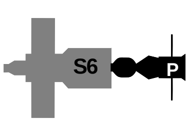


Soyuz 37 • Salyut 6 — September 26-30, 1980



Soyuz 37 • Salyut 6 • Progress 11 — September 30-October 11, 1980

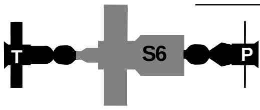
Principal Expedition 4 ends. Ryumin reported that his last 10 days on Salyut 6 were very busy. The Dneipers unloaded Progress 11, changed out the station’s communications equipment, and mothballed the station. Ryumin considered the communications gear changeout the most serious repair operation the Dneipers had carried out.



Salyut 6 • Progress 11 — October 11-November 28, 1980

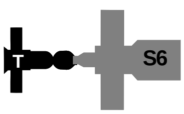
2.7.3.5 Salyut 6 Principal Expedition 5

Leonid Kizim, Oleg Makarov, Gennadi Strekalov
Crew code name—Mayak
Soyuz-T 3, November 27-December 10, 1980
13 days in space

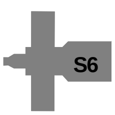


Soyuz-T 3 • Salyut 6 • Progress 11 November 28-December 9, 1980

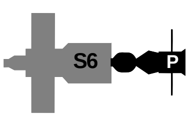
Experiments and repairs. The Mayaks were the first three-person space station crew since Soyuz 11 in 1971. Part of their mission was to further test the Soyuz-T. During their brief stay on Salyut 6, they performed the usual experiments using the Splav and Kristall units, and studied “biological objects” they brought with them in Soyuz-T 3. They used the Svetoblok and Oazis units. Much of their time, however, was devoted to space station maintenance. On December 2 they commenced conducting the Mikroklimat experiment to assess the station’s living conditions, and began work on the thermal control system. They installed a new hydraulic unit with four pumps. On December 4 they replaced electronics in the Salyut 6 telemetry system. December 5 saw them repairing electrical system faults. Other repairs included replacement of a program and timing device in the onboard control system and replacement of a power supply unit for the compressor in the refueling system. The Salyut 6 Principal Expedition 4 crew in the TsUP provided the crew with advice as they made their repairs. On December 8 Progress 11 carried out an orbit correction for the complex.[65]



Soyuz-T 3 • Salyut 6 December 9-10, 1980



Salyut 6 December 10, 1980-January 26, 1981

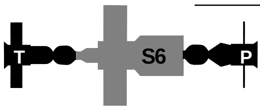


Salyut 6 • Progress 12 January 26-March 13, 1981

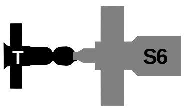
For Icon Key, see page 76

2.7.3.6 Salyut 6 Principal Expedition 6

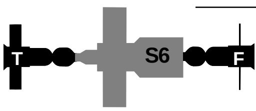
Vladimir Kovalyonok, Viktor Savinykh
Crew code name—Foton
Soyuz-T 4, March 12-May 26, 1981
75 days in space



Soyuz-T 4 • Salyut 6 • Progress 12 March 13-19, 1981

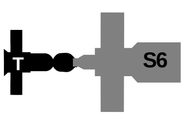


Soyuz-T 4 • Salyut 6 March 19-23, 1981

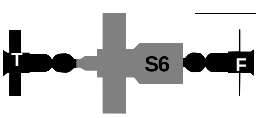


Soyuz-T 4 • Salyut 6 • Soyuz 39 March 23-30, 1981

Soyuz 39 Intercosmos flight. Soyuz 39 docked with the first Mongolian cosmonaut aboard. The Fotons assisted the Intercosmos crew with station equipment and oriented the station according to the needs of the Visiting Expedition's experiments. On March 24 the cosmonauts installed cosmic ray detectors in the work and transfer compartments. On March 26 the cosmonauts performed the Illyuminator ("viewing port") experiment, which studied the degradation of the station's viewports. On March 27 Kovalyonok and Savinykh used the Gologramma ("hologram") apparatus to image a viewing port damaged by micrometeoroids. They repeated this March 28, when they also collected samples of the station's air and microflora and removed the cosmic ray detectors for return to Earth. March 28-29 were largely devoted to studies of Mongolia from space. The Visiting Expedition crew checked out their spacecraft on March 29. The Soviet news service Tass noted that by March 29 Salyut 6 had conducted 20,140 revolutions of Earth.[66]

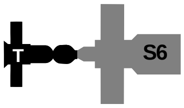


Soyuz-T 4 • Salyut 6 March 30-May 15, 1981

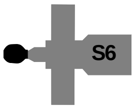


Soyuz-T 4 • Salyut 6 • Soyuz 40 May 15-22, 1981

Last Soyuz Ferry docks. Soyuz 40 was the last Soyuz Ferry and the last Soyuz spacecraft to dock with Salyut 6. It also ended the first phase of the Intercosmos program by carrying Romanian cosmonaut Dumitriu Prunariu and Soviet cosmonaut Leonid Popov to the station. Prunariu studied Earth's magnetic field. Earth observations had to be delayed until the last day of his flight, when Salyut 6 at last passed over Romania in daylight. During this time the crew also tested the station's orientation system.

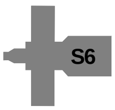


Soyuz-T 4 • Salyut 6 May 22-26, 1981

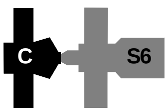


Soyuz-T 4 orbital module • Salyut 6 May 26-31, 1981

Soyuz-T 4 leaves behind orbital module. This procedure was first followed on Soyuz-T 3, though then the module was left attached to the station for only a few hours.



Salyut 6 May 31-June 19, 1981



Cosmos 1267 FGB • Salyut 6 June 19, 1981-July 29, 1982

Cosmos 1267 docks. Cosmos 1267 was the FGB component of a TKS vehicle launched on April 25, 1981. Its Merkur capsule had separated and landed in the Soviet Union on May 26.

Salyut 6 held in reserve. Salyut 6's replacement, Salyut 7, was launched on April 19, 1982. Salyut 6 remained in orbit, still docked to Cosmos 1267, at an average altitude of 385 km. The aged laboratory remained in orbit until after the conclusion of the joint Franco-Soviet mission to Salyut 7 (June 24-July 2), then was deorbited using the engines on Cosmos 1267. It may have been kept in orbit as a backup for the Franco-Soviet mission in the event Salyut 7 failed or had its launch delayed.[67] Sending Chretien to Salyut 7 seems to have represented a change in plans—in 1979, a French publication had quoted Vladimir Shatalov, head of cosmonaut training, as saying that a French cosmonaut would visit Salyut 6. The same publication stated in 1981 that Cosmos 1267 had been scheduled to be undocked from Salyut 6 to make ready for the joint Franco-Soviet crew, but that it was more likely that they would dock with Salyut 7.[68, 69]

2.8 Salyut 7/DOS-6 (April 19, 1982-February 7, 1991)

2.8.1 Salyut 7 Specifications

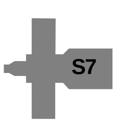
Length	about 16 m
Maximum diameter	4.15 m
Habitable volume	90 m^3
Weight at launch	19,824 kg
Launch vehicle	Proton (three-stage)
Orbital inclination	51.6°
Span across solar arrays	17 m
Area of solar arrays	51 m^2
Number of solar arrays	3
Electricity available	4.5 kW
Resupply carriers	Soyuz-T, Progress, TKS
Number of docking ports	2
Total manned missions	12
Total unmanned missions	15
Total long-duration missions	6
Number of main engines	2
Main engine thrust (each)	300 kg

2.8.2 Salyut 7 Notable Features

- In most ways very similar to Salyut 6 (figure 2-9). Below are some differences.
- Living conditions improved over those on Salyut 6. For example, Salyut 7 had hot plates for heating food and continuously available hot water.
- To kill bacteria on the station, two portholes admitted ultraviolet radiation. A large porthole for astronomy was added to the transfer compartment. All portholes were shielded from micrometeoroids by transparent covers when not in use.
- Improved exercise and medical facilities.
- A suite of X-ray detection instruments replaced the BST-1M multispectral telescope.
- Three sets of steerable solar arrays fitted with attachment points for extensions. Extensions would be added as the original arrays degraded in order to keep Salyut 7's electrical supply at a useful level.

2.8.3 Salyut 7 Career

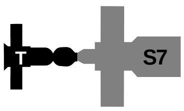
Changes in the configuration of the Salyut 7 station included dockings by Soyuz-T, Progress, the Cosmos 1443 TKS, and the Cosmos 1686 space station module, as well as Soyuz-T transfers from port to port. The icons on the following pages depict these changes. Aligned horizontally with each icon are names (arranged to match icon positions) of spacecraft and station modules depicted and the inclusive dates of the configuration. Port transfers are shown by flipping the Salyut icon and leaving the Soyuz icon in place because it was Salyut 7 that rotated during port transfers. The text blocks below the icons cover important hardware-related events, such as anomalies and EVAs. Refer to figure 2-10 for key to icons. For more information on Soyuz-T and Progress vehicles mentioned, see sections 1.12.3.3, and 1.10.4.3. For more information on the Cosmos 1443 TKS and Cosmos 1686 modified TKS, see sections 3.3.4 and 3.4.



Salyut 7 April 19-May 14, 1982

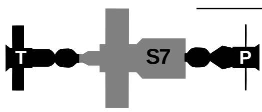
2.8.3.1 Salyut 7 Principal Expedition 1

Anatoli Berezevoi, Valentin Lebedev
Crew code name—Elbrus
Launched in **Soyuz-T 5**, May 13, 1982
Landed in **Soyuz-T 7**, December 10, 1982
211 days in space



Soyuz-T 5 • Salyut 7 May 14-25, 1982

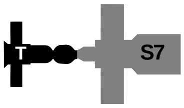
Launch of Iskra 2. The Elbrus crew ejected a 28-kg amateur radio satellite from a Salyut 7 trash airlock on May 17. The Soviets called this the first launch of a communications satellite from a manned space vehicle. They did this ahead of the launch of two large geostationary satellites from the U.S. Space Shuttle (STS-5, November 11-16, 1982).[70]



Soyuz-T 5 • Salyut 7 • Progress 13 May 25-June 4, 1982

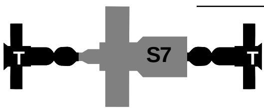
Violation of Progress docking procedure. The hatch from the work compartment to the intermediate compartment was to be closed when a Progress docked, but Lebedev and Berezevoi wished to watch the approach through an aft-facing porthole in the intermediate compartment. They therefore “clamped the endpoints of the hatch, thus simulating its closure for the TsUP’s benefit.” They forgot to remove the clamps after Progress 13 docked, giving the TsUP an indication that the hatch remained closed even though the Elbrus crew moved back and forth between Progress 13 and Salyut 7. The TsUP gently called them out for this violation of procedure.[71]

Unloading Progress 13. On May 25, the Elbrus crew reoriented Salyut 7 so the aft end of the Progress pointed toward Earth. This placed the station in gravity-gradient stabilization. Lebedev remarked in his diary that the attitude control jets were “very noisy,” and that they sounded like “hitting a barrel with a sledgehammer.” Of Salyut 7 during the unpacking of Progress 13, Lebedev said, “It looks like we’re getting ready to move or have just moved to a new apartment.” The following day the Elbrus crew closed the hatch from the work compartment into the intermediate compartment so the TsUP could pump fuel from Progress 13 to Salyut 7. The crew monitored the operation but played little active role in it. May 29 was spent organizing the supplies delivered. At the same time, according to Lebedev, “we filled the resupply ship with what we don’t need and tied them down with ropes. When I enter the resupply ship, it jingles with a metallic sound, so when we separate it will sound like a brass band.” Progress 13 pumped 300 liters of water aboard on May 31. On June 2 Progress 13 lowered the station’s orbit to 300 km to receive Soyuz T-6.[72]



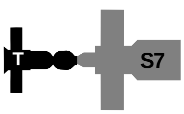
Soyuz-T 5 • Salyut 7 June 4-25, 1982

Taking a shower in space. June 12 was bath day on Salyut 7, the day the Elbrus crew was permitted its first monthly shower. Showering was a complicated process—so much so that the showers, which were expected to be completed by noon, lasted until after 6 p.m. On June 15 Lebedev reported that a brown residue had been deposited between the panes of Salyut 7's UV-transparent portholes. The residue was apparently produced when UV radiation struck the rubber gasket surrounding the panes.[73]

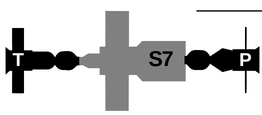


Soyuz-T 5 • Salyut 7 • Soyuz-T 6 June 25-July 2, 1982

Garbage disposal, and the French assessment of Salyut 7. During the stay of the Soyuz-T 6 Visiting Expedition, the Elbrus gave visiting Frenchman Jean-Loup Chretien "the honor" of ejecting a satellite—Salyut 7's weekly bag of waste—from the small trash airlock. In his diary, Lebedev quoted Chretien as saying Salyut 7 "is simple, doesn't look impressive, but is reliable."[74]



Soyuz-T 5 • Salyut 7 July 2-12, 1982

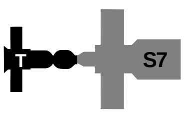


Soyuz-T 5 • Salyut 7 • Progress 14 July 12-August 10, 1982

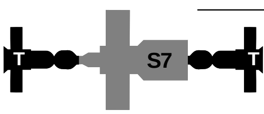
Plumbing problems. In his July 15 diary entry, Lebedev described how he woke in the middle of the night to urinate, only to find that the toilet (ASU system) overfill light was on. "If we were home, we could go outside," he wrote. But that's not a viable option up here, so I had to hold it for a whole hour while I pumped the urine out of the ASU." Lebedev had other problems with the water system later in the day: for a time he believed he had pumped waste water into the fresh water, spoiling the entire 500 liter supply.[75]

Debris in the air and cleaning Salyut 7. In his diary for July 23, Lebedev described how dust, trash, food crumbs, and droplets of juice, coffee, and tea floated in Salyut 7's air. Most eventually ended up on the cheesecloth which covered the intake grills of the station's air circulation fans. He said that the crew periodically disposed of these and replaced them with new ones. He also described a "wet cleaning" of Salyut 7. Once a week the crew used wet napkins soaked with katamine (a scouring detergent) to wipe the panels, handrails, hatches, control panel surfaces, and table. They also opened the wall panels and vacuumed the cable bundles, pipes, and fan grills.[76]

EVA—space construction experiments. On July 30, after more than a week of preparation, Lebedev and Berezevoi conducted a 2.5 hr EVA. Opening the hatch from the transfer compartment to the station hull produced a outgust of lost screws and bolts, dust, and a pencil. Lebedev first installed a movie camera and a floodlight. Then he replaced samples on the Etalon space exposure experiment, a checkerboard of different materials. He deployed and attached himself to the Yakor foot restraint platform. Once there, he spent considerable time looking at the Earth and inspecting the station. Lebedev was impressed by how still and silent the station's exterior seemed, given its complex and noisy interior mechanisms. He noted that the green insulation on Salyut 7 had already faded and become grayish, but was otherwise undamaged. He also noted two folded Yakor foot restraints and a cable winch near the base of one of the solar arrays. Part of the purpose of his EVA was to perform assembly and disassembly tasks to allow him to judge the feasibility of the next crew using these to put in place solar array extensions. Then the Elbrus replaced the micrometeoroid, Medusa biopolymer, and Elast thermo-insulation samples panels. Lebedev worked with the Istok panel, which tested his ability to turn bolts using a special wrench. When the station moved into sunlight, Lebedev could feel through his gloves that the EVA handrails became hot. The cosmonauts installed additional experiments before returning to the transfer compartment. After the EVA they spent a day storing their space suits. Lebedev found a 20-mm dent in his helmet, with a small split in the metal, possibly produced by striking it on apparatus in the transfer compartment. "Thank God the helmet is built with double layers of metal," he wrote in his diary.[77, 78]

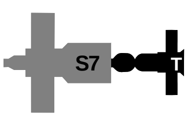


Soyuz-T 5 • Salyut 7 August 10-20, 1982

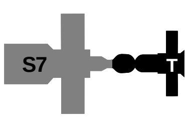


Soyuz-T 5 • Salyut 7 • Soyuz-T 7 August 20-27, 1982

Soyuz-T 7 Visiting Expedition. The Soyuz-T 7 crew (code name Dneiper) included Svetlana Savitskaya, the first woman to visit space in 20 years. She was given the orbital module of Soyuz-T 7 for privacy. The Soyuz-T 7 crew delivered experiments and mail from home to the Elbrus crew. On August 21 the five cosmonauts traded seat liners between the Soyuz-Ts. The Dneipers undocked in Soyuz-T 5, leaving the newer Soyuz-T 7 spacecraft for the long-duration crew.[79]



Salyut 7 • Soyuz-T 7 August 27-29, 1982



Salyut 7 • Soyuz-T 7 August 29-September 20, 1982

Port Transfer. Soyuz-T 7 was repositioned by rotating Salyut 7, freeing the aft port for Progress 15.

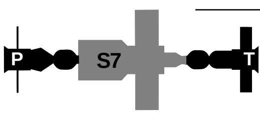
Salyut 7 is home. On September 1 Lebedev concluded his diary entry:

> I look around the station and view it with a different attitude. Now I think of it as home. The whole place looks so familiar. Everything in it is so near and dear to me now. When I look at the interior of the station, I feel no alienation, no sense that my surroundings are temporary or strange. Everything is ours. We've touched every square millimeter and object in here. We know exactly where every piece of equipment is mounted, not from documentation but from memory. Many little details, such as photographs on the panels, children's drawings, flowers,

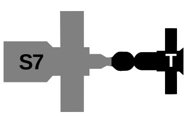
For Icon Key, see page 76

> and green plants in the garden [the Oazis, Fiton, and other plant growth units], turn this high-tech complex into our warm and comfortable, if a little bit unusual, home.[80]

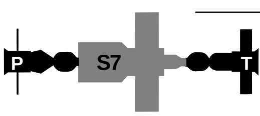
Emergency drills. On September 7 the cosmonauts practiced procedures which would come into play in the event of a depressurization of the station. The cosmonauts used a pressure measurement device called Diusa to calculate the time until the station's pressure dropped to 500 mm/Hg. This would tell them how long they had to deactivate the station, gather experiment results and records, put on spacesuits, and enter their Soyuz-T. According to Lebedev's diary, the most dangerous evacuation scenarios were those allowing 5 min or less for an escape. "In such a situation the station could not be saved," he wrote. He also described a scenario in which their Soyuz-T suffered a leak (they would close the hatch leading into the damaged craft and await a rescue ship). According to Lebedev, "we have permission for an emergency landing anywhere on Earth, although we would certainly do everything to land on Soviet territory, or at least on the ground." Specific contingency landing areas are the U.S. Midwest (90°-105° W, 42°-49° N), southern France, and the Sea of Okhotsk.[81] A bag containing experiment results was always kept near the Soyuz-T. According to Lebedev, a pressure drop requiring an hour to reach the critical level would give the crew time to locate and repair the leak. This would be done by sealing off the different compartments until the damaged one was identified. In the event of a fire, the crew would turn off all electrical equipment, put on protective suits and respirators, and use a fire extinguisher.[82]



Progress 15 • Salyut 7 • Soyuz-T 7 September 20-October 14, 1982

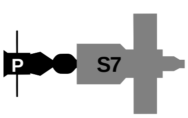


Salyut 7 • Soyuz-T 7 October 14-November 2, 1982

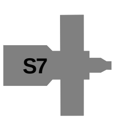


Progress 16 • Salyut 7 • Soyuz-T 7 November 2-December 10, 1982

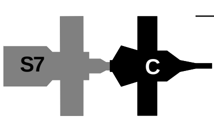
Iskra 3. Progress 16 delivered the Iskra 3 satellite. It was deployed from the trash airlock on November 18.



Progress 16 • Salyut 7 December 10-13, 1982



Salyut 7 December 13, 1982-March 10, 1983



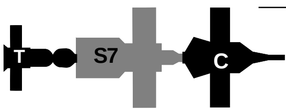
Salyut 7 • Cosmos 1443 March 10-June 28, 1983

Cosmos 1443 docks. The third TKS vehicle was launched on March 2. After docking, the Cosmos 1443 propulsion system was used to lower the average orbit of the combination below 300 km.

Soyuz-T 8 failure. The Soviets attempted to man Salyut 7 with the three-person crew of Soyuz-T 8 on April 21. However, the Soyuz Igla approach system antenna was damaged during ascent. The crew attempted a manual docking, but were forced to call it off and return to Earth. Further attempts to man Salyut 7 could not take place for 2 months because of launch and abort lighting constraints.[83]

2.8.3.2 Salyut 7 Principal Expedition 2

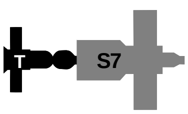
Vladimir Lyakhov and Alexandr Alexandrov
Crew code name—Proton
Soyuz-T 9, June 27-November 23, 1983
149 days in space



Soyuz-T 9 • Salyut 7 • Cosmos 1443 June 28-August 14, 1983

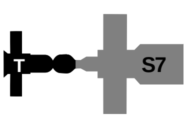
Protons unload Cosmos 1443. Almost immediately after docking at Salyut 7's aft port, the Protons entered Cosmos 1443 and commenced transferring the 3.5 tons of cargo lining its walls to Salyut 7.

Window impact. On July 27 a small object struck a Salyut 7 viewport. It blasted out a 4-mm crater, but did not penetrate the outer of the window's two panes. The Soviets believed it was a member of the Delta Aquarid meteor shower, though it may have been a small piece of orbital debris.[84]



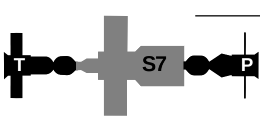
Soyuz-T 9 • Salyut 7 August 14-16, 1983

Casting off Cosmos 1443. The Protons loaded Cosmos 1443's Merkur capsule with 350 kg of experiment results and hardware no longer in use. It could have held 500 kg, had they had that much to put in. Cosmos 1443 then undocked, in spite of Western predictions that the FGB component would remain attached to Salyut 7 as a space station module. The Merkur capsule soft-landed on August 23, and the FGB component continued in orbit until it was deorbited over the Pacific Ocean on September 19.[85]



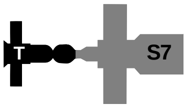
Soyuz-T 9 • Salyut 7 August 16-19, 1983

Port Transfer. Soyuz-T 9 was repositioned by rotating Salyut 7, freeing the aft port for Progress 17.



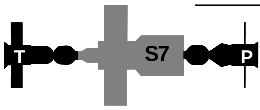
Soyuz-T 9 • Salyut 7 • Progress 17 August 19-September 17, 1983

Salyut 7 propulsion system failure. During refueling by Progress 17, the main oxidizer line of the Salyut 7 propulsion system ruptured. The seriousness of the malfunction was not immediately apparent in the West. However, after the malfunction, Salyut 7 had to rely on the main propulsion systems of visiting Progress freighters for maintaining orbital altitude.



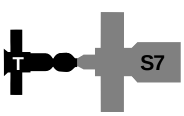
Soyuz-T 9 • Salyut 7 — September 17-October 22, 1983

Soyuz rocket launch failure. The Protons expected visitors in late September. On September 26 a Soyuz spacecraft bearing Vladimir Titov and Gennadi Strekalov stood atop a Soyuz booster at Baikonur Cosmodrome. About 90 sec before planned launch time, the booster caught fire. Titov and Strekalov, who had been unable to dock with Salyut 7 on the Soyuz-T 8 mission, were plucked free of the booster, which subsequently exploded.[86]

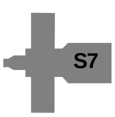


Soyuz-T 9 • Salyut 7 • Progress 18 — October 22-November 13, 1983

First and second EVAs—solar array augmentations. During his EVA of July 30, 1982, Valentin Lebedev tested space assembly and disassembly techniques to pave the way for the augmentation of Salyut 7's solar arrays. The station was designed to have its arrays augmented as their efficiency gradually diminished. The actual installation of the augmentation panels was to be done by "the new crew on the next mission."[87] The arrays were delivered by Cosmos 1443. However, the next mission, the three-person Soyuz-T 8, was unable to dock. The Protons docked with Salyut 7 in Soyuz-T 9, and removed the panels from Cosmos 1443 before casting it off. Soyuz-T 8 crewmen Titov and Strekalov, who were trained for the panel augmentation EVA, were then grounded by the September 26 Soyuz booster explosion. It was up to Lyakhov and Alexandrov to carry out the much-delayed augmentation EVAs. They used two Yakor foot restraints installed on Salyut 7 near the base of the solar array. Their first EVA, on November 1, lasted 2 hr, 49 min. The cosmonauts added a new panel to one edge of Salyut 7's top (center) array. The second EVA, on November 3, was a repeat of the first. It lasted 2 hr, 55 min. Together the two new panels increased Salyut 7's available electricity by 50%. The Protons replaced air lost through the EVAs from tanks in Progress 18 before casting it off.[88, 89] Progress 18's main engine raised Salyut 7's altitude to 356 km by 326 km on November 4.



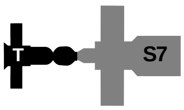
Soyuz-T 9 • Salyut 7 — November 13-23, 1983



Salyut 7 — November 23, 1983-February 9, 1984

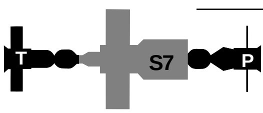
2.8.3.3 Salyut 7 Principal Expedition 3

Leonid Kizim, Vladimir Solovyov, Oleg Atkov
Crew code name—Mayak
Launched in **Soyuz-T 10**, February 8, 1984
Landed in **Soyuz-T 11**, October 2, 1984
237 days in space

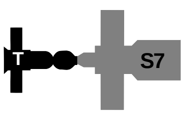


Soyuz-T 10 • Salyut 7 February 9-22, 1984

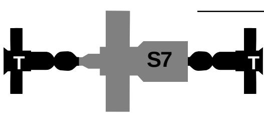
Mayaks arrive. The three-person Mayak crew entered the darkened Salyut 7 station carrying flashlights. The cosmonauts commented on the burnt-metal odor of the drogue docking unit. By February 17, Salyut 7 was fully reactivated, and the cosmonauts had settled into a routine. Physician Oleg Atkov did household chores and monitored his own health and that of his colleagues, who conducted experiments.



Soyuz-T 10 • Salyut 7 • Progress 19 February 22-March 31, 1984

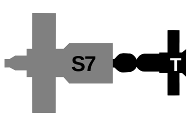


Soyuz-T 10 • Salyut 7 March 31-April 4, 1984

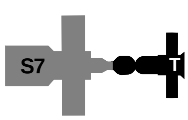


Soyuz-T 10 • Salyut 7 • Soyuz-T 11 April 4-11, 1984

Indian cosmonaut. Rakesh Sharma conducted an Earth observation program concentrating on India. He also did life sciences and materials processing experiments.

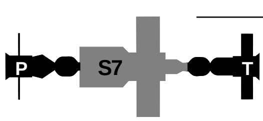


Salyut 7 • Soyuz-T 11 April 11-13, 1984



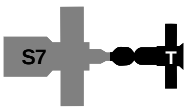
Salyut 7 • Soyuz-T 11 April 13-17, 1984

Port Transfer. Soyuz-T 11 was repositioned to the front port by rotating Salyut 7, freeing the aft port for Progress 20.

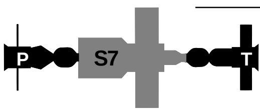


Progress 20 • Salyut 7 • Soyuz-T 11 April 17-May 6, 1984

First, second, third, and fourth EVAs—first phase of Salyut 7 propulsion system repair. The propulsion systems of Progress spacecraft filled in for the Salyut 7 propulsion system after its main oxidizer line ruptured in September 1983. Progress 20 delivered a special ladder for reaching the area of the damaged line. In addition, before launch the exterior of Progress 20's orbital module was fitted with a special extension with foot restraints, as well as with containers for 25 special tools. Kizim and Solovyov spent 4 hr, 15 min outside Salyut 7 on April 23. They attached the ladder and prepared the repair site. On April 26 the cosmonauts cut through thermal insulation and the station's hull to reach the damaged plumbing. They installed a valve in the reserve propellant line before going back inside Salyut 7. The second EVA lasted about 5 hr. On April 29 they again returned to the repair site. They installed a new propellant line to bypass the damaged section in 2 hr, 45 min. During a fourth EVA, on May 4, Kizim and Solovyov installed a second bypass line and covered the opening in Salyut 7's side with thermal insulation. However, they were unable to complete repairs because they lacked tools to close the by-passed propellant line. The fourth EVA lasted 2 hr, 45 min.[90]

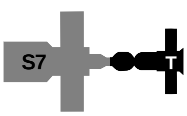


Salyut 7 • Soyuz-T 11 May 6-10, 1984

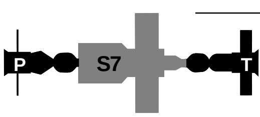


Progress 21 • Salyut 7 • Soyuz-T 11 May 10-26, 1984

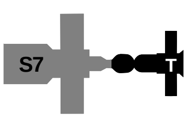
Fifth EVA—second solar array augmentation. Progress 21 delivered two 9 m^2 solar array extensions, similar to those added by the Salyut 7 Principal Expedition 2 crew. Solovyov and Kizim added them in an EVA May 19 which lasted over 3 hr. During the EVA, Atkov remained inside Salyut 7. He rotated the array 180° to bring its other edge within reach of the spacewalkers, permitting them to attach the second panel without having to move their foot restraints and equipment. The handle used to operate the winch for raising the array broke, but the cosmonauts were able to complete the operation.



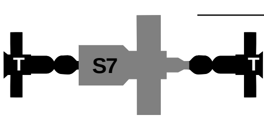
Salyut 7 • Soyuz-T 11 May 26-30, 1984



Progress 22 • Salyut 7 • Soyuz-T 11 May 30-July 15, 1984

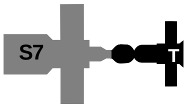


Salyut 7 • Soyuz-T 11 July 15-18, 1984



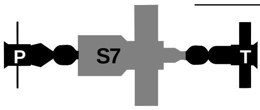
Soyuz-T 12 • Salyut 7 • Soyuz-T 11 July 18-29, 1984

Soyuz-T 12. The Pamirs, the second Visiting Expedition to visit the Mayaks, included veteran cosmonaut Vladimir Dzhanibekov, Buran shuttle program cosmonaut Igor Volk, and Svetlana Savitskaya. On July 25 Dzhanibekov and Savitskaya performed a 3 hr, 30 min EVA, during which they tested the URI multipurpose tool. They cut, welded, soldered, and coated metal samples. During the Pamirs' stay, the six cosmonauts aboard Salyut 7 also conducted Rezonans tests and collected station air samples.

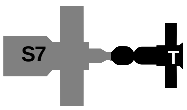


Salyut 7 • Soyuz-T 11 — July 29-August 16, 1984

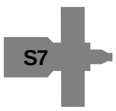
Sixth EVA—propellant system repair completed. Soyuz-T 12 delivered a pneumatic hand press. The tool was used during an August 8 EVA to crush both ends of the bypassed fuel line, sealing it. Solovyov and Kizim also collected a piece of a solar array for analysis. In spite of the repair, Salyut 7's main propulsion system was not used again to boost the station's orbit.



Progress 23 • Salyut 7 • Soyuz-T 11 — August 16-26, 1984



Salyut 7 • Soyuz-T 11 — August 26-October 2, 1984



Salyut 7 — October 2, 1984-June 8, 1985

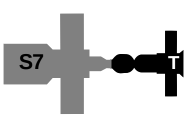
Salyut 7 comatose. In February the Salyut 7 space station abruptly ceased communicating with the TsUP. On March 2 the Soviet newspaper Pravda printed the following announcement:

> In view of the fact that the planned program of work on Salyut 7 has been fulfilled completely, at the present time the station has been deactivated and is continuing its flight in automatic mode.[91]

2.8.3.4 Salyut 7 Principal Expedition 4

Vladimir Dzhanibekov, Viktor Savinykh
Crew code name—Pamir
Soyuz-T 13, June 6-September 26, 1985
112 days in space

Savinykh remained aboard Salyut 7 when Dzhanibekov departed in Soyuz-T 13.

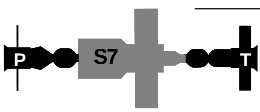


Salyut 7 • Soyuz-T 13 — June 8-23, 1985

Salyut 7 revived. The March 2 announcement notwithstanding, by the end of March the Soviets resolved to attempt a Salyut 7 rescue. The effort turned out to be one of the most impressive feats of in-space repairs in history. As the Pamirs approached the inert station, they saw that its solar arrays were pointing randomly as it rolled slowly about its long axis. They used a handheld laser range finder to judge their distance, and conducted a fly-around inspection to be certain the exterior was intact. Dzhanibekov noted that the thermal blankets on the transfer compartment had turned a dull gray from prolonged exposure to sunlight. Upon achieving hard dock—the first time a Soyuz docked with an inactive station—the crew confirmed through the electrical connectors in the docking collars that the Salyut 7 electrical system was dead. They carefully sampled the air in the station before opening the hatch. The station air was

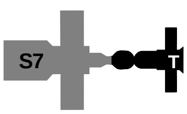
For Icon Key, see page 76

very cold, but breathable. Frost covered the walls and apparatus. The cosmonauts wore winter garb, including fur-lined hats, as they entered the station. The first order of business was to restore electric power. Of the eight batteries, all were dead, and two were destroyed. Dzhanibekov determined that a sensor had failed in the solar array pointing system, preventing the batteries from recharging. A telemetry radio problem prevented the TsUP from detecting the problem. Salyut 7 had quickly run down its batteries, shutting down all its systems and accounting for the break in radio contact. The cosmonauts set about recharging the batteries. They used Soyuz-T 13 to turn the station to put its solar arrays in sunlight. On June 10 they turned on the air heaters. The cosmonauts relied on the Soyuz-T 13 air regeneration system until they could get the Salyut 7 system back in order. On June 13 the attitude control system was successfully reactivated. This was cause for jubilation, as it meant a Progress bearing replacement parts could dock with Salyut 7. Wall heaters were turned on only after all the frost had evaporated, in order to prevent water from entering equipment. Normal atmospheric humidity was achieved only at the end of July. The station's water tanks thawed by the end of June. Freezing destroyed the water heater, so the cosmonauts used a powerful television light to heat fluids.[92]

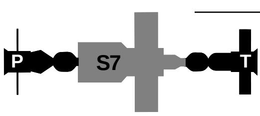


Progress 24 • Salyut 7 • Soyuz-T 13 June 23-July 15, 1985

Progress 24. The freighter delivered propellant, solar array extensions, a new water heater, three new batteries, and about 40 kg of other replacement parts.



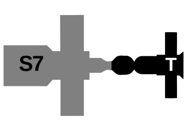
Salyut 7 • Soyuz-T 13 July 15-21, 1985



Cosmos 1669 • Salyut 7 • Soyuz-T 13 July 21-August 29, 1985

Cosmos 1669. During its flight, the Soviets claimed Progress 1669 was a freeflyer prototype. Now it is known that the spacecraft was a Progress incorporating upgrades for use with Mir.

EVA—third solar array augmentation. On August 2 the Pamirs stepped outside to add the third and final pair of solar array add-ons to Salyut 7. They wore new semirigid suits delivered by Progress 24. The EVA duration was about 5 hr.

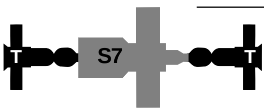


Salyut 7 • Soyuz-T 13 August 29-September 18, 1985

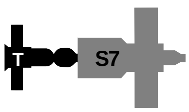
2.8.3.5 Salyut 7 Principal Expedition 5

Vladimir Vasyutin, Viktor Savinykh, Alexandr Volkov
Crew code name—Cheget
Soyuz-T 14, September 17-November 21, 1985
65 days in space

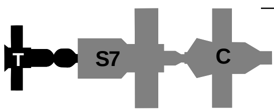
Savinykh returned with Vasyutin and Volkov in Soyuz-T 14. Savinykh's total time in space (Principal Expedition 4 and Principal Expedition 5) was 177 days.



Soyuz-T 14 • Salyut 7 • Soyuz-T 13 September 18-25, 1985



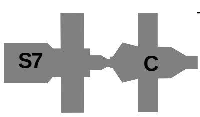
Soyuz-T 14 • Salyut 7 September 25-October 2, 1985



Soyuz-T 14 • Salyut 7 • Cosmos 1686 October 2-November 21, 1985

Cosmos 1686. The main goals of the Chegets were to receive Cosmos 1686, a modified TKS, and conduct spacewalks with application to future space stations. The first goal was achieved on October 2. Cosmos 1686 contained 4500 kg of freight, including large items like a girder to be assembled outside Salyut 7, and the Kristallizator materials processing apparatus.

Vasyutin ill. However, the Chegets were unable to achieve their second goal. By late October Vasyutin was no longer helping with experiments because he was ill. On November 13 the cosmonauts began scrambling their communications with the TsUP. Return to Earth occurred soon after.

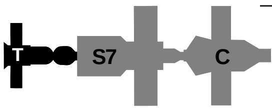


Salyut 7 • Cosmos 1686 November 21, 1985-May 6, 1986

2.8.3.6 Salyut 7 Principal Expedition 6

Leonid Kizim, Vladimir Solovyov
Crew code name—Mayak
Soyuz-T 15, Arrived from Mir – May 6, 1986; Departed for Mir – June 25, 1986.
51 days on Salyut 7

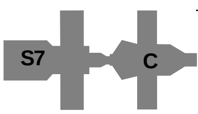
See Mir Principal Expedition 1 note.



Soyuz-T 15 • Salyut 7 • Cosmos 1686 May 6-June 25, 1986

First EVA—girder experiment. Vasyutin's illness left loose ends on Salyut 7. Most notably, the Chegets were unable to perform EVAs with implications for the Mir program. On May 28 the Mayaks climbed outside to retrieve space exposure experiments and test the Ferma-Postroital ("girder-constructor") device. A deployment canister converted a folded girder cartridge into a 15-m girder in only a few minutes. The girder was retracted by reversing the process at the end of the EVA. The EVA lasted 3 hr, 50 min.

Second EVA—girder and welding experiments. On May 31 Kizim and Solovyov attached measurement devices to the top of the retracted girder, then re-extended it with an aim toward studying its rigidity. They then used an electron gun to weld several of the girder's joints. The EVA lasted 5 hr.



Salyut 7 • Cosmos 1686 June 25, 1986-February 7, 1991

Salyut 7 abandoned; reenters after 4 years. The Mayaks removed 20 instruments with a total mass of 350-400 kg from Salyut 7 before returning to Mir. Between August 19 and August 22, engines on Cosmos 1686 boosted Salyut 7 to a record-high mean orbital altitude of 475 km to forestall reentry. Atmospheric drag took its toll, however, and the station reentered over South America 54 mo later. Pieces of Salyut 7 and Cosmos 1686 were found in Argentina.

2.9 Mir/DOS-7 (February 19, 1986-present)

The Mir space station is the centerpiece of the Russian manned space program. Its base block (figure 2-11) has been in orbit for 9 years. Continual modifications have more than tripled Mir's original mass and increased its capabilities (figure 2-12) beyond those of any previous space station.

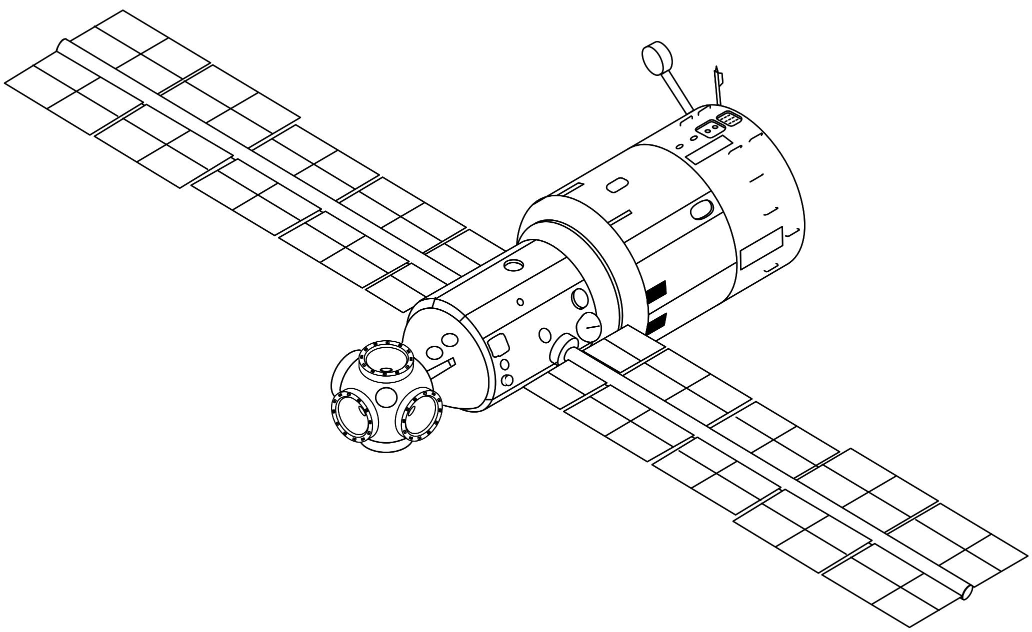


Figure 2-11. Mir base block. The multiport node at the station's forward end (left) has one longitudinal docking port and four lateral berthing ports.

2.9.1 Mir Specifications

Mir base block

Length	13.13 m
Maximum diameter	4.15 m
Habitable volume	90 m^3
Weight at launch	20,400 kg
Launch vehicle	Proton (three-stage)
Orbital inclination	51.6°
Number of solar arrays	2 (3rd added by EVA)
Span across solar arrays	29.73 m
Area of solar arrays	76 m^2 (98 sq/m w/third array)
Electricity available	9-10 kW at 28.6 v
Resupply carriers	Progress, Progress M
Number of docking/berthing ports	2 docking; 4 berthing
Number of main engines	2
Main engine thrust (each)	300 kg

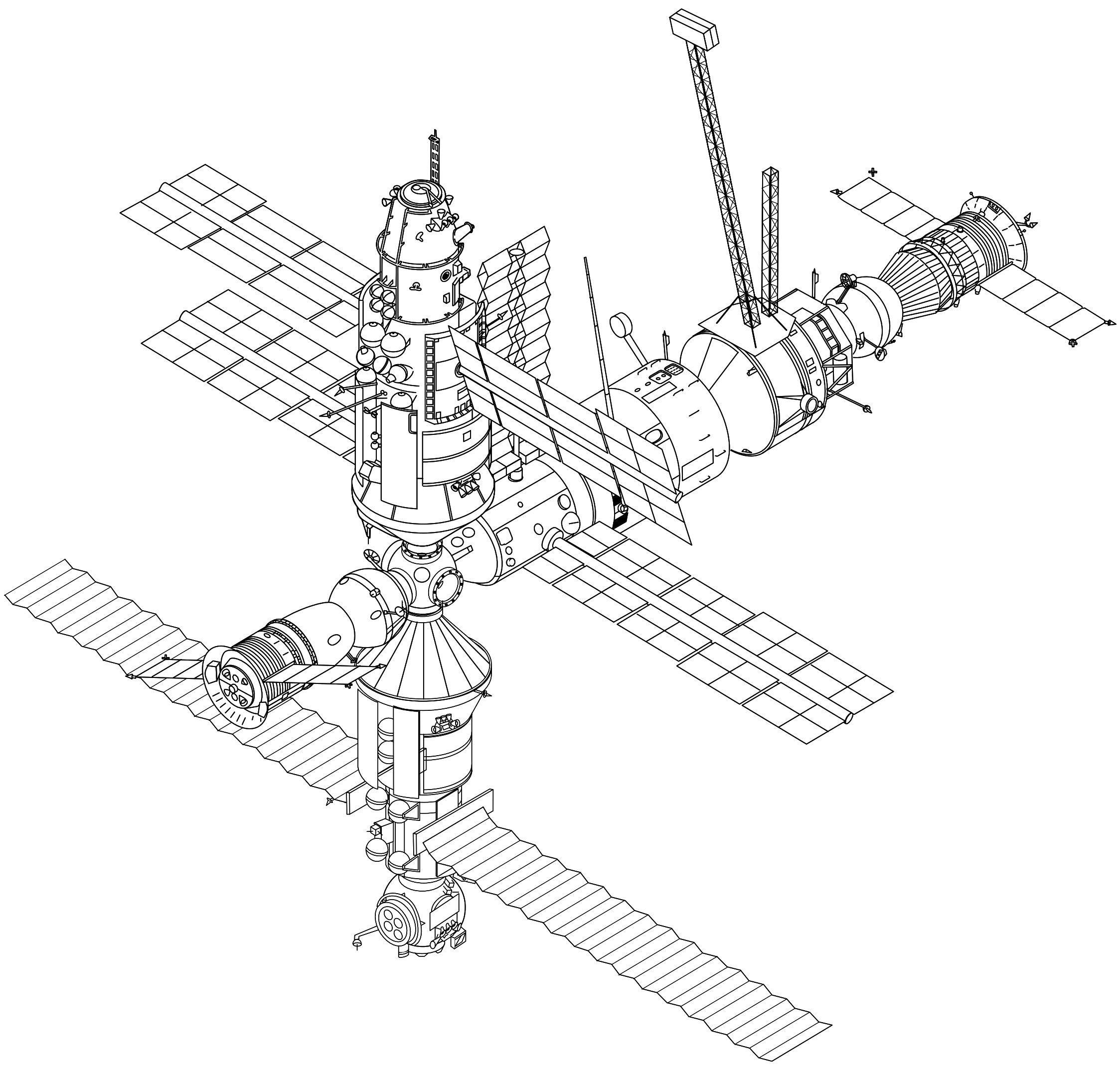


Figure 2-12. The Mir complex as of June 1994, with docked Progress-M 23 (right) and Soyuz-TM 18 (left) spacecraft.

Mir complex (Mir base block—Kvant, Kvant 2, and Kristall) with docked Soyuz-TM and Progress-M spacecraft (as of November 15, 1994)

Length	33 m
Maximum span across habitable modules	~28 m
Maximum diameter of habitable modules	4.35 m
Habitable volume	372 m^3
Weight	93,649 kg
Orbital inclination	51.6°
Number of solar arrays	11
Area of solar arrays	224 m^2
Span across solar arrays	29.73 m
Electricity available (theoretical maximum)	~27.8 kW
Number of docking/berthing ports	4 docking*; 4 berthing**
Total manned missions	20
Total long-duration missions	17

*Two of the docking ports are of APAS-89 androgynous design; two are standard Soyuz drogue units. The drogue ports are longitudinal. One is located on the Mir base block and another is at the aft of the Kvant module. The two APAS-89 ports are attached to the node on the lateral end of the Kristall module.

**Two of the four berthing ports (that is, the lateral ports on the Mir base block) are occupied by the Kvant 2 and Kristall modules. However, the two occupied ports can still be freed for use by moving the berthed modules to another lateral berthing port with their Lyappa arms. The existing modules will be shuffled when the Spektr and Priroda modules are added to Mir.

2.9.2 Mir Base Block Detailed Description and Notable Features

The conical transfer compartment at the front of the DOS-type Salyut stations is replaced by a five-port docking and berthing node. Four ports are lateral, with their docking planes parallel to the station's long axis. They are used to berth modules which have docked at the fifth, longitudinal port (the front port). There is no EVA hatch on the Mir base block, though before the arrival of Kvant 2 and Kristall the cosmonauts could egress through any of the five ports. The node is shorter than the Salyut 7 transfer compartment, accounting for Mir's shorter overall length.

The sixth docking port is located at the aft end of the base block. It closely resembles the aft ports on Salyut 6 and Salyut 7. It is notable because it has been occupied by the Kvant module since April 1987. Electrical connectors and ports for gas and fluids transfers which permitted Progress to service Mir prior to Kvant's arrival now link Kvant and the Mir base block. Progress vehicles now dock with the aft port on Kvant and transfer fluids and gases through the module to the Mir base block through these ports.

The forward longitudinal port of the Mir base block is equipped with ducts for transferring propellant and water from Progress-M supply ships.

Gallium arsenide solar arrays produce a 30% increase in power density over Salyut 7's silicon arrays (to 120 W/m^2). The Soviets conducted many gallium arsenide experiments since 1978 on Salyut 6 and Salyut 7. Mir's arrays have nearly twice the span of Salyut 7's arrays. Mir was launched with a fixture on top of its small-diameter pressurized compartment for attachment of an auxiliary solar array.

Mir was designed to be used with the Soviet Altair/SR geosynchronous voice and data relay satellites **(**figure 2-13**)**. These are satellites operated under the ubiquitous Cosmos designation. The satellite system is sometimes designated SDRN (Satellite Data Relay Network) or Luch. A large antenna for radio communications with the Altair/SR system extends from the aft end of Mir.

Although most Mir trash is disposed of in the cargo compartments of Progress freighters, Mir, like its DOS-type Salyut predecessors, has a small airlock which can be used for trash disposal. It is also used for scientific experiments requiring access to vacuum.

Sergei Krikalev, who flew on the Space Shuttle Atlantis in February 1994 and spent two long-duration stints aboard Mir, made several statements comparing conditions on the U.S. Shuttle with those on Mir. In general, Krikalev states that living conditions aboard Mir are more hospitable than those on the Shuttle. This he attributes to Mir's being designed for long-duration flight, while the Shuttle is designed to support a crew for only short periods of time.[93]

Long stays in space also affect training and timeline preparation for Mir crews. Mir crews experience more "on-the-job-training" than Shuttle crews, because it is impossible to simulate a 6-month or 12-month stint on a station and train for every eventuality. Their schedules are much more loosely planned than those of Shuttle astronauts, who spend only a few precious days in space and must put virtually every minute to productive use. In addition, Mir cosmonauts have evenings and weekends off. (In practice, the cosmonauts often work in their free time, either because they are highly self-motivated or because experiments require it.)

Krikalev further stated that living conditions on the station depend heavily on the preferences of the resident crew. Krikalev stated that levels of cleanliness and odors varied according to the standards the resident crew was willing to accept. Similarly, the level of clutter varied considerably. Krikalev stated that, on his stays, Mir was kept relatively tidy. The crews he was part of attempted to keep unused equipment and supplies behind the wall panels, and attempted to avoid attaching netting full of equipment to the station's ceiling.[94]

Mir relies much more heavily on automation than previous DOS-type stations, part of a general Soviet trend toward increasing automation in manned spacecraft. This is also evidenced by Soyuz-TM and Progress-M modifications. A French publication called it "the first computerized station in orbit." In addition to the station's control computers, each cosmonaut has a personal computer.[95] The station was launched with the Argon 16B computer. In 1990, its more capable Salyut 5B replacement, which had been delivered by Kvant 2 in 1989, was phased in.

Mir was launched with its front longitudinal port equipped with the Kurs ("course") rendezvous system used by Soyuz-TM (and now also by Progress-M). The rear port was equipped with the older Igla system so Progress freighters could continue to dock there, and also to permit docking by Igla-equipped Kvant in April 1987. The rear port of Kvant was equipped with both Igla and Kurs. The Igla system is no longer used.

Attachment of the Kvant module blocked—apparently permanently—the orbit maintenance engines on the Mir base block. All orbit maintenance maneuvers since 1987 have been conducted by docked spacecraft (Progress, Progress-M, and Soyuz-TM).

The Mir pressure hull is chemically-milled aluminum sheet averaging 2 mm thick, welded to webs 4 mm thick. The hull is 5 mm thick in the area of the multiport docking unit, and 1.2 mm thick in the area of the small-diameter work compartment. The large-diameter compartment is covered by a 2-mm-thick radiator with a 20-mm standoff from the hull. Other portions of the hull are covered by a multilayer thermal blanket comprising on average 25 layers of aluminized Mylar and scrim. Each layer is 5 micrometers thick. Layers of kevlar-like material cover the thermal blanket.[96]

The cosmonauts have two separate cabins (pockets in the walls of the large-diameter compartment) for sleep and privacy. A sealed lavatory compartment is located in the wall aft of one of the compartments. Storage drawers take up much of the wall space in both the large- and small-diameter compartments.

Mir has many portholes, with shutters to protect them from orbital debris impacts and deposits formed through use of the attitude control engines. Each cosmonaut cabin has a small porthole, and there is a porthole in the station's "floor" for Earth observation.

The lavatory compartment has a spherical hair-washing unit with rubber gaskets through which the head and hands can be inserted.

The living area (large- and small-diameter sections) measures 7.6 m in length. The small-diameter section has dark-green floor and light-green

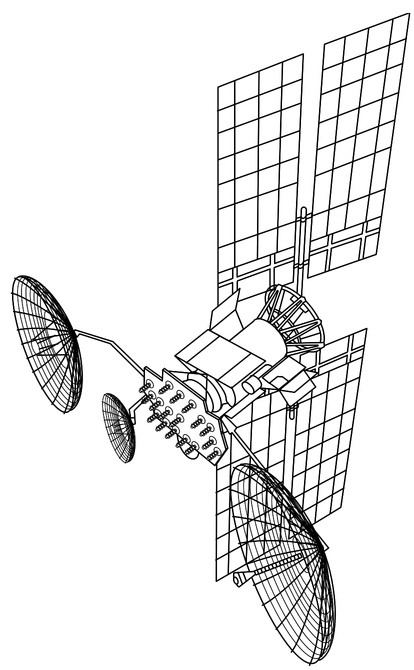


Figure 2-13. Altair/SR relay satellite.

walls; the large-diameter section has a brown floor and yellow walls. Both sections have white ceilings with fluorescent lighting.

The exercise area of Mir is also a theater with equipment for watching videocassettes and listening to music while exercising.[97] The Mir velo-ergometer (exercise bike) can retract into the floor. There is also a treadmill/running track.

Mir's "sick bay" is a cabinet located in the frustum linking the large- and small-diameter sections of the living compartment, near the exercise area. Mir's control console faces the forward docking unit, as on earlier DOS-type Salyuts. Two television screens permit face-to-face communications with the TsUP. Four more, arranged in pairs on either side of the hatch separating the living compartment from the multiport docking unit, permit monitoring of the modules attached to the multiport node (one screen per module).

Different fates have been proposed for Mir over the past several years. At one time, a Buran space shuttle was to have delivered a new base block in 1992. Buran would have used a manipulator arm to pluck free the add-on modules on the existing base block and dock them to the new one. The old base block would then have been returned to Earth in Buran. According to Yuri Antoshechkin, Deputy Flight Director for Mir Systems, Mir will host its last crew in 1997, by which time its base block will have been in orbit for eleven years (more than twice as long as originally planned). It will continue flight in unmanned mode for a further year, serving as an experiment platform for a solar dynamic power system jointly developed by the U.S. and Russia. The station may then be deorbited over a preselected area of the Pacific Ocean, as was done with several of the Salyut stations.[98]

2.9.3 Mir Career to Date

Changes in the configuration of the Mir station have included dockings by new modules; assembly of new components; dockings by Soyuz-T, Soyuz-TM, Progress, and Progress-M spacecraft; and Soyuz-TM transfers from port to port. The icons on the following pages depict these changes. Aligned horizontally with each icon are names (arranged to match icon positions) of spacecraft and station modules depicted and the inclusive dates of the configuration. The Mir station is left in the same orientation (forward end left) throughout this section because it did not rotate during port transfers (as did Salyut 6 and Salyut 7). In later combinations in this section, Kvant sprouts an inclined bar, which is later capped with a small rectangle. This represents the Sofora girder and subsequent addition of the VDU thruster unit atop Sofora. The text blocks cover important hardware-related events, such as anomalies and EVAs. Refer to figure 2-10 for key to icons. For more information on Soyuz-T, Progress, Soyuz-TM, and Progress-M vehicles mentioned, see section 1.12.3.4, 1.10.4.4, 1.13.3, and 1.11.3. For more information on Kvant, Kvant 2, Kristall, and the Kvant FSU, see sections 3.5, 3.6, 3.7, 3.8.1.

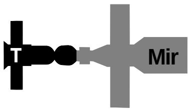
Mir February 19-March 15, 1986

Mir launch. Salyut 7/Cosmos 1686 remained in orbit while Mir was launched. Because it was a ton heavier than its precursors, Mir reached an initial mean altitude of only 235 km. It was maneuvered using its main engines to a mean altitude of 330 km within a few days. Mir launch time was set by the need to match planes with the Salyut 7/Cosmos 1686 complex for the planned transfer by Soyuz-T 15 from Mir to the older station.

2.9.3.1 Mir Principal Expedition 1 (Salyut 7 Principal Expedition 6)

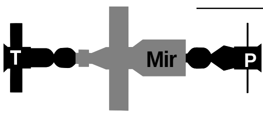
Leonid Kizim, Vladimir Solovyov
Crew code name—Mayak
Soyuz-T 15, March 13-July 16, 1986
73 days on Mir

Kizim and Solovyov stayed aboard Mir in two stints (52 days and 21 days) separated by a visit to Salyut 7 (51 days). Total time in space was 124 days.



Soyuz-T 15 • Mir March 15-21, 1986

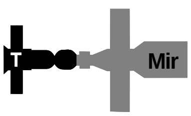
Unusual docking procedure. The Soviets intended to dock Soyuz-T 15 with Mir's forward port, leaving the aft port free for arriving Progress spacecraft. However, Soyuz-T 15, like its Soyuz-T precursors, was equipped with the Igla approach system, not the Kurs system used on Mir's front port. Soyuz-T 15 approached Mir from behind. At 20 km Soyuz-T 15's Igla system acquired its counterpart on Mir's aft port. At 200 m the Igla system was shut off, and the Mayaks manually maneuvered around the station to dock at the front port. They used the same laser range finder used by Soyuz-T 13 to dock with the uncooperative Salyut 7 station in 1985.[99]



Soyuz-T 15 • Mir • Progress 25 March 21-April 20, 1986

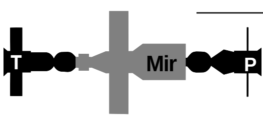
Altair/SR tests. First tests of the Soviet data and voice relay system, the Altair/SR system, were conducted on March 29 using Mir's large aft antenna and the geosynchronous (95° E) Cosmos 1700 satellite.

Rezonans tests. The Mayaks conducted Rezonans tests of the Soyuz-T 15-Mir base block-Progress 25 complex on March 31.



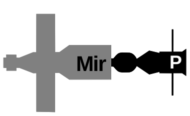
Soyuz-T 15 • Mir April 20-26, 1986

More Rezonans tests. The Mayaks subjected the Mir base block-Soyuz-T 15 assemblage to further Rezonans tests. They also for the first time placed Mir in gravity gradient stabilization mode, with its long axis pointed toward the center of the Earth, and tested the station's atmosphere.



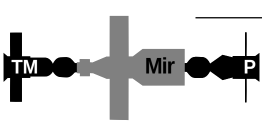
Soyuz-T 15 • Mir • Progress 26 April 26-May 5, 1986

Getting ready for the transfer to Salyut 7. The Mayaks loaded Soyuz-T 15 with their personal belongings, plants grown on Mir, and other items in preparation for the trip to Salyut 7, which was about 4000 km ahead of Mir in a lower orbit. On May 4 Mir was lowered by 13 km to speed the approach to Salyut 7 and conserve Soyuz-T 15's limited fuel supply for the transfer.



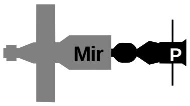
Mir • Progress 26 May 5-23, 1986

Soyuz-T 15 transfers to Salyut 7. Soyuz-T 15 separated from Mir when Salyut 7 was 2500 km away. The crossing required 29 hr.

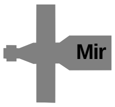


Soyuz-TM 1 • Mir • Progress 26 May 23-29, 1986

Mir's Soyuz tested. Just as Soyuz-T represented a Soyuz upgrade for Salyut 7, Soyuz-TM represented an upgrade for Mir. Soyuz-TM 1 arrived unmanned at the unoccupied station and remained for 9 days.

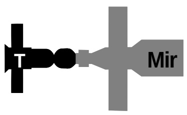


Mir • Progress 26 — May 29-June 22, 1986



Mir — June 22-26, 1986

Preparations to receive Soyuz-T 15. Mir maneuvered twice June 24-25, raising its orbit slightly and moving closer to Salyut 7. On June 25 Soyuz-T 15 undocked from Salyut 7 and began the 29-hr journey back to Mir.



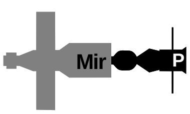
Soyuz-T 15 • Mir — June 26-July 16, 1986

The Mayaks return to Mir. Soyuz-T 15 arrived at Mir with a cargo of 350-400 kg of instruments from Salyut 7. On July 3 Kizim surpassed Valeri Ryumin's record for time spent in space. On July 6 he became the first human to spend a full year in space. The Mayaks spent their last 20 days on Mir conducting Earth observations.

Mir — July 16, 1986-January 18, 1987

Mir to remain unmanned until 1987. Shortly after the Mayaks returned to Earth, Soviet sources announced that Mir would not be staffed again in 1986.

Cosmos 1700 fails. In September 1986 the Altair/SR relay satellite Cosmos 1700 ceased operating and drifted off its geosynchronous orbit position.



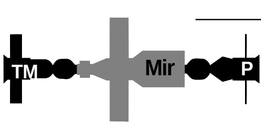
Mir • Progress 27 — January 18-February 7, 1987

Computer problems on Mir. Progress 27 boosted Mir's mean altitude by 16 km to 345 km on January 26. Alexandr Laveikin, who was soon to be launched on Soyuz-TM 2 to Mir, told an interviewer during this period that only one of Mir's computers was functional.[100]

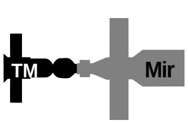
2.9.3.2 Mir Principal Expedition 2 (a)

Yuri Romanenko, Alexandr Laveikin
Crew code name—Tamyr
Soyuz-TM 2, February 5-July 30, 1987
176 days in space

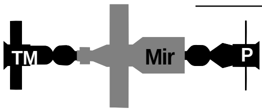
See Mir Principal Expedition 2 (b) note.



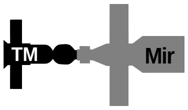
Soyuz-TM 2 • Mir • Progress 27 — February 7-23, 1987



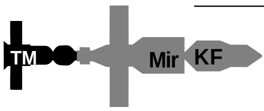
Soyuz-TM 2 • Mir — February 23-March 5, 1987



Soyuz-TM 2 • Mir • Progress 28 March 5-26, 1987



Soyuz-TM 2 • Mir March 26-April 9, 1987



Soyuz-TM 2 • Mir • Kvant with FSM April 9-12, 1987

Kvant misses Mir. Kvant consisted of the space station module (11 tons) and a unique FGB-based vehicle called the Functional Service Module (FSM)(9.6 tons). The FSM carried out major maneuvers on April 2 and April 5. On April 5 its Igla approach system began homing on Mir's aft port. The Tamyrs retreated to Soyuz-TM 2 so that they could escape in the event the module got out of control. About 200 m out, the Igla system lost its lock on Mir's aft port Igla antenna. The cosmonauts watched from within Soyuz-TM 2 as the Kvant/FSM combination passed within 10 m of the station.

Kvant achieves soft dock. Kvant and its FSM drifted 400 km from Mir before being guided back for a second docking attempt. Soft-dock occurred early on April 9. Kvant's probe unit would not retract fully, preventing hard docking between Mir and Kvant. The Soviets left Kvant soft-docked while they considered a solution. Maneuvers were impossible during this period, because the probe of the Kvant/FSM combination would wobble loosely in Mir's aft port drogue unit, banging the docking collars together.[101]

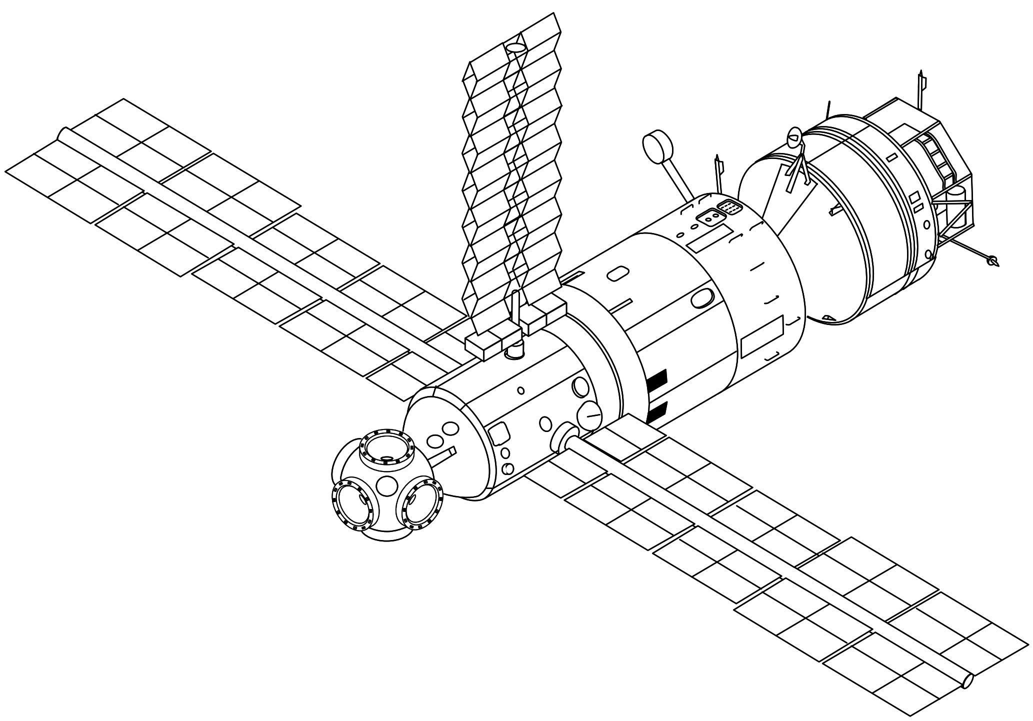
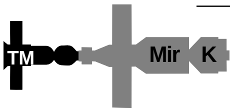


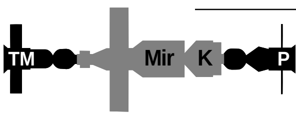
Figure 2-14. Mir base block (left) and Kvant (right) (1987). Note third solar array added to the top of the Mir base block. It was delivered inside Kvant. Soyuz-TM and Progress vehicles omitted for clarity.

Emergency EVA and hard dock. On April 11 Romanenko and Laveikin exited Mir to examine and, if possible, repair the problem with Kvant. They discovered a foreign object lodged in the docking unit, probably a trash bag they had left between Progress 28 and Mir's drogue. On command from the TsUP, Kvant extended its probe unit, permitting the cosmonauts to pull the object free and discard it into space. Kvant then successfully completed docking at a command from the ground. The EVA lasted 3 hr, 40 min. The Kvant FSM undocked from Kvant on April 12, freeing the module's aft port to fill in for the Mir aft port (figure 2-14).[102]



Soyuz-TM 2 • Mir • Kvant — April 12-23, 1987

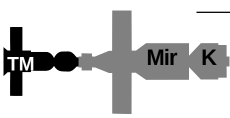
Unloading Kvant. The Tamyrs entered Kvant on April 13 and began unloading equipment into the base block. Kvant added 40 m^3 of pressurized volume to Mir, bringing the total to about 130 m^3. On April 16 the pointing motors on Mir's two solar arrays were linked to sensors on Kvant. Kvant carried stowed solar arrays intended to be attached to a fixture on top of the small-diameter section of the base block.



Soyuz-TM 2 • Mir • Kvant • Progress 29 — April 23-May 11, 1987

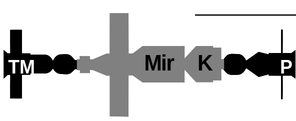
Testing Kvant. Beginning April 30, the Tamyrs tested orienting the Mir complex using Kvant's gyrodynes. In part this was in preparation for pointing the new module's roughly 1000 kg of astrophysical instruments.

Progress 29's short stay. During this period, propellant was pumped through Kvant to Mir's ODU for the first time. The Elektron system aboard Kvant, which produced oxygen by electrolysis of water, was readied on May 8.



Soyuz-TM 2 • Mir • Kvant — May 11-21, 1987

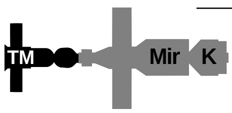
Mir power shortage. The Soviets acknowledged that Mir was short on electricity. The situation became particularly difficult when melts lasting days were conducted using Korund 1-M. The Tamyrs spent most of May conducting medical experiments and Earth resources photography, activities which required little electricity.[103]



Soyuz-TM 2 • Mir • Kvant • Progress 30 — May 21-July 19, 1987

First and second EVAs—solar array installation. On June 12 the Tamyrs exited Mir's multiport node for the first of two EVAs to install the solar array delivered by Kvant. There was insufficient room available in the multiport node for two spacesuited cosmonauts plus the main boom and first two sections of the new array, so Laveikin and Romanenko sealed the hatch between the Soyuz-TM 2 docking module and orbital module and left the hatch between the orbital module and the multiport node open, creating an extended airlock. One cosmonaut worked outside while the other handed out needed parts. The main boom of the array was an extendible girder like the one assembled outside Salyut 7 by the Mir Principal Expedition 1/Salyut 7 Principal Expedition 6 crew (Kizim and Solovyov, 1986). The first EVA lasted less than 2 hr. The second EVA, on June 16, installed the remainder of the solar array, attached its electrical connections to the Mir power system, and extended it to its full 10.6-m length. The new, 22-24 m^3 array brought Mir's total capacity to 11.4 kW. The EVA lasted 3 hr, 15 min.

Kvant begins its astronomical work with a bang. The Roentgen Observatory on Kvant was uniquely placed to study Supernova 1987a in the Large Magellanic Cloud. The cosmonauts examined the exploding star during 115 sessions between June and September.

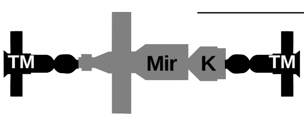


Soyuz-TM 2 • Mir • Kvant July 19-24, 1987

2.9.3.3 Mir Principal Expedition 2 (b)

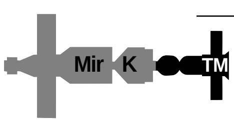
Yuri Romanenko, Alexandr Alexandrov
Crew code name–Tamyr
Soyuz-TM 3, July 22-December 29, 1987
160 days in space

Romanenko remained on Mir after Laveikin's departure in Soyuz-TM 2. Laveikin replaced by Alexandrov from Soyuz-TM 3. Romanenko's total stay time on long-duration expeditions Mir-2 (a) and Mir-2 (b) was 336 days.

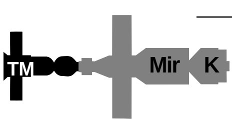


Soyuz-TM 2 • Mir • Kvant • Soyuz-TM 3 July 24-29, 1987

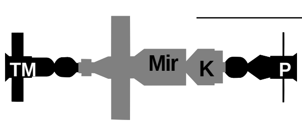
Soyuz-TM 3. Syrian guest cosmonaut Mohammed Faris and Soviet cosmonaut Alexandr Viktorenko returned to Earth in Soyuz-TM 2 with Alexandr Laveikin, who was diagnosed by ground-based doctors as having minor heart problems. He was replaced by Alexandr Alexandrov. The Visiting Expedition observed Syria and conducted materials processing experiments.[104]



Mir • Kvant • Soyuz-TM 3 July 29-30, 1987

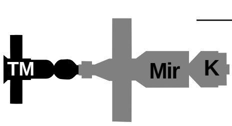


Soyuz-TM 3 • Mir • Kvant July 30-August 5, 1987

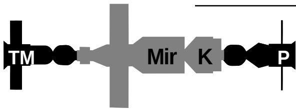


Soyuz-TM 3 • Mir • Kvant • Progress 31
August 5-September 21, 1987

X-rays from Supernova 1987a. On August 10 the astrophysical instruments on Kvant became the first to detect X-rays from Supernova 1987a. On August 31 the cosmonauts conducted a preplanned emergency evacuation drill, retreating to Soyuz-TM 3.



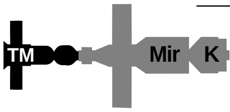
Soyuz-TM 3 • Mir • Kvant September 21-26, 1987



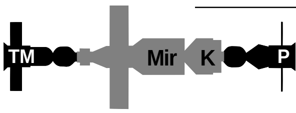
Soyuz-TM 3 • Mir • Kvant • Progress 32

September 26-November 17, 198

Progress 32 docking test. At 0409 UT on November 6, Progress 32 backed away from Mir to 2.5 km. It redocked at 0547 UT, in a test designed to study ways of reducing the amount of fuel used during approach and docking operations.[105]



Soyuz-TM 3 • Mir • Kvant November 17-23, 1987

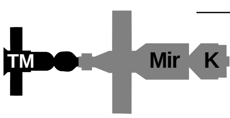


Soyuz-TM 3 • Mir • Kvant • Progress 33

November 23-December 19, 1987

Kvant problems. By late in the year, investigators in Britain and Holland noted sporadic problems with their TTM wide-angle X-ray camera and with ESA's Sirene 2 gas-scintillation proportional counter. They queried the TsUP in Moscow as to whether crew activity could be causing interference with the instruments.[106]

Cosmos 1897. This was a communications relay satellite of the Altair/SR series, designed to increase the amount of time Mir could be in touch with the TsUP on each orbit. It was launched on November 26 and stationed in geosynchronous orbit at 95° E. At the same time, fatigue reduced the cosmonauts' workday to 4.5 hr.[107, 108]

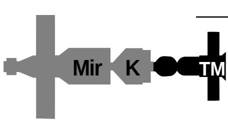


Soyuz-TM 3 • Mir • Kvant December 19-23, 1987

2.9.3.4 Mir Principal Expedition 3

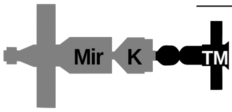
Vladimir Titov, Musa Manarov
Crew code name—Okean
Launched in **Soyuz-TM 4**, December 21, 1987
Landed in **Soyuz-TM 6**, December 21, 1988
365 days in space

Valeri Polyakov joined Titov and Manarov on Mir August 31, 1988, arriving on Soyuz-TM 6. See Mir Principal Expedition 4 note.

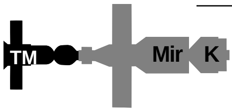


Soyuz-TM 3 • Mir • Kvant • Soyuz-TM 4 December 23-29, 1987

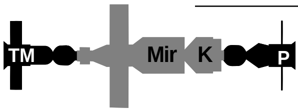
Handover. Before departing Mir, Romanenko and Alexandrov demonstrated use of EVA equipment to the Okeans. The Okeans delivered biological experiments, including the Aynur biological crystal growth apparatus, which they installed in Kvant. The combined crews conducted an evacuation drill, with the Mir computer simulating an emergency.



Mir • Kvant • Soyuz-TM 4 December 29-30, 1987



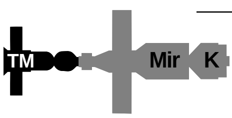
Soyuz-TM 4 • Mir • Kvant December 30, 1987-January 23, 1988



Soyuz-TM 4 • Mir • Kvant • Progress 34 January 23-March 4, 1988

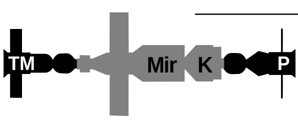
Glazar operations. Titov and Manarov conducted part of an ongoing survey of galaxies and star groups in the ultraviolet part of the spectrum using the Glazar telescope on Kvant. The survey required photography with exposure times up to 8 min. Even small cosmonaut movements could shake the complex. This produced blurring of astronomical images, so all cosmonaut movements had to be stopped during the exposures.

First EVA—solar array work. On February 12 the cosmonauts began preparations for an EVA to replace and augment Mir's solar arrays. They tested their EVA suits February 23-25, and on February 26 they exited the station. The Okeans removed one portion of the array Romanenko and Laveikin had assembled in June 1987. They replaced it with an eight-part array set which increased electricity output by 20% and also tested new solar cell materials and allowed telemetric monitoring of output. They also found time to wipe several of Mir's portholes, which had accumulated a dusty coating, and extensively photographed Mir's exterior. The EVA lasted 4 hr, 25 min.



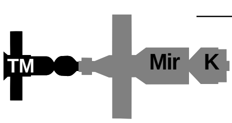
Soyuz-TM 4 • Mir • Kvant March 4-25, 1988

Sounds and smells. On March 17 the cosmonauts studied the effects of noise produced by fans and other equipment on their living quarters as part of the Akustika experiment. During the same period, a Soviet spokesman stated that dust and odors on Mir bothered the cosmonauts.[109]



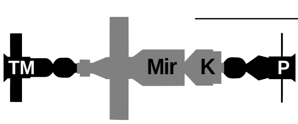
Soyuz-TM 4 • Mir • Kvant • Progress 35 March 25-May 5, 1988

Communications system upgrades. In late March and early April, Titov and Manarov installed and tested a new telefax system and unspecified equipment to improve communications between Mir and Earth.

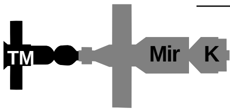


Soyuz-TM 4 • Mir • Kvant May 5-15, 1988

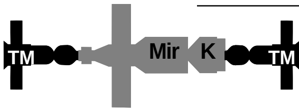
Orbital debris impact. During May a particle the Soviets identified as a piece of space debris blasted a crater in a two-pane Mir viewport. The damaged area was 6-8 mm across.[110]



Soyuz-TM 4 • Mir • Kvant • Progress 36 May 15-June 5, 1988

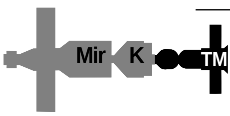


Soyuz-TM 4 • Mir • Kvant — June 5-9, 1988

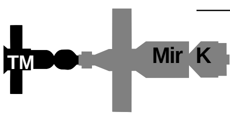


Soyuz-TM 4 • Mir • Kvant • Soyuz-TM 5 — June 9-17, 1988

Bulgarian in space. Before this flight, Bulgaria was the only eastern European Soviet ally not to have had a citizen visit a Soviet space station. This was because of the Soyuz 33 failure in 1979. Bulgarian cosmonaut-researcher Alexandr Alexandrov, not to be confused with the Soviet cosmonaut of the same name, used nearly 2,000 kg of equipment delivered by Progress freighters to conduct 46 experiments in the Shipka program during his stay on Mir.

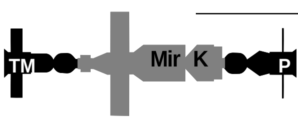


Mir • Kvant • Soyuz-TM 5 — June 17-18, 1988



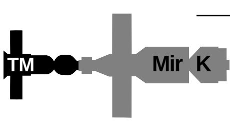
Soyuz-TM 5 • Mir • Kvant — June 18-July 20, 1988

Second EVA—X-ray telescope repair fails. On June 30 the Okeans left Mir via one of the lateral ports for an unrehearsed EVA to replace Kvant’s TTM shadow mask X-ray telescope. They had trained for the EVA by videotape sent up by the Progress 38 supply ship along with needed tools. They also spoke with cosmonauts who had rehearsed the repair in the hydrobasin in Zvezdny Gorodok (“Star City”). In addition to their suits, the Okeans carried 40 kg of tools and equipment between them. Upon reaching the work site, they cut through 20 layers of thermal blanket to reach the Roentgen suite of instruments. The EVA ended unsuccessfully when a wrench needed to remove a clamp snapped. The EVA duration was 5 hr, 10 min.

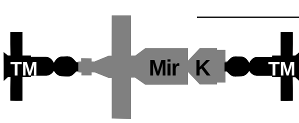


Soyuz-TM 5 • Mir • Kvant • Progress 37 — July 20-August 12, 1988

Cosmos 1897 moves east. In late July the Altair/SR relay satellite Cosmos 1897 was moved from its station at 95° E to 12° E to support the Buran shuttle test flight of November 14, 1988.



Soyuz-TM 5 • Mir • Kvant — August 12-31, 1988

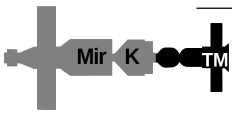


Soyuz-TM 5 • Mir • Kvant • Soyuz-TM 6 — August 31-September 5, 1988

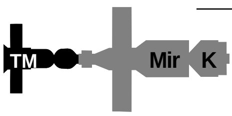
Soyuz-TM 6 arrives. Its crew had a unique makeup, with a commander (Vladimir Lyakhov) who had been trained to fly a Soyuz-TM solo in the event a rescue ship needed to be sent to recover two cosmonauts from Mir, no flight engineer, and two inexperienced cosmonaut-researchers. One was Dr. Valeri Polyakov, who would remain aboard Mir with Titov and Manarov to monitor their health during the final months of their planned year-long stay. The other

For Icon Key, see page 76

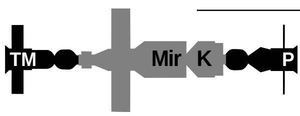
was Intercosmos cosmonaut Abdul Ahad Mohmand, from Afghanistan. Mohmand's experiment program was dominated by a series of observations of Afghanistan, called Shamshad. During return to Earth, Soyuz-TM 5 suffered a combined computer software and sensor problem, which delayed its reentry by 24 hr.



Mir • Kvant • Soyuz-TM 6 September 5-8, 1988



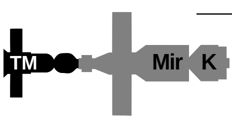
Soyuz-TM 6 • Mir • Kvant September 8-12, 1988



Soyuz-TM 6 • Mir • Kvant • Progress 38

September 12-November 23, 1988

Third EVA—X-ray telescope repair succeeds. On October 20 Titov and Manarov stepped outside Mir, leaving Polyakov in the Soyuz-TM 6 descent module. The spacewalkers wore improved spacesuits which did not need an umbilical connection to the station. Using tools delivered by Progress 38, Titov and Manarov removed the old TTM shadow mask X-ray unit and successfully replaced it. They then installed equipment in anticipation of the upcoming Franco-Soviet EVA. The EVA lasted 4 hr, 12 min.

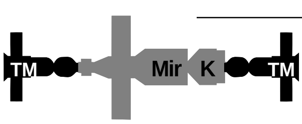


Soyuz-TM 6 • Mir • Kvant November 23-28, 1988

2.9.3.5 Mir Principal Expedition 4

Alexandr Volkov, Sergei Krikalev, Valeri Polyakov
Crew code name—Donbass
Soyuz-TM 7, November 26, 1988-April 27, 1989
151 days in space

Polyakov remained on Mir with Volkov and Krikalev when Titov and Manarov returned to Earth in Soyuz-TM 6. Polyakov's total stay time (part of Principal Expedition 3 and all of Principal Expedition 4) was 242 days. See Mir Principal Expedition 3 note.



Soyuz-TM 6 • Mir • Kvant • Soyuz-TM 7

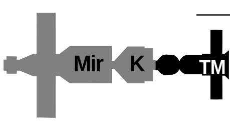
November 28-December 21 1988

Long French visit to Mir— the Franco-Soviet Aragatz mission begins. The arrival of Soyuz-TM 6 with French cosmonaut Jean-Loup Chretien (on his second mission to a Soviet space station) and Soviet cosmonauts Alexander Volkov and Sergei Krikalev increased Mir's population to six. According to Krikalev, this was the "worst-case scenario" as far as crowding on the station was concerned. Not only were there more cosmonauts than usual aboard Mir; the station was also full of equipment and life support supplies delivered by

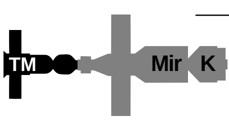
Progress freighters for the joint Franco-Soviet mission. The crowding was exacerbated because there was no docking port free for a Progress freighter. Therefore, the crew could not use a Progress as a "pantry" or "storage room" for the station. The large joint experiment manifest—mostly medical and technology experiments chosen to support the French-led European Space Agency Hermes shuttle project—strained Mir's electricity supply. The total mass of the experiments was 580 kg.[111, 112, 113]

French EVA. Preparations for the first EVA involving a non-Soviet/non-U.S. space traveler forced the cosmonauts to cut short a TV meeting with diplomats from 47 countries on December 8. On December 9 Chretien and Volkov depressurized the multiport docking adapter and clambered outside Mir. Chretien was first out. He installed handrails, then attached the 15.5 kg Enchantillons experiment rack to the handrails by springs and hooks. He also attached electrical wires leading from the rack to Mir's power supply. Enchantillons carried five technological experiments with applications to the Hermes shuttle program. Volkov and Chretien then assembled the 240-kg ERA experiment. They attached a mount to handrails on the frustum linking the multiport docking unit to the small-diameter portion of the work compartment. After resolving problems with cables linking ERA to a control panel inside Mir, they attached the folded ERA structure to a support arm on the platform. The structure was designed to unfold to form a flat six-sided structure 1 m deep by 3.8 m across. From inside Mir, Krikalev commanded the structure to unfold, but to no avail. Volkov then kicked ERA, causing it to unfold properly. According to Krikalev, taking the ERA outside helped relieve the crowding problems. The EVA lasted 5 hr and 57 min.[114, 115]

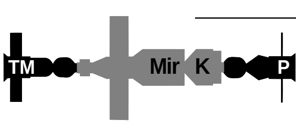
The Aragatz mission ends. After the EVA, Titov and Manarov showed Krikalev and Volkov the peculiarities of living and working on Mir. On December 15, their 359th day in space, Titov and Manarov officially beat Romanenko's 326-day single-flight endurance record by the required 10%. On December 19, Soyuz–TM 6 was powered up for descent. The spacecraft undocked on December 21. Titov, Manarov, and Chretien landed under low clouds, in sub-freezing temperatures, near Dzhezhkazgan in Kazakhstan.[116]



Mir • Kvant • Soyuz-TM 7 — December 21-22, 1988



Soyuz-TM 7 • Mir • Kvant — December 22-27, 1988

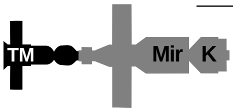


Soyuz-TM 7 • Mir • Kvant • Progress 39

December 27, 1988-February 7, 1989

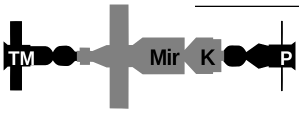
Progress 39 boosts orbit. Orbit boost was necessary because of greater than normal atmospheric drag. This in turn was caused by atmospheric expansion produced by atmospheric heating, the result of solar activity during the solar maximum period. According to Krikalev, it was not possible to visually detect any difference in the station's altitude after the reboost was completed. Krikalev, Volkov, and Polyakov then cleaned Mir and loaded Progress 39's orbital module with waste and excess equipment used on the joint Franco-Soviet Aragatz mission.[117]

For Icon Key, see page 76



Soyuz-TM 7 • Mir • Kvant February 7-12, 1989

Cosmos 1897 moves west. During February the Altair/SR satellite was moved from 12° E to its original position at 95° E.

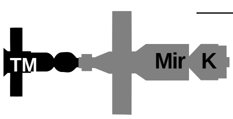


Soyuz-TM 7 • Mir • Kvant • Progress 40 February 12-March 3, 1989

D-module (Kvant 2) delayed. In mid-February the Soviets announced that launch of the D-module (also called the augmentation module, or Kvant 2) was the victim of delays in the production of the module to be added after it, the T-module (technology module, or Kristall). The D-module had been at Baikonur, awaiting launch, since July 1988, but the T-module would not be ready until December 1989, and the Soviets did not wish to let 3 months go by with Mir in an asymmetrical configuration (that is, with only one lateral port filled). Rather than handing over to another Principal Expedition crew, the Donbass cosmonauts would mothball Mir and return to Earth at the end of their stint.[118]

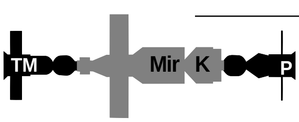
EVAs cancelled. Krikalev and Volkov had been trained to perform a total of six EVAs during Mir Principal Expedition 4. Krikalev was to have been the first cosmonaut to fly the Soviet equivalent of the NASA manned maneuvering unit (MMU), the YMK. But delay of Kvant 2, which carried the YMK, pushed back the EVAs to the next Principal Expedition, the crew for which would consist of Krikalev and Volkov's backups.

Diagramma. The cosmonauts extended a 10-m pole from the Mir base block's small airlock. It carried sensors used as part of the Diagramma program to characterize the environment around Mir.



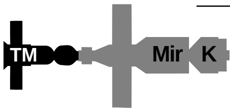
Soyuz-TM 7 • Mir • Kvant March 3-18, 1989

Antenna experiment. When Progress 40 backed away from Mir, it deployed an antenna consisting of two loops of wire, each 20 m across, from a pair of containers on either side of the Progress cargo module. The cosmonauts observed the deployment. During the 2 days before its destructive reentry, Progress 40 continued in free flight while characteristics of the antenna were assessed by the TsUP.



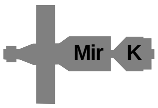
Soyuz-TM 7 • Mir • Kvant • Progress 41 March 18-April 21, 1989

Mir mothballed. On April 10 Soviet reports had the cosmonauts beginning the process of preparing Mir for unmanned operation. Also during this period the cosmonauts replaced power supply units which were nearing the end of their design lives. Heightened solar activity led to some concern over the cosmonauts' safety, but Soviet sources stated that radiation levels were not hazardous.



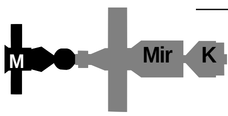
Soyuz-TM 7 • Mir • Kvant April 21-26, 1989

Soyuz-TM 7 leaves Mir unstaffed. The engine on Soyuz-TM 7 was used to boost the Mir complex to a new record mean altitude of 410 km in mid-April. Volkov, Krikalev, and Polyakov then loaded Soyuz-TM 7 with experiment results and film and returned to Earth. The landing was unusually rough because of high winds in the recovery zone. Krikalev sustained a minor knee injury, though he downplayed its importance.[119]



Mir • Kvant April 26-August 25, 1989

Astronomical observations. Throughout the time it was unstaffed, astronomers on Earth used Mir's Kvant astrophysical instruments to study Supernova 1987a and conduct more than 70 other observations.

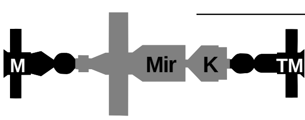


Progress-M 1 • Mir • Kvant August 25-September 6, 1989

Progress-M 1 arrives. This was the first flight of a modified Progress freighter. It became the first of its class to dock with the front port of a space station. While there, it topped off the station's attitude control propellant tanks.

2.9.3.6 Mir Principal Expedition 5

Alexandr Viktorenko, Alexandr Serebrov
Crew code name—Vityaz
Soyuz-TM 8, September 5, 1989-February 19, 1990
168 days in space.



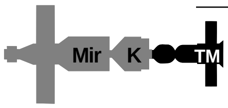
Progress-M 1 • Mir • Kvant • Soyuz-TM 8

September 6-December 1, 1989

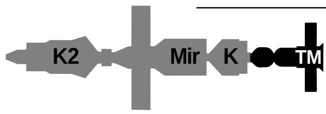
Docking system work. On September 29 the cosmonauts installed equipment in the docking system in preparation for the arrival of Kvant 2, the first of Mir's 20-ton add-on modules.

Solar storm warnings. On September 30 a powerful flare burst out on the Sun. Initial predictions indicated that the cosmonauts could receive many times the maximum permissible level of radiation. In the event, the cosmonauts received only about as much radiation as they would normally receive in 2 weeks of flight.

Kvant 2 delayed. It was announced on October 10 that problems with a batch of computer chips pushed back the launch of Mir's second add-on module by at least 40 days from the planned October 16 launch date. The major focus of Viktorenko and Serebrov's mission was to receive, check out, and activate the module, so their schedule underwent heavy revision.



Mir • Kvant • Soyuz-TM 8 December 1-6, 1989



Kvant 2 • Mir • Kvant • Soyuz-TM 8 December 6-8, 1989

Kvant 2 joins Mir. Kvant 2 was launched on November 26. Soon after launch the TsUP discovered that the right solar array had not deployed properly, allowing it to flop freely. By rolling Kvant 2 and rotating the array simultaneously, the TsUP was able to fully extend and lock the array. On December 2 Kvant 2 closed to within 20 m of the Mir front port before its Kurs control system terminated the approach. It had sensed that the module was moving too fast. Problems also developed on Mir: the Argon 16B control computer shut down the attitude control gyrodynes in Kvant after detecting an error. Viktorenko and Serebrov assumed manual control of Mir for the second attempt, which was successful. The Lyappa manipulator arm on Kvant 2 then inserted itself into a fixture on the multiport docking node and pivoted the module into place at the top lateral port. The transfer required about 1 hr **(**figure 2-15**)**.

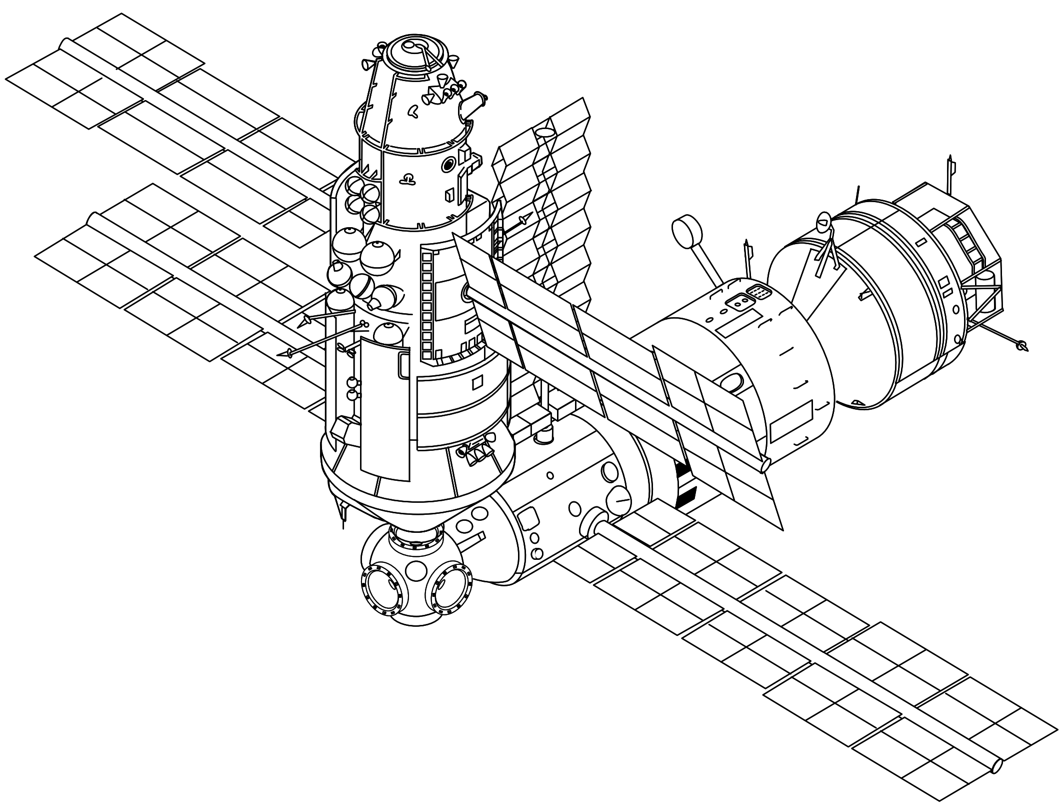
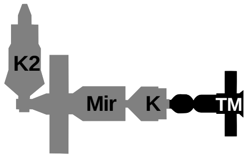
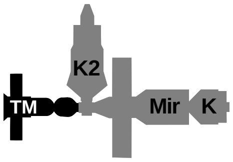


Figure 2-15. Mir base block (left), Kvant, and Kvant 2 (top) (1989). Soyuz-TM and Progress vehicles are omitted for clarity.



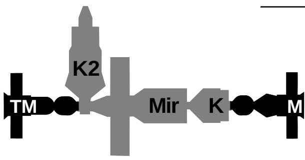
December 8-12, 1989

Kvant 2
Mir • Kvant • Soyuz-TM 8



December 12-22, 1989

Kvant 2
Soyuz-TM 8 • Mir • Kvant



December 22, 1989-February 9, 1990

Kvant 2
Soyuz-TM 8 • Mir • Kvant • Progress-M 2

First EVA—star sensor installations. The new guidance control computer for Mir, the Salyut 5B system delivered by Kvant 2, needed star sensors more capable than those in place on Kvant. On January 8, in the first of the EVAs postponed from Principal Expedition 4, Viktorenko and Serebrov opened one of the three free docking node hatches, transferred the twin 80-kg sensor packages outside, and installed them on Kvant. Start of the 2-hr, 56-min EVA was delayed 1 hour by a depressurization problem in Soyuz-TM 8—when the cosmonauts lowered pressure in the docking node, an improperly set valve released air from the spacecraft as well.

Second EVA—many tasks. On January 11 the cosmonauts became the last to use a docking node hatch for an EVA. They removed for return to Earth the Enchantillons space exposure experiment rack set up by Chretien during his December 1988 EVA, removed and discarded the ERA platform installed by Chretien and Volkov, and made modifications to the docking node in preparation for the arrival of the next large module, Kristall.

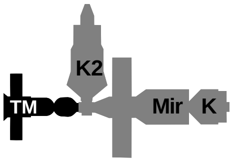
Cosmos 2054. The third Altair/SR geosynchronous satellite took up position at 344° E in mid-January. It was launched on December 27, 1989. Combined with Cosmos 1897, it permitted Mir to maintain contact with the TsUP in Moscow about 70% of the time.

Third EVA—testing new EVA systems. On January 26 Viktorenko and Serebrov donned new Orlan-DMA spacesuits. These were improved versions of the Orlan suits they had worn on their first two EVAs. They then entered and depressurized the special EVA airlock compartment at the outboard end of Kvant 2. The EVA airlock hatch is wider than the docking hatches (1 m vs 0.8 m) to permit passage of the YMK, the Soviet MMU equivalent, which is stored in Kvant 2. The central instrument-science compartment of Kvant 2 can also be sealed and depressurized, expanding the size of the airlock and providing a backup. The cosmonauts attached a mooring post to the outside of the airlock compartment and removed a Kurs antenna so it could not interfere with future EVAs. EVA duration was 3 hr, 2 min.

Fourth EVA—YMK tests. The Soviet “flying armchair” maneuvering unit weighed 218 kg. Serebrov donned the unit on February 1 and moved up to 33 m from the station. In case the YMK malfunctioned, during the test he was bound by a tether attached to a winch on the mooring post installed on the previous EVA. The EVA lasted 4 hr, 59 min.

For Icon Key, see page 76

Fifth EVA—More YMK tests. On February 5 Viktorenko flew the YMK to a distance of 45 m. He carried the Spin-6000 device, which measured radiation from Mir induced by cosmic ray bombardment. EVA duration was 3 hr, 45 min.

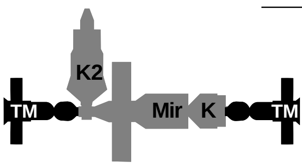


February 9-13, 1990

Kvant 2
Soyuz-TM 8 • Mir • Kvant

2.9.3.7 Mir Principal Expedition 6

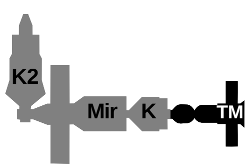
Anatoli Solovyov, Alexandr Balandin
Crew code name—Rodnik
Soyuz-TM 9, February 11-August 9, 1990
179 days in space



February 13-19, 1990

Kvant 2
Soyuz-TM 8 • Mir • Kvant • Soyuz-TM 9

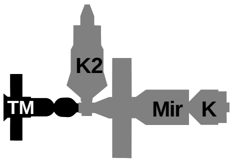
Soyuz-TM 9 arrives in tatters. Soon after they arrived in orbit, Balandin and Solovyov noted that three of eight thermal insulation blankets on their spacecraft's descent module had come loose at their lower (heat shield) ends and were waving about as the spacecraft maneuvered in space. It was thought they could block optical navigation sensors, and that the damaged insulation might cause the spacecraft to overheat or cool down so much that condensation would form on its optical equipment. The possibility existed that an electrical short might occur if condensation developed on equipment. Docking with Mir occurred as normal. The cosmonauts and TsUP worked out procedures by which the TsUP monitored Soyuz-TM 9's temperature and maneuvered Mir to move it in and out of sunlight as needed to maintain proper temperature. In the meantime, cosmonauts worked in the hydrolab training facility in Zvezdny Gorodok, outside Moscow, to develop EVA repair procedures. Consideration was also given to sending a rescue Soyuz-TM carrying a single cosmonaut to pick up the cosmonauts and return them to Earth.[120]



February 19-21, 1990

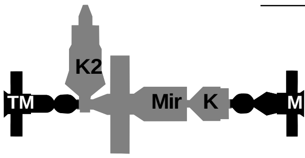
Kvant 2
Mir • Kvant • Soyuz-TM 9

Viktorenko and Serebrov give a press conference on Earth. Mir's previous occupants, the Vityazis, claimed that profits generated by the production of 297 g of gallium arsenide semiconductors had allowed their mission to pay for itself. The gallium arsenide had returned to Earth with them in the Soyuz-TM 8 descent module. They also complained that on Mir there were no fixtures for holding them at their work stations.[121]



February 21-March 3, 1990

Kvant 2
Soyuz-TM 9 • Mir • Kvant

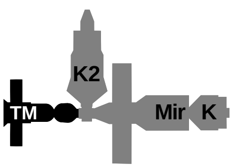


March 3-April 27, 1990

Kvant 2
Soyuz-TM 9 • Mir • Kvant • Progress-M 3

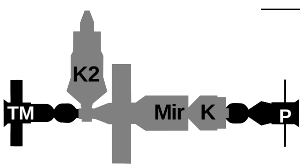
Maintenance. Progress-M 3 delivered replacement parts for Mir, including new storage batteries, electrical system components, and computer parts. The cosmonauts began installing these by March 7. Most of March was taken up with work on the computer system.

Kristall delayed. When Soyuz-TM 9 was launched, the Soviets stated that Kristall would launch on March 30 and dock April 7. On April 20 the Soviets announced that the Kristall module would not be launched until June 1. The cause of the delay was continued work to turn over control of the Mir complex to the new Salyut 5B computer. Difficulty had also been experienced in integrating Kvant 2's gyrodynes into the Mir attitude control system.[122]



April 27-May 7, 1990

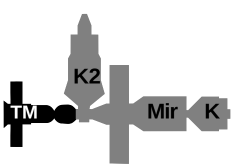
Kvant 2
Soyuz-TM 9 • Mir • Kvant • Progress-M 2



May 7-27, 1990

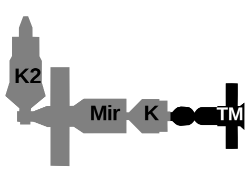
Kvant 2
Soyuz-TM 9 • Mir • Kvant • Progress 42

Last Progress. Progress 42 was the last of the highly successful series of Progress vehicles. It marked the 43rd Progress docking (counting Cosmos 1669), all of which were successful. The Progress freighters delivered 99 tons of material to Salyut 6, Salyut 7, and Mir. Use of Progress 42 forced a delay in the integration of the Salyut 5B control computer delivered with Kvant 2, as Progress 42 could interface only with the old Argon 16B system.



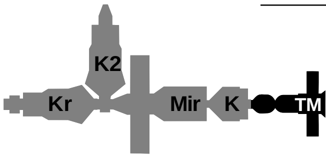
May 27-28, 1990

Kvant 2
Soyuz-TM 9 • Mir • Kvant



May 28-June 10, 1990

Kvant 2
Mir • Kvant • Soyuz-TM 9



June 10-11, 1990

Kvant 2
Kristall • Mir • Kvant • Soyuz-TM 9

Kristall arrives. The long-awaited, much-delayed Kristall module arrived at Mir's front port on June 10, and was relocated to the lateral port opposite Kvant 2 on June 11 (figure 2-16). This restored the equilibrium of the complex, which had been asymmetrical since Kvant 2 was placed at a lateral port in December 1989. The module was launched May 31. It had aborted its first

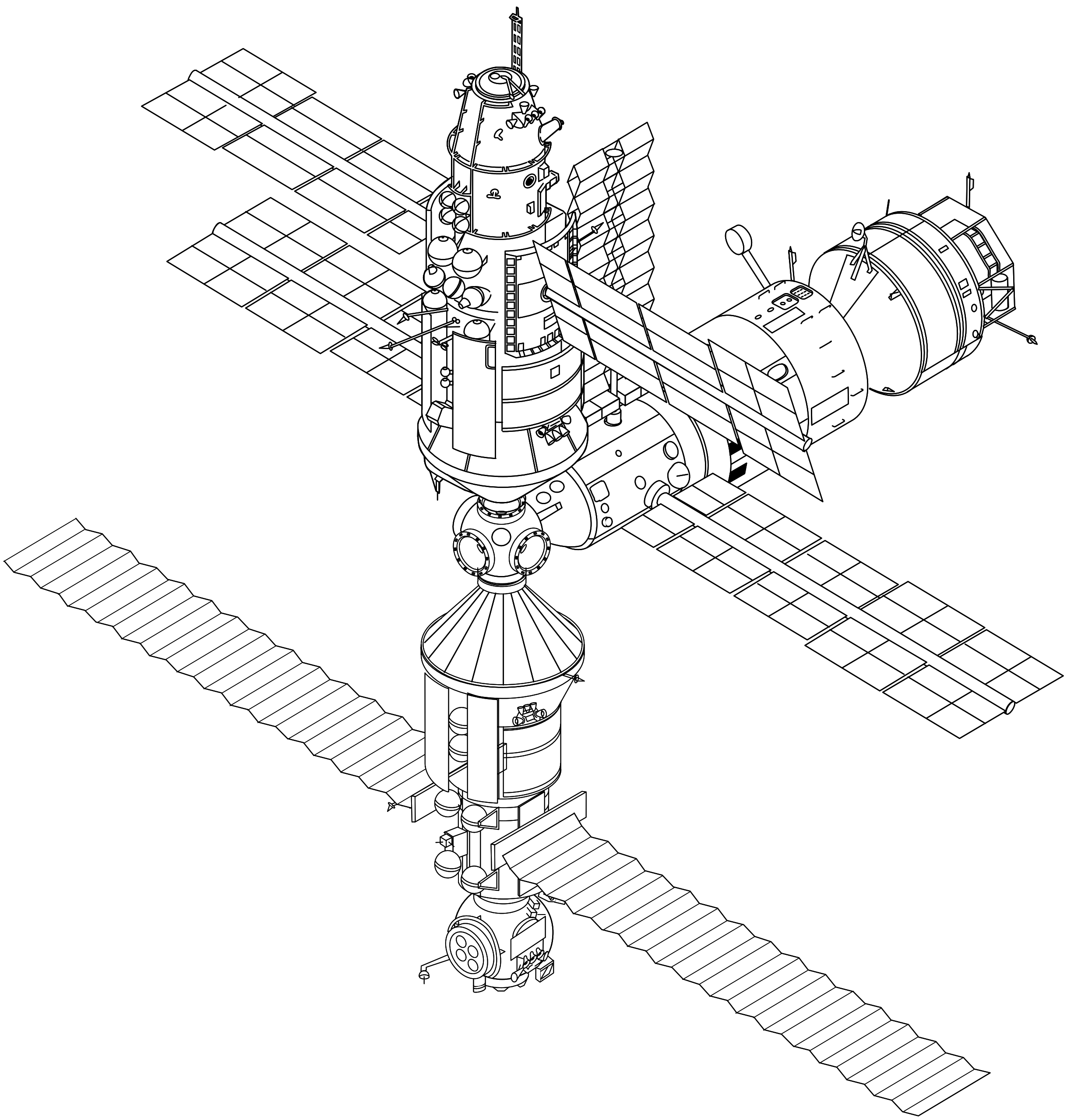
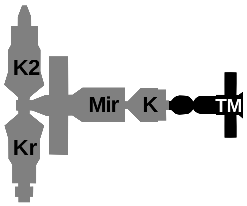


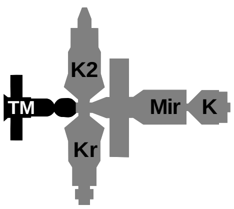
Figure 2-16. Mir base block (center), Kvant (right), Kvant 2 (top), and Kristall (bottom) (1990). Note the EVA mooring post for YMK tests near Kvant 2's EVA airlock hatch. It was added during a January 26, 1990 EVA. Soyuz-TM and Progress vehicles are omitted for clarity.

docking attempt on June 6 due to an attitude control thruster failure. Delays in launch and docking affected Balandin and Solovyov, who were scheduled to return to Earth at the end of July. Their mission was extended 10 days to permit them to activate Kristall's systems, and to accommodate the EVA to repair the loose thermal blankets on Soyuz-TM 9.



June 11-July 3, 1990

Kvant 2
Mir • Kvant • Soyuz-TM 9
Kristall



July 3-August 3, 1990

Kvant 2
Soyuz-TM 9 • Mir • Kvant
Kristall

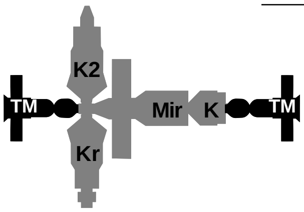
First EVA—Kvant 2 hatch damaged. Solovyov and Balandin had not previously been trained to perform an EVA. They trained by videotape sent up from the ground on a Progress spacecraft, and also by observing practice sessions televised from the hydrobasin. Special EVA tools were manufactured and sent to the cosmonauts. On July 3 they moved Soyuz-TM 9 to the Mir front port so it could be more easily reached for repairs. On July 17 they opened the Kvant 2 EVA hatch before the airlock was completely evacuated of air. The hatch slammed back on its hinges. They used a pair of clamps, which they attached to handholds, to move down Kvant 2. They also secured themselves with long and short ropes. After 1.5 hr they reached the multiport docking node. They attached to Kvant 2 ladders for reaching the damage site on their Soyuz-TM. The cosmonauts determined that the Soyuz-TM 9 descent module remained in excellent condition. However, the thermal blankets had shrunk, making them impossible to reattach. They fell back on a contingency plan by folding two of the three blankets in half. They were well behind schedule by this point. They left their tools and ladders at the repair site and hurried to return to Mir, as the rated endurance of their suits (6.5 hr) had been exceeded. This meant crawling over Kvant 2's hull in the dark. They found that the Kvant 2 hatch would not close. To permit them to reenter the pressurized portion of Mir, the central compartment of Kvant 2 was called into play as an emergency airlock, as it had been designed to do. The EVA lasted 7 hr, 16 min.[123]

Second EVA—sizing up the damage. Solovyov and Balandin depressurized the Kvant 2 central compartment on July 25. After several attempts to close the outside hatch from inside, they televised images of the damaged hinge to the TsUP, then returned to the multiport node to secure their ladders. Finally, they removed a portion of the hinge cover, which had broken and become lodged between the hatch and its frame. They found the hatch much easier to close and seal after this. They repressurized the EVA airlock. The EVA lasted 3 hr, 31 min.[124]

For Icon Key, see page 76

2.9.3.8 Mir Principal Expedition 7

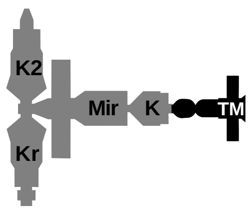
Gennadi Manakov, Gennadi Strekalov
Crew code name—Vulkan
Soyuz-TM 10, August 1-December 10, 1990
131 days in space



August 3-9, 1990

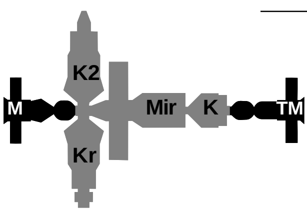
Kvant 2
Soyuz-TM 9 • Mir • Kvant • Soyuz-TM 10
Kristall

Soyuz-TM 10 arrives, Soyuz-TM 9 departs. The Vulkans arrived at Mir's aft port with four passengers—quail for cages in Kvant 2. A quail laid an egg en route to the station. It was returned to Earth, along with 130 kg of experiment results and industrial products, in Soyuz-TM 9. The spacecraft landed without incident.



August 9-17, 1990

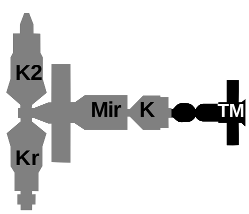
Kvant 2
Mir • Kvant • Soyuz-TM 10
Kristall



August 17-September 17, 1990

Kvant 2
Progress-M 4 • Mir • Kvant • Soyuz-TM 10
Kristall

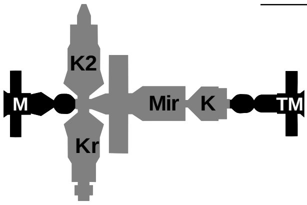
Integrating Kristall and emergency drills. The Vulkans linked Kristall's attitude control system to the Mir complex on August 28. On August 30 they practiced dealing with emergency situations which might arise in the expanded Mir complex. Between August 22 and September 11, Progress-M 4 boosted the complex to a mean altitude of 390 km.



September 17-29, 1990

Kvant 2
Mir • Kvant • Soyuz-TM 10
Kristall

Plasma experiment. Strekalov and Manakov installed a device for producing plasma on Progress-M 4's docking unit before casting off the spacecraft. For three days it flew formation with the station, releasing plasma for the Vulkans to observe and record.

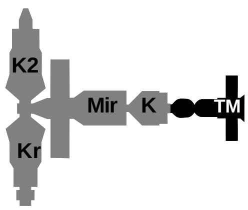


September 29-November 28, 1990

Kvant 2
Progress-M 5 • Mir • Kvant • Soyuz-TM 10
Kristall

Progress-M 5 and Raduga. Progress-M 5 carried television equipment for the upcoming joint Soviet-Japanese mission. It was also the first Progress-M equipped with a Raduga return capsule. On October 1 Soyuz-TM 10's main engine pushed Mir to a mean altitude of 397 km. The KAP-350 and Priroda 5 cameras were used as part of the Makhichevan-90 Earth resources observation program, which studied the region between the Black and Caspian seas.

EVA—Kvant 2 EVA hatch damage more severe than expected. The Soviets postponed the EVA several days after Strekalov came down with a cold. On October 29 the cosmonauts exited Mir through the Kvant 2 hatch and removed thermal insulation. They found that the hatch was beyond their ability to repair. They attached a device to the hatch to allow it to close properly.

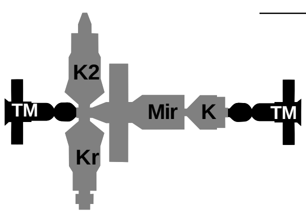


November 28-December 4, 1990

Kvant 2
Mir • Kvant • Soyuz-TM 10
Kristall

2.9.3.9 Mir Principal Expedition 8

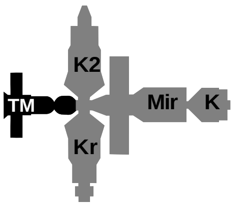
Viktor Afanaseyev, Musa Manarov
Crew code name—Derbent
Soyuz-TM 11, December 2, 1990-May 26, 1991
175 days in space



December 4-10, 1990

Kvant 2
Soyuz-TM 11 • Mir • Kvant • Soyuz-TM 10
Kristall

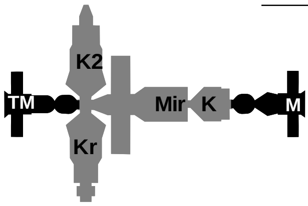
Soyuz-TM 11 arrives. Viktor Afanaseyev, Musa Manarov (on his second Mir visit), and Japanese television journalist Toyohiro Akiyama were welcomed aboard Mir by the Vulkans. Akiyama's network, the Tokyo Broadcasting System (TBS), paid for the flight. The Soviets called this their first commercial spaceflight and claimed to have earned $14 million. The journalist was scheduled to make one 10-min TV broadcast and two 20-min radio broadcasts each day. Electrical power and video and TV system incompatibilities forced the Japanese to make extensive use of converters. His equipment, which weighed about 170 kg, was delivered by Progress-M spacecraft and set up in advance by Manakov and Strekalov. On December 5 Akiyama's couch was transferred to Soyuz-TM 10. On December 8 Manakov and Strekalov commenced loading Soyuz-TM 10's descent module with film and experiment results. TBS broadcast Akiyama's landing live from Kazakhstan.



December 10, 1990-January 16, 1991

Kvant 2
Soyuz-TM 11 • Mir • Kvant
Kristall

First EVA—hinge repair. On January 4 Afanaseyev and Manarov prepared their spacesuits for an EVA to repair the Kristall EVA hatch hinge damaged by Solovyov and Balandin in July 1990. They suited up and practiced in the Kvant 2 airlock. On January 7 the Derbents opened Kvant 2's EVA hatch and clambered outside. They repaired the damaged hinge, tested their handiwork by closing and sealing the hatch, then reopened the hatch and went about other tasks. These included transfer outside the station of equipment scheduled for installation on later EVAs. They also removed a TV camera from Kvant 2 for repairs inside the station. The EVA lasted 5 hr, 18 min.



January 16-March 15, 1991

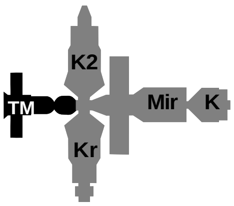
Kvant 2
Soyuz-TM 11 • Mir • Kvant • Progress-M 6
Kristall

Second EVA—boom installation. On January 23 the Derbents opened the newly-repaired hatch and slowly transferred a carton 6 m long to a worksite on the base block. The container held Strela, a folded boom with a pivot mechanism at its base. They attached Strela to supports which originally held the base block's launch faring. The 45-kg boom was meant to play a key role in the transfer of Kristall's twin 500-kg collapsible solar arrays to the sides of Kvant. Maximum boom length was 14 m; maximum capacity, up to 700 kg. The EVA lasted 5 hr, 33 min.

Third EVA—support structures. On January 26 the Derbents spent 6 hr, 20 min installing support structures on Kvant. They were meant to hold the Kristall solar arrays.

Five years of Mir. February 19 marked the fifth anniversary of Mir's launch. The Derbents spent February working with materials science apparatus in Kristall. They used the Pion unit to study the effects on semiconductor production of changing patterns of microacceleration aboard Mir caused by operation of its equipment. On March 7 the cosmonauts extended a pole bearing a magnetic sensor through a Mir scientific airlock as part of the Diagramma program to characterize the environment outside the station.

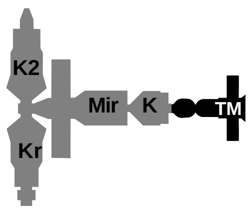
Observing the Gulf War. Afanaseyev and Manarov could easily see evidence of war as they passed over the Persian Gulf. They sent back TV images of oil spills, smoke pouring from a coastal town, and fires.



March 15-26, 1991

Kvant 2
Soyuz-TM 11 • Mir • Kvant
Kristall

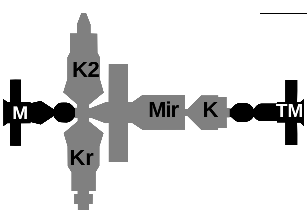
Progress-M 7 near-miss. On March 21 Progress-M 7 broke off its approach 500 m from the aft docking port. On March 23 the craft made a second approach, but 20 m from the rear port a controller in the TsUP detected a "catastrophic error" and broke off the approach. Progress-M 7 passed within 5 to 7 m of the station, narrowly avoiding antennas and solar arrays.[125]



March 26-28, 1991

Kvant 2
Mir • Kvant • Soyuz-TM 11
Kristall

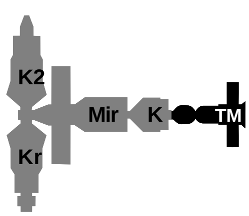
Kurs antenna problem diagnosed. Afanaseyev and Manarov undocked Soyuz-TM 11 from the front port and transferred it to the aft. During approach to the aft port, they used Kurs, rather than carrying out the transfer under manual control, as was typical. They found that their spacecraft mimicked Progress-M 7's behavior, veering away from the docking port. The cosmonauts completed a normal manual docking at the aft port, having determined that the problem was in Mir's aft port Kurs antenna. Subsequently, Progress-M 7 docked at Mir's front port. If it had failed to dock, the cosmonauts might have had to draw on a 1–mo reserve of emergency supplies while a standby Progress was readied.



March 28-May 6, 1991

Kvant 2
Progress-M 7 • Mir • Kvant • Soyuz-TM 11
Kristall

Fourth EVA. On April 25 Manarov filmed the damaged Kvant Kurs antenna. He reported that one of its dishes was missing. During the EVA the cosmonauts also replaced the camera they had removed from Kvant 2 on their first EVA and repaired inside Mir. The EVA lasted 3 hr, 34 min.



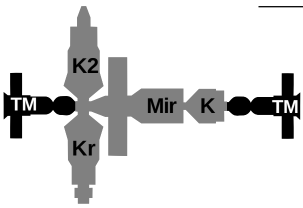
May 6-20, 1991

Kvant 2
Mir • Kvant • Soyuz-TM 11
Kristall

2.9.3.10 Mir Principal Expedition 9

Anatoli Artsebarski, Sergei Krikalev
Crew code name—Ozon
Soyuz-TM 12, May 18-October 11, 1991
145 days in space

See Mir Principal Expedition 10 note.

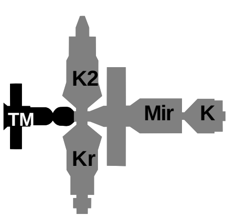


May 20-May 26, 1991

Kvant 2
Soyuz-TM 12 • Mir • Kvant • Soyuz-TM 11
Kristall

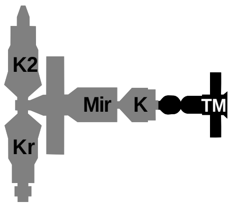
Arrival of Soyuz-TM 12. The Derbents welcomed aboard Mir Anatoli Artsebarski, Sergei Krikalev (on his second visit to the station), and British cosmonaut-researcher Helen Sharman, who was aboard as part of Project Juno, a cooperative venture partly sponsored by British private enterprise. Sharman's experimental program, which was designed by the Soviets, leaned heavily toward life sciences. A bag of 250,000 pansy seeds was placed in the Kvant 2 EVA airlock, a compartment not as protected from cosmic radiation as other Mir compartments. Sharman also contacted nine British schools by radio and conducted high-temperature superconductor experiments with the Elektropograph-7K device. Sharman commented that she had difficulty finding equipment on Mir as there was a great deal more equipment than in the trainer in the cosmonaut city of Zvezdny Gorodok. Krikalev commented that, while Mir had more modules than it had had the first time he lived on board, it did not seem less crowded, as it contained more equipment. Krikalev also noted that some of the materials making up the station's exterior had faded and lost color, but that this had had no impact on the station's operation.[126]

Solar power problems. During a communication session with a British girls' school on May 21, Sharman commented that Mir was experiencing solar array problems because of the station's changing orientation. Late that day the level of background noise on the station suddenly fell from the customary 75 decibels as fans, circulating pumps, and other equipment shut down. The lights began to fade. A computer in the orientation system had failed, preventing the solar arrays from tracking on the Sun, and causing Mir to drain its batteries. Sharman stated that Afanaseyev and Manarov told her such power problems had occurred before. When it reentered sunlight, the station was turned to recharge its batteries.[127]



May 26-28, 1991

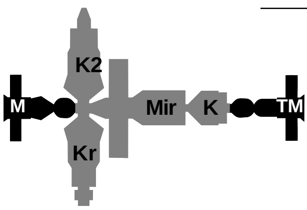
Kvant 2
Soyuz-TM 12 • Mir • Kvant
Kristall



May 28-June 1, 1991

Kvant 2
Mir • Kvant • Soyuz-TM 12
Kristall

Moving Soyuz-TM 12. The Ozons needed to move their spacecraft to Mir's aft port to make way for Progress-M 8, which could not dock with the rear port because of the damage to the Kurs approach system antenna there. The move required 42 min.



June 1- August 15, 1991

Kvant 2
Progress-M 8 • Mir • Kvant • Soyuz-TM 12
Kristall

MAK-1. The cosmonauts released the small MAK-1 satellite from the Mir base block's experiment airlock on June 17. It was designed to study Earth's ionosphere. However, a probable power failure prevented its antennas from deploying, and the satellite remained inert.

First EVA—fixing Kurs. On June 24 the Ozons exited the hatch on Kvant 2 and clambered over Mir's hull to the aft end of Kvant, where they removed the damaged Kurs approach system unit and replaced it. They also assembled a prototype thermomechanical joint to be used in the assembly of space structures. The EVA lasted 4 hr, 53 min.

Second EVA —TREK. On June 28 the cosmonauts attached to Mir's hull the TREK instrument, a device for studying cosmic ray superheavy nuclei. The experiment was devised by the University of California and delivered by Progress-M 8. The Ozons used the Strela telescoping boom to move about the station. EVA duration was 3 hr, 24 min.

Third EVA—Preparing for Sofora construction. On July 15 the Ozons used the Strela boom to transfer equipment from the Kvant 2 EVA hatch to the work site on Kvant. They attached two ladders to Kvant to give them handholds, then assembled a platform for Sofora on Kvant. Sofora was to be a 14.5-m girder extending from Kvant. The EVA lasted 5 hr, 56 min.

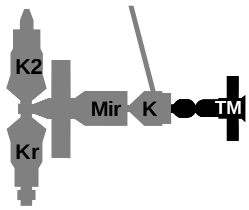
Fourth EVA—Sofora construction commences. On July 19 Krikalev and Artsebarski installed an automated assembly unit similar to the one Kizim and Solovyov had experimented with on Salyut 7 in 1986. Sofora was also an experimental construction, but the Soviets had plans to attach an attitude control thruster unit to it if it functioned as expected. The thruster unit would augment Mir's attitude control systems. They assembled 3 of 20 segments planned for Sofora before returning to Mir. The EVA lasted 5 hr, 28 min.

Fifth EVA—Sofora construction continues. On July 23 the Ozons added 11 segments to the Sofora girder. The EVA lasted 5 hr, 34 min.

Sixth EVA—Sofora construction completed. On July 27 the cosmonauts added the last six segments to the Sofora girder. They also attached a Soviet flag in a metal frame to the top of the girder. This was not planned in advance; the cosmonauts decided independently to attach the flag. Artsebarski's visor

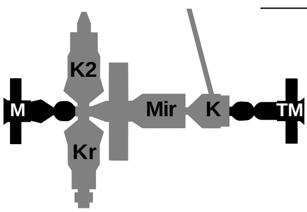
For Icon Key, see page 76

fogged up from exertion, but Krikalev was able to help him back to the Kvant 2 hatch. EVA duration was 6 hr, 49 min.[128]



August 15-23, 1991

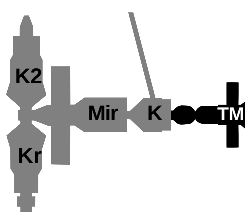
Kvant 2
Mir • Kvant • Soyuz-TM 12
Kristall



August 23-September 30, 1991

Kvant 2
Progress-M 9 • Mir • Kvant • Soyuz-TM 12
Kristall

Failed coup d'état in Moscow. The coup against Mikhail Gorbachev had little immediate impact on Mir operations. Progress-M 9 was launched as the coup attempt fell apart, on August 21. Boris Belitsky, a Radio Moscow space and science reporter, stated that the TsUP relayed broadcasts of Soviet Central TV (pro-coup) and Russian Radio (anti-coup) to the Ozons. He stated that there were never any plans to abandon the station during the coup, but revealed that such provisions existed in the event of the outbreak of a major war on Earth.[129]



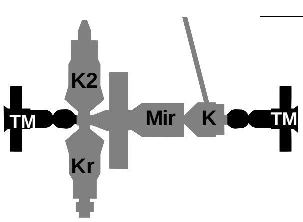
September 30-October 4, 1991

Kvant 2
Mir • Kvant • Soyuz-TM 12
Kristall

2.9.3.11 Mir Principal Expedition 10

Alexandr Volkov, Sergei Krikalev
Crew code name—Donbass
Soyuz-TM 13, October 2, 1991-March 25, 1992
175 days in space

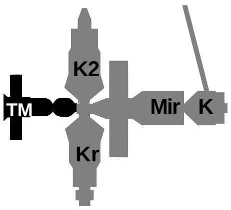
Krikalev remained on board Mir while Artsebarski returned to Earth in Soyuz-TM 12. Volkov arrived on Soyuz-TM 13 to replace Artsebarski. Krikalev's total time in space (Principal Expedition 9 and 10) was 320 days.



October 4-10, 1991

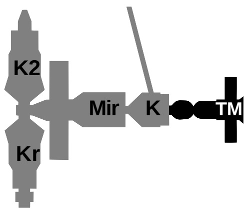
Kvant 2
Soyuz-TM 13 • Mir • Kvant • Soyuz-TM 12
Kristall

Soyuz-TM 13 arrives. Soyuz-TM 13 carried Austrian cosmonaut-researcher Franz Viehboeck and Kazakh cosmonaut-researcher Toktar Aubakirov. The flight was unusual for carrying no flight engineer. Veteran Russian cosmonaut Alexandr Volkov commanded. The Austrians paid $7 million to fly Viehboeck to Mir, and the Kazakh cosmonaut flew partly in an effort to encourage newly-independent Kazakhstan to continue to permit launchings from Baikonur Cosmodrome. The cosmonaut-researchers photographed their respective countries from orbit and conducted the usual range of materials processing and medical experiments. Artsebarski traded places with Volkov and returned to Earth in Soyuz-TM 12.



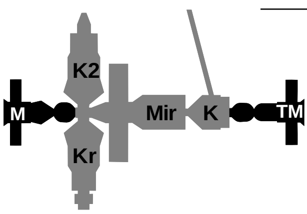
October 10-15, 1991

Kvant 2
Soyuz-TM 13 • Mir • Kvant
Kristall



October 15-21, 1991

Kvant 2
Mir • Kvant • Soyuz-TM 13
Kristall



October 21, 1991-January 20, 1992

Kvant 2
Progress-M 10 • Mir • Kvant • Soyuz-TM 13
Kristall

Impact damage. By this date the Mir base block had suffered orbital debris and meteoroid damage on the flat sealing surface of one of its docking rings and on most of its windows.[130]

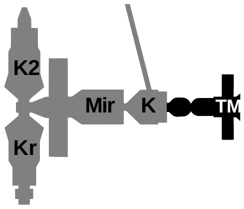
Progress-M 10 aborts docking. The spacecraft broke off its first docking attempt on October 19 at a distance of 150 m. It successfully docked on October 21.

Cosmos 1897 drifts off station. The Altair/SR satellite drifted to 90° E in the geostationary belt by March. By late April the Soviets had maneuvered it back to 95° E, but by the end of 1991 it had drifted to 77° E and was widely considered inoperative. The other Altair/SR satellite, Cosmos 2054, continued to serve as a communications relay between Russia and Mir.

Diagramma. In October the cosmonauts extended a Diagramma boom from Mir's small airlock to test the atmosphere around the station.

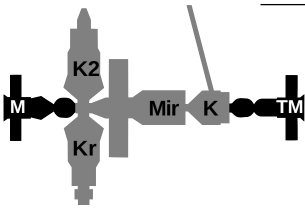
Mir problems. The cosmonauts ended 1991 by replacing storage batteries and conducting ongoing repairs on the complex. At the end of the year total solar array power production was down to 10 kW. In addition, 4 of 6 gyrodynes on Kvant 2 and 1 of 6 gyrodynes on Kvant (5 of Mir's total of 12) had failed.

Progress-M 10 undocking delayed. The spacecraft topped off Mir's propellant tanks on January 13. Undocking planned for January 18 was postponed by a problem with the wiring of Mir's gyrodynes, which affected the station's attitude. When it undocked on January 20, it carried a Raduga return capsule, which was safely recovered.



January 20-27, 1992

Kvant 2
Mir • Kvant • Soyuz-TM 13
Kristall



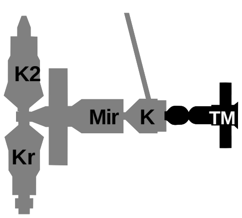
January 27-March 13, 1992

Kvant 2
Progress-M 11 • Mir • Kvant • Soyuz-TM 13
Kristall

Progress-M 11. The spacecraft carried a repair kit for the station's gyrodynes. During its approach to the station, flight controllers in the TsUP were on strike for higher rates of pay, but they did not interfere with the docking. Progress-M 11 boosted the complex into a 413 km by 380 km orbit before undocking.

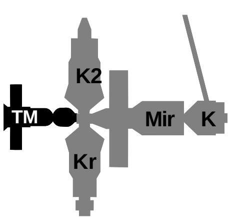
Communication cutbacks. In January 1991 the fleet of ocean-going tracking ships in place since the early 1960s was phased out of Mir operations to save funds. Some of the ships continued to operate to support unmanned missions, and could step in as a backup when needed to support Mir. By mid-February, Mir was spending up to 9 hrs each day out of touch with the TsUP because of tracking system cutbacks.[131]

EVA. On February 20 Volkov and Krikalev opened the Kvant 2 EVA hatch for what would be Krikalev's seventh EVA in less than a year. The heat exchanger on Volkov's Orlan-DMA spacesuit failed, forcing a hasty revision of the EVA plans. Volkov remained near the hatch, so could not operate the Strela boom to move Krikalev to the prime work site on Kvant. Volkov assisted in installation of space exposure experiments near the hatch, then Krikalev clambered down Kvant 2 and over the hull to Kvant. He disassembled equipment used in building the Sofora girder in July 1991, then cleaned the cameras on Kvant. Finally, he collected samples of solar cells added to the third (top) array on the base block in 1988. The EVA lasted 4 hr, 12 min.



March 13-14, 1992

Kvant 2
Mir • Kvant • Soyuz-TM 13
Kristall

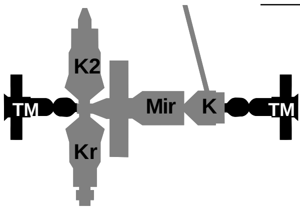


March 14-19, 1992

Kvant 2
Soyuz-TM 13 • Mir • Kvant
Kristall

2.9.3.12 Mir Principal Expedition 11

Alexandr Viktorenko, Alexandr Kaleri
Crew code name—Vityaz
Soyuz-TM 14, March 17-August 10, 1992
147 days in space

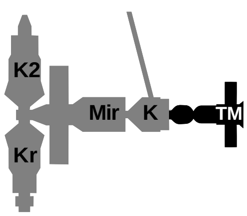


March 19-25, 1992

Kvant 2
Soyuz-TM 13 • Mir • Kvant • Soyuz-TM 14
Kristall

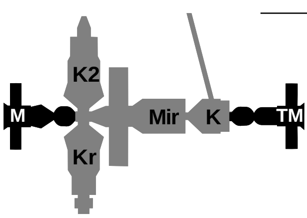
Soyuz-TM 14 arrives . . . Klaus Dietrich Flade became the second German to visit a space station when he reached Mir with the Vityaz crew. The first was Sigmund Jahn of East Germany, who visited Salyut 6 in 1978. Flade conducted 14 German experiments as part of Germany's preparation for participation in the Freedom and Columbus space station projects.

. . . and Krikalev departs. Sergei Krikalev was to have returned to Earth in October 1991, but moves to cut costs had forced modifications to his mission. A Soyuz-TM flight was cancelled, and his replacement, Alexandr Kaleri, was bumped from the Soyuz-TM 13 flight to make way for Toktar Aubakirov on the Soyuz-TM 13 flight. Krikalev had to remain on board Mir. Western news agencies had reported that Krikalev was stranded on Mir, though this was of course incorrect. NPO Energia paid Kazakh authorities $15,000 in rents for airports and helicopters during the recovery operation.



March 25-April 21, 1992

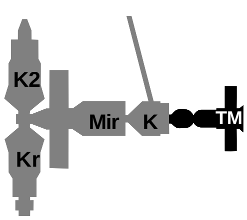
Kvant 2
Mir • Kvant • Soyuz-TM 14
Kristall



April 21-June 27, 1992

Kvant 2
Progress-M 12 • Mir • Kvant • Soyuz-TM 14
Kristall

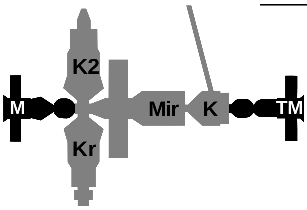
Mir sleepy. During this period, NPO Energia representative B. Chertok stated that the Mir station, by this time 6 years old, could no longer be mothballed. It would, he stated, "doze off forever" within 2 months without the attentions of a resident crew.[132]



June 27-July 4, 1992

Kvant 2
Mir • Kvant • Soyuz-TM 14
Kristall

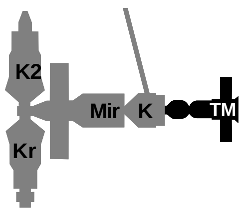
For Icon Key, see page 76



July 4-24, 1992

Kvant 2
Progress-M 13 • Mir • Kvant • Soyuz-TM 14
Kristall

EVA—inspecting gyrodynes. Kvant 2's gyrodynes were installed on its exterior, within easy reach of the Kvant 2 EVA hatch. The Vityazi's spent 2 hr, 3 min examining the gyrodynes in anticipation of a future repair and replacement mission.

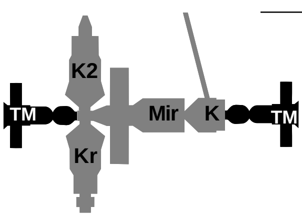


July 24-29, 1992

Kvant 2
Mir • Kvant • Soyuz-TM 14
Kristall

2.9.3.13 Mir Principal Expedition 12

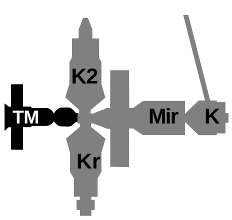
Anatoli Solovyov, Sergei Avdeyev
Crew code name—Rodnik
Soyuz-TM 15, July 27, 1992-February 2, 1993
191 days in space



July 29-August 9, 1992

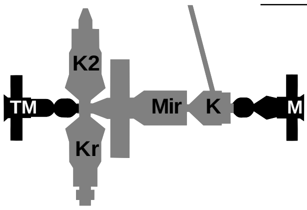
Kvant 2
Soyuz-TM 15 • Mir • Kvant • Soyuz-TM 14
Kristall

Franco-Russian Antares mission. Michel Tognini, passenger aboard Soyuz-TM 15, was the third Frenchman to visit a space station. He conducted ten experiments using 300 kg of equipment delivered by Progress-M flights.



August 9-18, 1992

Kvant 2
Soyuz-TM 15 • Mir • Kvant
Kristall



August 18-October 21, 1992

Kvant 2
Soyuz-TM 15 • Mir • Kvant • Progress-M 14
Kristall

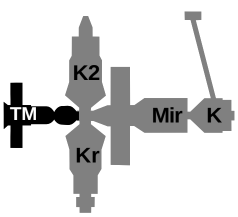
Progress-M 14 delivers VDU. The modified Progress-M spacecraft docked at the Kvant port. In place of a tanker compartment, it carried a 700-kg VDU thruster unit designed to be installed atop the Sofora girder mounted on Kvant. The unit was designed to improve Mir's attitude control capabilities. Commands from the TsUP automatically unloaded the VDU unit on September 2.

First EVA—preparing for VDU installation. Avdeyev and Solovyov moved the VDU to the work site and prepared the Sofora girder on September 3. EVA duration was 3 hr, 56 min.

Second EVA—laying a cable. On September 7 the cosmonauts bent Sofora back on a hinge at one-third of its length to make its top more accessible, and laid a control cable along the girder. They also removed the remnants of the Soviet flag placed on the mast during its assembly in 1991. It had been reduced to shreds by UV degradation and orbital debris and meteoroid impacts. EVA duration was 5 hr, 8 min.

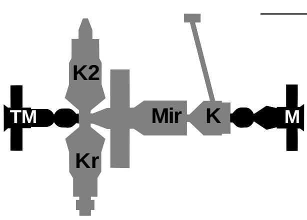
Third EVA—VDU installation complete. On September 11 the cosmonauts attached the VDU unit atop the Sofora girder and hoisted it into position by straightening the girder. The EVA lasted 5 hr, 44 min.

Fourth EVA—preparing for Soyuz-TM 16. On September 15 Solovyov and Avdeyev retrieved solar cell and materials samples and moved the Kurs rendezvous antenna on Kristall so it could be used by Soyuz-TM 16.



October 21-29, 1992

Kvant 2
Soyuz-TM 15 • Mir • Kvant
Kristall



October 29, 1992-January 26, 1993

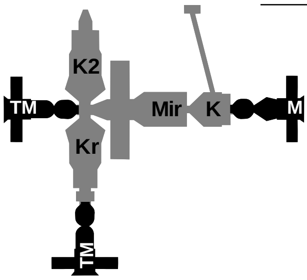
Kvant 2
Soyuz-TM 15 • Mir • Kvant • Progress-M 15
Kristall

MAK-2 deployed. The cosmonauts released the 16.5-kg satellite from the Mir base block's experiment airlock on November 20. Its purpose was to study Earth's ionosphere.

Near-miss by satellite. The derelict 550-kg Cosmos 1508 satellite, launched by the Soviet Union in 1983, passed within 300 m of Mir on November 8.[133]

2.9.3.14 Mir Principal Expedition 13

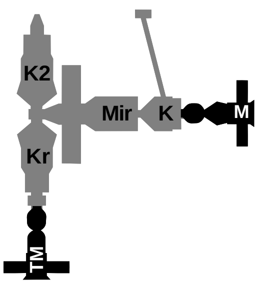
Gennadi Manakov, Alexandr Poleshchuk
Crew code name—Elbrus
Soyuz-TM 16, January 24, 1993-July 22, 1993
178 days in space



January 26-February 1, 1993

Kvant 2
Soyuz-TM 15 • Mir • Kvant • Progress-M 15
Kristall
Soyuz-TM 16

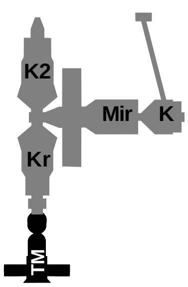
Soyuz-TM 16 creates a unique Mir configuration. Soyuz-TM 16 docked with the lateral APAS-89 docking unit on Kristall. This tested the unit for future operations. Mission commander Manakov was paying his second visit to Mir. On January 28 the cosmonauts carried out Rezonans tests on the Mir complex, which at this time weighed more than 90 tons (its heaviest ever) and included seven separately launched spacecraft.[134]



February 1-4, 1993

Kvant 2
Mir • Kvant • Progress-M 15
Kristall
Soyuz-TM 16

Avdeyev and Solovyov return to Earth. The Soyuz-TM 15 descent module lowered to Earth beneath low clouds, touched down, and rolled partway down a hillock. It came to rest 150 m from a frozen marsh.[135]

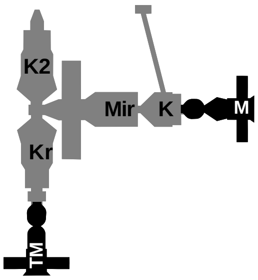


February 4-23, 1993

Kvant 2
Mir • Kvant
Kristall
Soyuz-TM 16

Znamya. On February 4 Progress-M 15 undocked from Mir and backed to a distance of 230 m. The spacecraft fired thrusters to cause it to rotate about its long axis, after which it successfully deployed a 20-m, 40-kg foil reflector called Znamya ("banner") from its orbital module. It was a test of a future solar reflector/solar sail designed to illuminate and warm regions on the Earth's surface not in direct sunlight, such as the polar regions in winter. The experiment lasted only 6 min, during which time Progress-M 15 and the nearby Mir complex passed over Europe along a path from Lyon, in southern France, through Prague in the Czech Republic, to Gomel in eastern Belarus. Znamya was sighted in the predawn sky in many places along the path, including southern France, eastern Poland, and Belarus. Manakov and Poleshchuk observed the test from Mir. Znamya was then cast off. The collapsed, tumbling reflector remained visible from the surface for 24 hr. It was seen as a glittering object over much of Canada.[136, 137]

Progress-M 15 in teleoperations experiment. After discarding Znamya, Progress-M 15 was controlled by the cosmonauts on Mir at a distance of 200 m. The test lasted 12 min. Progress-M 15 was deorbited by command from the TsUP on February 7.

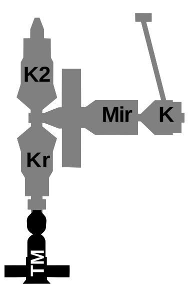


February 23-March 27, 1993

Kvant 2
Mir • Kvant • Progress-M 16
Kristall
Soyuz-TM 16

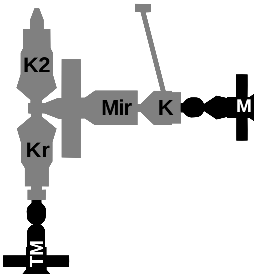
Progress-M 16 delivers replacement parts. On March 2 Manakov and Poleshchuk replaced Mir's air conditioning unit. They also replaced components in the part of the communication system linking Mir to the Cosmos 2054 Altair/SR satellite. Over the next week the cosmonauts installed new gyrodynes in Kvant 2 and replaced parts in the computers. On March 19 Poleshchuk and Manakov connected the electrical systems of Kvant 2 and Kristall. Soon after, they tested the new gyrodynes in Kvant 2 by moving the complex.

Progress-M 16 controlled from Mir. The cargo craft undocked early on March 26 and backed off to a distance of 70 m under control of the cosmonauts inside Mir. They then commanded Progress-M 16 to approach and dock. The operation was completed within 20 min of initial undocking. Final undocking on March 27 was initiated and controlled in its initial stages by Poleshchuk and Manakov. The TsUP took control for the final stages of the cargo ship's flight and its destructive reentry.



March 27-April 2, 1993

Kvant 2
Mir • Kvant
Kristall
Soyuz-TM 16

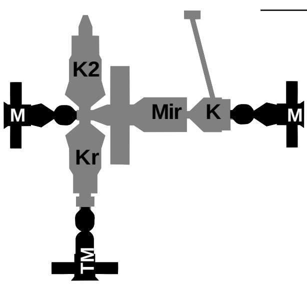


April 2-May 24, 1993

Kvant 2
Mir • Kvant • Progress-M 17
Kristall
Soyuz-TM 16

First EVA—loss of Strela handle. Late on April 19, Poleshchuk and Manakov opened the airlock hatch on Kvant 2 to begin the first of three planned EVAs. Its objective was to install solar array electric drives on the sides of Kvant. These would later receive the collapsible solar arrays from Kristall. Poleshchuk climbed down the length of Kvant 2 to the base of the Strela telescoping boom attached to the base block. Manakov then fixed himself to the end of the boom, at which point Poleshchuk swung the boom to move him to the installation site on Kvant. A container holding one of the electric drives was transferred using the boom. With difficulty the cosmonauts attached the drive to one of the frameworks which had been assembled on opposite sides of Kvant in 1991 by Titov and Manarov. Poleshchuk noticed that one of two control handles for the Strela boom had come off and floated away. A new handle would have to be sent up from Earth before work could continue. The EVA lasted 5 hr, 25 min.

Waiting for the replacement handle. The second EVA, planned for April 23, was cancelled. The cosmonauts carried out routine maintenance on the water regeneration, electricity supply, and onboard computer systems. They also conducted Rezonans tests.



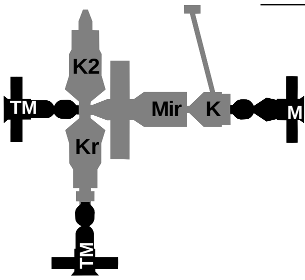
May 24-July 3, 1993

Kvant 2
Progress-M 18 • Mir • Kvant • Progress-M 17
Kristall
Soyuz-TM 16

Second EVA—solar array drive installation completed. Progress-M 18's docking marked the first time a Soviet station was attended by two Progress craft at the same time. In addition to the replacement handle for the telescoping boom, Progress M-18 delivered replacement water pumps for the thermal control system and computer parts. On June 18 Poleshchuk and Manakov exited the station and repaired the boom, then installed the second solar array electric drive. They completed their EVA tasks by televising images of Mir's exterior.

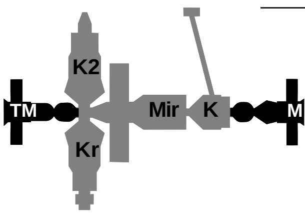
2.9.3.15 Mir Principal Expedition 14

Vasili Tsibliyev, Alexandr Serebrov
Crew code name—Sirius
Soyuz-TM 17, July 1, 1993-January 14, 1994
198 days in space



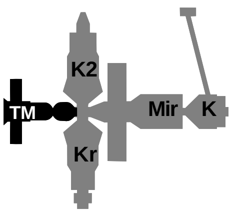
July 3-22, 1993

Kvant 2
Soyuz-TM 17 • Mir • Kvant • Progress-M 17
Kristall
Soyuz-TM 16



July 22-August 10, 1993

Kvant 2
Soyuz-TM 17 • Mir • Kvant • Progress-M 17
Kristall

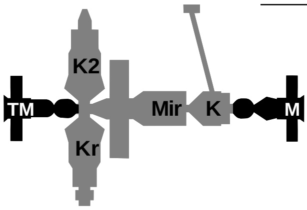


August 10-13, 1993

Kvant 2
Soyuz-TM 17 • Mir • Kvant
Kristall

Perseids peak. The night of August 12-13, the Perseid meteor shower peaked. The Perseids occur every year at this time, but in 1993 an unusually high peak was predicted. Because of this, the U.S. delayed launch of the Space Shuttle Discovery, which was scheduled to be in orbit at this time. The Sirius crew continued to work aboard Mir, but Russia took precautions: planes and helicopters stood by for the possible emergency return of Soyuz-TM 17. During the shower, the cosmonauts mounted an around-the-clock watch, and observed about 240 meteoroids burning up in the atmosphere beneath Mir.[138] They also noted ten window impacts, which produced craters from 1.5 to 4 mm across. Mir impact sensors noted a particle flux of up to 2000 times the normal mean rate during the Perseid shower. Mir sustained no readily apparent consequential damage from the meteoroids, but the Russians decided to mount EVAs to inspect Mir's exterior nonetheless.

For Icon Key, see page 76



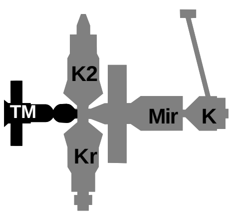
August 13-October 12, 1993

Kvant 2
Soyuz-TM 17 • Mir • Kvant • Progress-M 19
Kristall

First EVA—Rapana girder. The Sirius cosmonauts spent 4 hr, 18 min outside Mir assembling the Rapana girder on top of Kvant on September 16. This was a girder assembly experiment with implications for Mir 2 space station development.

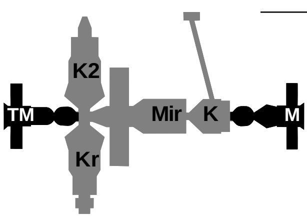
Second EVA—Rapana girder. Tsibliyev and Serebrov spent 3 hr, 13 min completing assembly of Rapana on September 20 (figure 2-17).

Third EVA—Mir inspection. On September 28 the Sirius cosmonauts spent 1 hr, 52 min carrying out miscellaneous tasks and inspecting Mir's exterior in the first phase of the Panorama program. They spotted a 5-mm hole through one of the solar arrays. The hole was surrounded by an area of cracks several cm across. The cosmonauts were unable to determine if a Perseid meteoroid was the impactor.[139]



October 12-13, 1993

Kvant 2
Soyuz-TM 17 • Mir • Kvant
Kristall

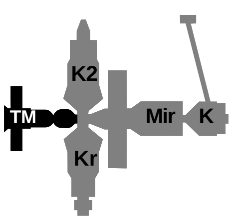


October 13-November 21, 1993

Kvant 2
Soyuz-TM 17 • Mir • Kvant • Progress-M 20
Kristall

Fifth EVA—Mir inspection. The cosmonauts spent 38 min conducting the Panorama inspection of Mir and performing miscellaneous tasks on October 22.

Sixth EVA—Mir inspection. The Sirius cosmonauts spent 4 hrs on October 29 inspecting Mir as part of the Panorama program and conducting miscellaneous tasks. By the end of Panorama they had inspected the entire skin of Mir. Panorama revealed many small impact sites on Mir, though no hull penetrations. During one of their EVAs, a piece of metal of indeterminate origin drifted past the working cosmonauts.[140]



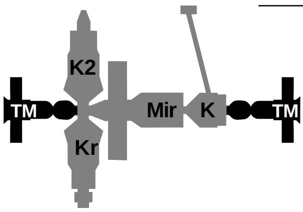
November 21, 1993-January 10, 1994

Kvant 2
Soyuz-TM 17 • Mir • Kvant
Kristall

2.9.3.16 Mir Principal Expedition 15

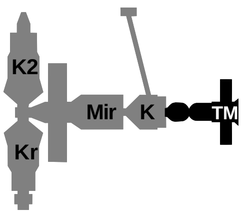
Viktor Afanaseyev, Yuri Usachyov, Valeri Polyakov
Crew code name—Derbent
Soyuz-TM 18, January 8-July 9, 1994
186 days in space

Valeri Polyakov remained aboard with the Mir Principal Expedition 16 crew. Plans are for him to live aboard Mir for 15 months.



January 10-14, 1994

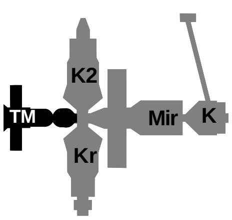
Kvant 2
Soyuz-TM 17 • Mir • Kvant • Soyuz-TM 18
Kristall



January 14-24, 1994

Kvant 2
Mir • Kvant • Soyuz-TM 18
Kristall

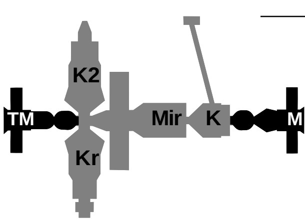
Soyuz-TM 17 recontact. Soyuz-TM 17 struck Mir during the customary inspection fly-around prior to deorbit burn. For details see section 1.13.3. Tsibliyev and Serebrov were conducting proximity operations with Mir. Among other things, they were photographing a NASA JSC-built docking target they had installed during one of their EVAs. They were unable to arrest Soyuz-TM 17's forward movement because of an improperly set switch, and so struck Kristall two glancing blows with its descent module. The blows temporarily disabled Mir's orientation system. Masterful piloting by Tsibliyev prevented Soyuz-TM 17 from striking Mir's antennas and solar arrays. After the incident, the Sirius cosmonauts and ground controllers checked over Soyuz-TM 17, while the Derbents on Mir checked over Kristall. They found no damage. Normal Mir operations resumed, and Soyuz-TM 17 made a normal reentry.[141, 142]



January 24-30, 1994

Kvant 2
Soyuz-TM 18 • Mir • Kvant
Kristall

Kristall inspection. Afanaseyev, Usachov, and Polyakov examined Kristall when they repositioned their spacecraft at the Mir forward port. They detected no damage from the Soyuz-TM 17 recontact.



January 30-March 23, 1994

Kvant 2
Soyuz-TM 18 • Mir • Kvant • Progress-M 21
Kristall

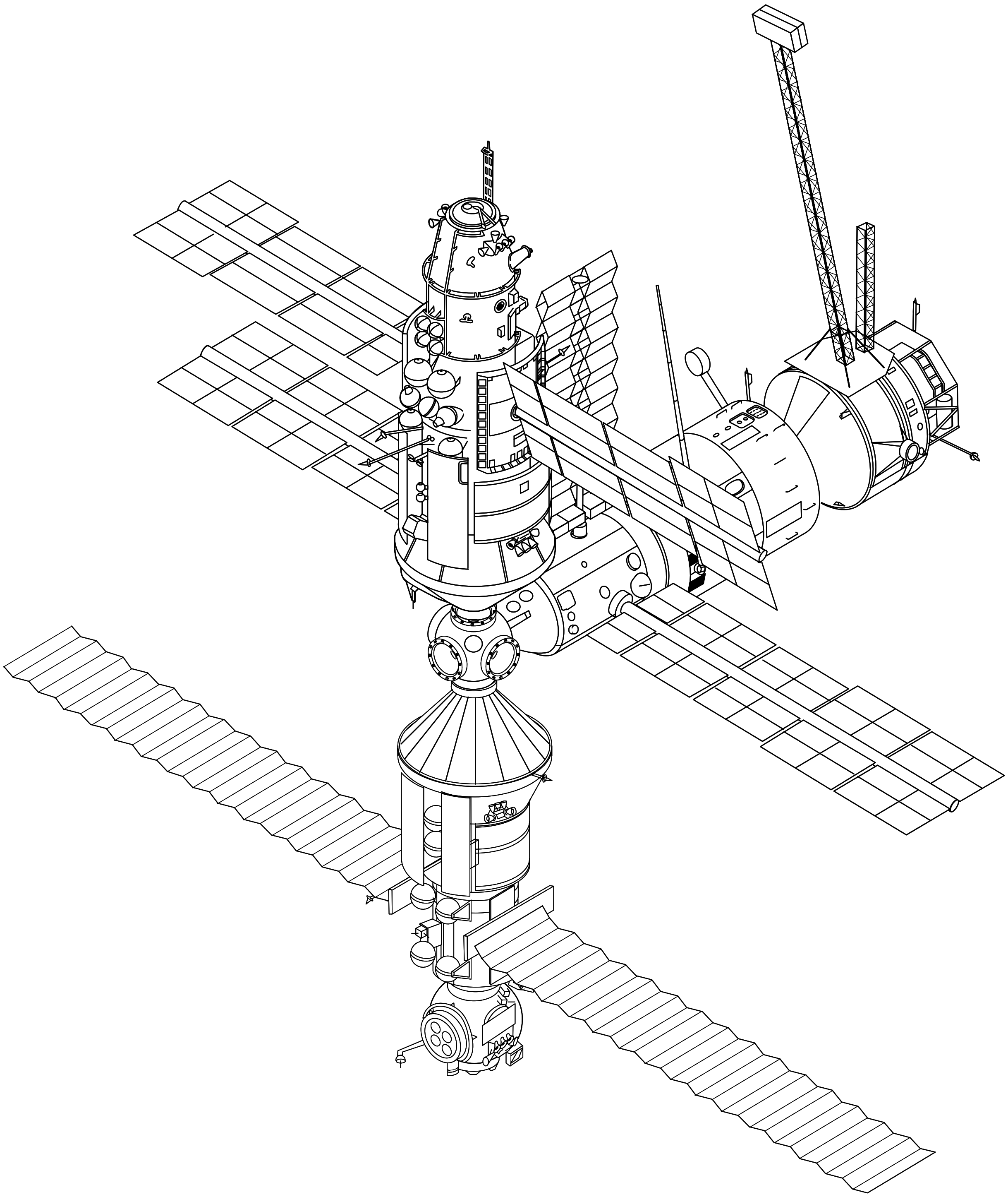
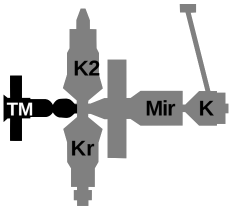
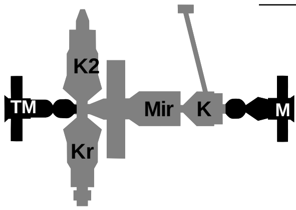


Figure 2-17. Mir base block, Kvant, Kvant 2, and Kristall (1994). Note the Sofora boom and VDU and the Rapana girder attached to the top of Kvant, the Strela boom attached to the side of the base block, and the support on the side of the Kvant module. A matching support is attached to Kvant's other side, out of view. Eventually Kristall's two solar arrays will be relocated to these supports. Soyuz-TM and Progress spacecraft are omitted for clarity.



March 23-24, 1994

Kvant 2
Soyuz-TM 18 • Mir • Kvant
Kristall

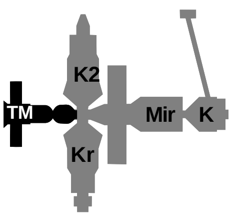


March 24-May 23, 1994

Kvant 2
Soyuz-TM 18 • Mir • Kvant • Progress-M 22
Kristall

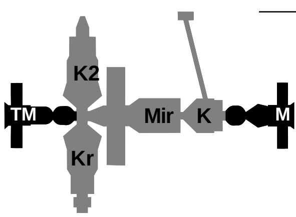
Progress-M 22 delayed. Launch of the thirty-ninth Progress mission to Mir was delayed to March 22 from March 19 by heavy snowfall at Baikonur Cosmodrome. The rails used to transport Progress-M 22 to its launch pad were covered in snowdrifts up to 7 m deep, so the spacecraft and booster could not be moved from their assembly building.

Mir/Freja electron beam tests. The week of March 28, Mir cosmonauts fired an electron beam gun at the Swedish Freja plasma and magnetospheric physics satellite to study space plasmas and Earth's magnetosphere. At the time Mir was 383 km above the Pacific, south of Alaska, while the 214-kg Freja satellite was 1770 km above the southeast Alaskan coast. A Canadian ground station monitored the test, which resembled one conducted on the STS-45 Space Shuttle mission (March 24-April 2, 1992).



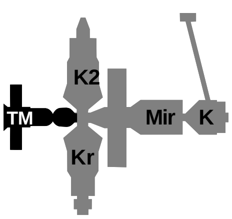
May 23-24, 1994

Kvant 2
Soyuz-TM 18 • Mir • Kvant
Kristall



May 24-July 2, 1994

Kvant 2
Soyuz-TM 18 • Mir • Kvant • Progress-M 23
Kristall



July 2-3, 1994

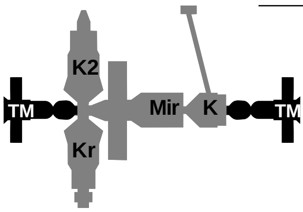
Kvant 2
Soyuz-TM 18 • Mir • Kvant
Kristall

For Icon Key, see page 76

2.9.3.17 Mir Principal Expedition 16

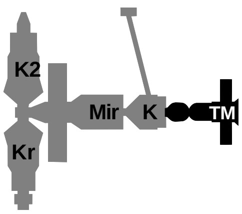
Yuri Malenchenko, Talgat Musabayev, Valeri Polyakov
Crew code name—Agat
Soyuz-TM 19, July 1-November 4, 1994

Valeri Polyakov arrived on Mir with the Principal Expedition 15 crew. He is scheduled to return to Earth with the Principal Expedition 17 crew in Soyuz-TM 20 in March 1995.



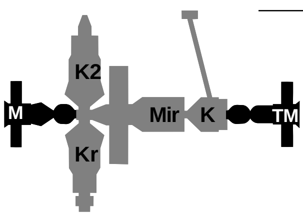
July 3-9, 1994

Kvant 2
Soyuz-TM 18 • Mir • Kvant • Soyuz-TM 19
Kristall



July 9-September 2, 1994

Kvant 2
Mir • Kvant • Soyuz-TM 19
Kristall



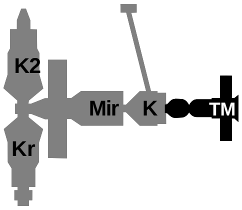
September 2-October 4, 1994

Kvant 2
Progress-M 24 • Mir • Kvant • Soyuz-TM 19
Kristall

Progress-M 24 problems. Progress-M 24's first automatic docking attempt failed on August 27. During the second attempt, on August 30, Progress-M 24 bumped into Mir's forward longitudinal port two to four times at low speed, then drifted away. The Agat crew was running low on supplies, so the Russians gave consideration to mothballing Mir in late September in the event Progress-M 24 could not dock. Ground controllers stated that the station had sufficient propellant to operate in unmanned mode for 4 months. On September 2 Malenchenko took manual control of Progress-M 24 using a control panel on Mir. A TV on Mir displayed an image of the station's front port transmitted from cameras on Progress-M 24; the same image appeared on screens in the TsUP. In an impressive demonstration of remote piloting, Malenchenko docked Progress-M 24 without additional incident. The technique had been tested using Progress-M 15 and Progress-M 16 during Principal Expedition 13 (1993). For additional details, see 1.11.3.

First EVA—many tasks. Malenchenko and Musabayev opened the Kvant 2 EVA airlock outer hatch on September 9 to begin humanity's 100th spacewalk. During the spacewalk, which lasted 5 hr, 4 min, they inspected the docking port struck by Progress-M 24—it proved to be undamaged—and mended a thermal blanket torn when Soyuz-TM 17 struck the station on January 14. They also prepared equipment for moving the Kristall solar arrays to Kvant, and affixed test materials to Mir's exterior.

Second EVA—solar array transfer preparations. On September 14 cosmonauts Musabayev and Malenchenko carried out assembly work connected with the ongoing effort to move Kristall's solar arrays to supports on Kvant. They also inspected the Sofora girder. The EVA lasted 6 hr, 1 min.



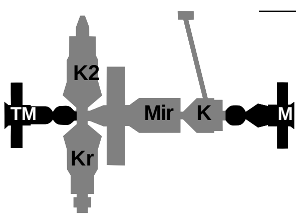
October 4-6, 1994

Kvant 2
Mir • Kvant • Soyuz-TM 19
Kristall

2.9.3.18 Mir Principal Expedition 17

Alexandr Viktorenko, Yelena Kondakova, Valeri Polyakov
Crew code name—Vityaz
Soyuz-TM 20, October 3, 1994-

Polyakov was launched on Soyuz-TM 18 on January 8, 1994. He is scheduled to return to Earth with Viktorenko and Kondakova in March 1995, after more than 420 days in space.



October 6-November 4, 1994

Kvant 2
Soyuz-TM 20 • Mir • Kvant • Soyuz-TM 19
Kristall

Euromir 94 begins. Viktorenko was on his fourth visit to Mir. During final approach, Soyuz-TM 20 yawed unexpectedly. He assumed manual control and completed docking without incident. Kondakova, the mission rookie, was the third Russian female cosmonaut and the first female to take part in a long-duration flight. They were accompanied by ESA astronaut Ulf Merbold, a physicist and veteran of two U.S. Space Shuttle missions. The month-long Euromir 94 experiment program was considered a precursor to the ESA Columbus module planned for the joint U.S.-Russia-ESA-Japan-Canada space station. Merbold's program was planned rapidly, final agreement between ESA and Russian having been concluded in November 1992. It was also constrained by funding limitations—ESA budgeted only about $60 million for Euromir 94. Because of these limitations, Merbold relied heavily on equipment left on Mir by earlier French, Austrian, and German visitors to the station, as well as the Czech-built CSK-1 materials processing furnace. He also used equipment delivered by Progress-M 24 and Soyuz-TM 20. Merbold's experiment program included 23 life sciences, 4 materials sciences, and 3 technology experiments. The mission is to be followed by the 135-day Euromir 95 mission, scheduled to start in August 1995.

Power shortage and materials processing furnace problems. On October 11 the six cosmonauts aboard Mir were unable to activate a video camera and TV lights while recharging Soyuz-TM 20's batteries. A short circuit had disabled the computer which guided Mir's solar arrays, forcing the station to drain its batteries. The cosmonauts used reaction control thrusters on the Soyuz-TM spacecraft docked to the station to orient it so its solar arrays would point toward the Sun, and switched on a backup computer. Normal conditions

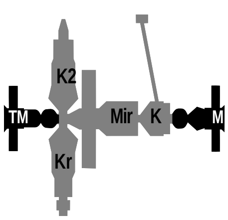
For Icon Key, see page 76

were restored by October 15. According to Yuri Antoshechkin, Deputy Flight Director for Mir Systems, speaking in December at JSC, the shortage afflicted only the Mir core module. Antoshechkin stated through an interpreter that unspecified minor crew error, coupled with a long period out of contact with monitors in the TsUP (caused by Altair/SR relay satellite "prophylactic work") during a crew sleep period, contributed to the base block discharging its batteries unnoticed, and that an automatic alarm awakened the crew when the power shortage reached a critical level.[143] Ground teams rescheduled Merbold's experiments to allow completion of those interrupted by the power problems, and moved experiments using large amounts of electricity to the end of Merbold's stay. In addition, the Czech-built CSK-1 furnace malfunctioned, forcing postponement of five of Merbold's experiments until after his return to Earth.

Testing Mir's Kurs System. On November 3 Malenchenko, Musabayev, and Merbold undocked in Soyuz-TM 19 and withdrew to a distance of 190 m. They then activated its Kurs system, which successfully guided the spacecraft to an automatic docking with Mir's aft port. The cosmonauts then went back into Mir. The test was a response to the Progress-M 24 docking problems. If it had failed, the Soyuz-TM 19 cosmonauts would have made an emergency return to Earth.

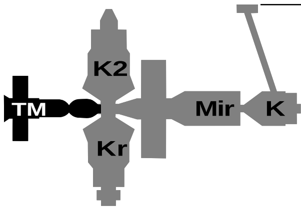
Two European space travelers. The Space Shuttle Atlantis lifted off from Kennedy Space Center on an 11-day atmospheric research mission on November 3. French astronaut Jean-Francois Clervoy was aboard as a mission specialist. In remarks made after Atlantis' launch, ESA Director-General Jean-Marie Luton stated that there was "a French astronaut flying on an American Space Shuttle to perform experiments from U.S., French, German, and Belgian scientists....Meanwhile, on Russia's Mir space station, ESA astronaut Ulf Merbold is completing a month-long mission, the longest in European spaceflight. By the end of the decade, this level of cooperation will be routine aboard the international space station."[144]

Euromir 94 ends. On November 4 Merbold again squeezed into the Soyuz-TM 19 descent module, this time with 16 kg of the life sciences samples he collected during his stay on the station. Additional samples—including materials processing samples to be produced when the Principal Expedition 17 cosmonauts carry out the experiments Merbold was to have conducted during his stay—may be returned to Earth by Space Shuttle Atlantis in mid-1995. Soyuz-TM 19 undocking, deorbit burn, reentry, and landing occurred without significant incident.



November 4-13, 1994

Kvant 2
Soyuz-TM 20 • Mir • Kvant
Kristall



November 13-

Kvant 2
Soyuz-TM 20 • Mir • Kvant • Progress-M 25
Kristall

Progress-M 25 arrives. Viktorenko stood by at the remote control panel on Mir during approach, but manual intervention was unnecessary. Polyakov, veteran of the Progress-M 24 problems, called Progress-M 25 “an ideal freighter.” Among other cargoes, Progress-M 25 delivered replacement parts for the failed CSK-1 materials processing furnace.[145]

50,000 orbits. On November 18 the Mir base block completed its 50,000th orbit of the Earth, having covered about 1.9 billion km since launch on February 20, 1986.[146]

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122. Neville Kidger, "Cosmonauts Fly Their Space Motorcycle," *Spaceflight*, July 1990, p. 232.

123. *Spaceflight* interview with Solovyov and Balandin, pp. 11-13.

124. *Spaceflight* interview with Solovyov and Balandin, p. 13.

125. Neville Kidger, "Progress-M 7 – Catastrophe Avoided," *Spaceflight*, June 1991, p. 192.

126. Interview, David S. F. Portree with Sergei Krikalev, February 28, 1994.

127. Neville Kidger, "Helen's 8-day Mission," *Spaceflight*, July 1991, pp. 226-227.

128. Interview, David S. F. Portree with Sergei Krikalev, February 28, 1994.

129. Neville Kidger, "Austrian Mission Follows Failed Coup," *Spaceflight*, January 1992, p. 12.

130. Portree and Loftus, p. 76.

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132. Mikhail Arkhipov, "Flights When One is Asleep and When One is Awake," *Rossiya*, No. 20, May 13-19, 1992, p. 11. Translated in *JPRS Report, Science & Technology, Central Eurasia: Space*, November 17, 1992 (JPRS-USP-92-006), p. 26.

133. Portree and Loftus, p. 89.

134. "Cosmonauts Determine Dynamic Parameters of Space Complex," ITAR-TASS news release in English, January 28, 1993. In *JPRS Report, Science & Technology, Central Eurasia: Space*, March 25, 1993, (JPRS-USP-93-001), p. 4.

135. "TV Reports Cosmonauts' Landing, Comments on Future Flights," *JPRS Report, Science & Technology, Central Eurasia: Space*, March 25, 1993 (JPRS-USP-93-001), p. 4. Translated transcript of Novosti TV newscast by Pyotr Orlov and Vladimir Avdeyev, 1800 GMT February 1, 1993.

136. Sergei Leskov, "Gigantic Mirror in Orbit," *Izvestiya*, February 5, 1993, p. 2. Translated in *JPRS Report, Science & Technology, Central Eurasia: Space*, March 25, 1993 (JPRS-USP-93-001), p.

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138. Valeri Baberdin, "The Siriuses: We Were in Orbit with You," *Krasnaya Zvezda*, February 26, 1994, p. 3. Interview with Tsibliyev and Serebrov translated in *JPRS Report, Science & Technology, Central Eurasia: Space*, May 16, 1994 (JPRS-USP-94-004), pp. 1-4.

139. Donald Kessler, personal communication.

140. Baberdin, pp. 2-3.

141. Vadim Chernobrov, "Collision in Space," *Rossiskiye Vesti*, January 21, 1994, p. 9. Translated in JPRS Report, March 22, 1994 (JPRS-USP-94-003), pp. 1-2.

142. M. Chernyshev, "Details: Was the Incident in Space an Accident? Awards were Given Before the State Commission Drew Its Conclusions," *Segodnya*, January 26, 1994, p. 1. Translated in *JPRS Report, Science & Technology, Central Eurasia: Space* (JPRS-USP-94-003), p. 2.

143. Shuttle/Mir Media Workshop, Mir Familiarization session, NASA Johnson Space Center, December 14, 1994.

144. "STS-66/ATLAS-3 Mission Status Report," Status Report #1, ESA Press Office, Thursday, November 2. 1994.

145. MIRNEWS #239, e-mail report based on monitoring of Mir transmissions, Chris Vandenberg, November 13, 1994 (forwarded by James Oberg, November 21, 1994).

146. Vandenberg.

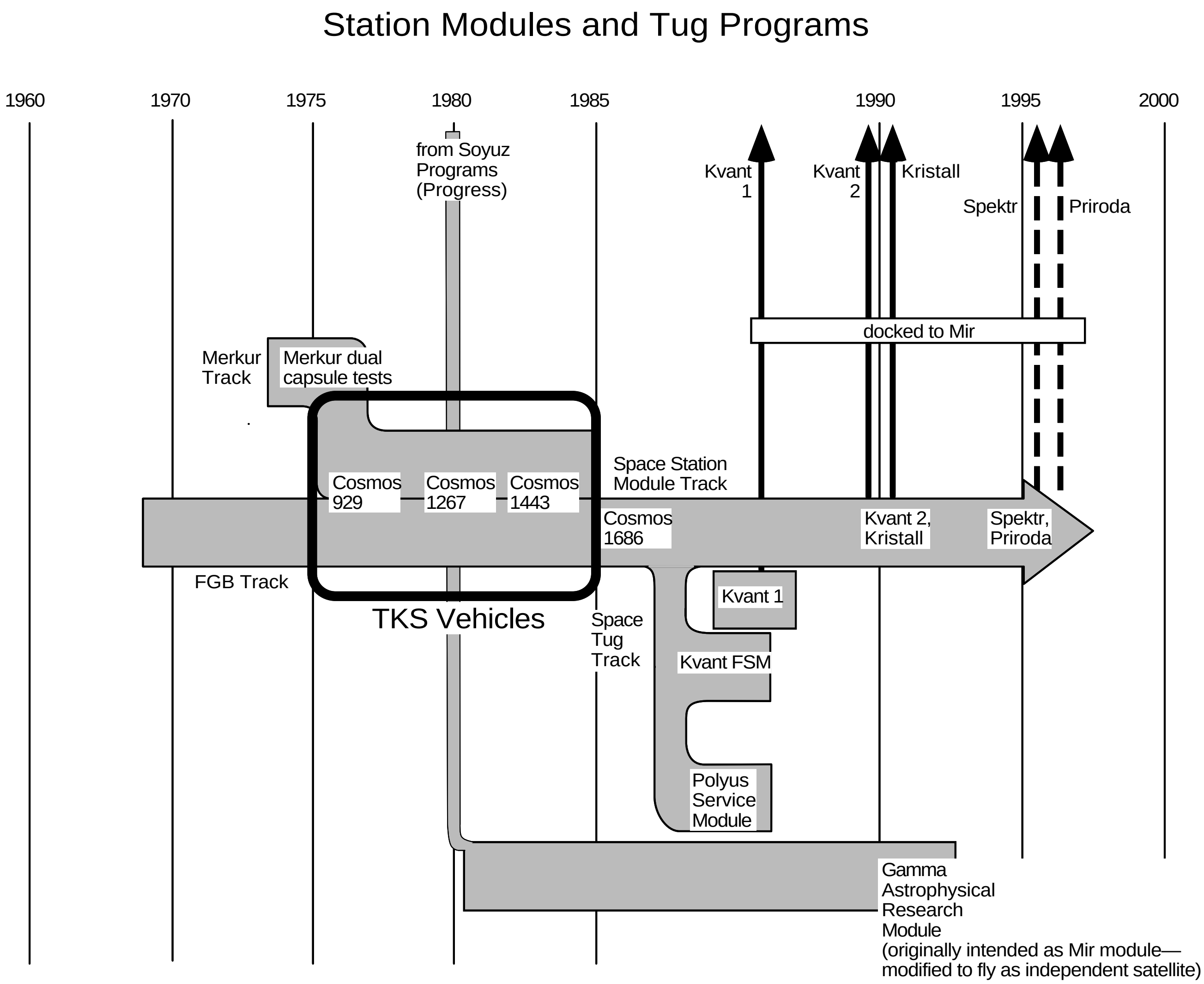

Figure 3-1. Station modules and tugs evolution. The chart above summarizes the evolution of vehicles originally developed as transport craft for the Almaz space station program and subsequently reapplied to many new functions. The narrow light gray arrow coming down from the top leads from the Soyuz Programs chart (figure 1-1). The broad gray arrows trace what is generally known in the West about the evolution of Soviet/Russian space station modules and tugs. The black-lined box encloses the TKS program, and the black arrows (solid and dashed) lead to the Station Programs chart (figure 2-1).

Part 3
Space Station Modules

3.1 General Description

The heritage of the space station modules joined to Mir is convoluted (figure 3-1). In all cases, however, they are based on a "universal block," a vehicle referred to by the Russian acronym FGB (figure 3-2).

For our purposes, we can group FGB-based vehicles into three categories:

- Transport Logistics Spacecraft (Russian acronym TKS) (1976-1983)
- Space station modules (1985-present)
- Space tugs (1987-present)

All these categories have in common the following "predesigned systems."[1, 2]

- Basic FGB structure, including pressurized volume
- Rendezvous and docking systems
- ΔV engines
- Thrusters and attitude control systems
- Propellant tanks
- Power systems
- Guidance and control systems
- Thermal control systems

To form the vehicles in the different categories, the common predesigned systems are grouped or modified in various ways.[3,4] Modifications are made in

- Location of engines
- Number and size of propellant tanks–up to 16 tanks may be added
- Electric power system capacity–expandable to 7.5 kW, with nominal consumption of 3 kW
- Solar array configuration (if arrays are used)
- Internal layout of the FGB
- Volume of the FGB pressurized compartment
- Configuration of the modules added to the FGB "aft" section

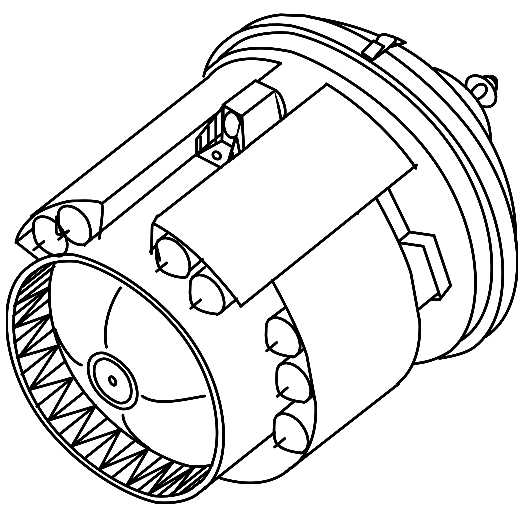

Figure 3-2. FGB. This is a simplified aft view of the propulsion/cargo module used in the TKS vehicles and as the basis for subsequent space station modules and tugs. Aft (left) details are conjectural. Solar arrays are omitted for clarity.

In many cases, these spacecraft performed multiple functions; for example, the Cosmos 1443 TKS served as a tug, boosting the orbit of the Salyut 7 station, delivered cargo, and was also identified as a space station module.

3.2 Detailed Overview (1962-Present)

3.2.1 The Beginning of Soviet Multimodular Space Stations (1962-1964)

While primarily concerned with circumlunar flight, the prospectus "Complex for the Assembly of Space Vehicles in Artificial Satellite Orbit (the Soyuz)" also included reference to a space station assembled from independently-launched modules. The prospectus was the product of Special Design Bureau-1 (Russian acronym OKB-1), which today is called RKK Energia (until recently, NPO Energia). The document was approved by OKB-1's director, Sergei Korolev, on March 10, 1962. However, OKB-1 rapidly became preoccupied with the Soyuz vehicles it was developing for the Soviet lunar program. It fell to V. N. Chelomei's OKB-52 organization (today called NPO Mashinostro-yeniye) to start building the first Soviet space stations. On October 12, 1964, OKB-52 began development of a space station system called Almaz ("diamond"). When approved in 1967, Almaz comprised the single-launch Almaz space station with crew capsule; the TKS (figure 3-3) which supplied the station, delivered its crews, and provided them with living quarters; and the Proton booster for launching both Almaz station and TKS.

Development of the crew capsule, sometimes called Merkur ("Mercury") (figure 3-4) was coordinated

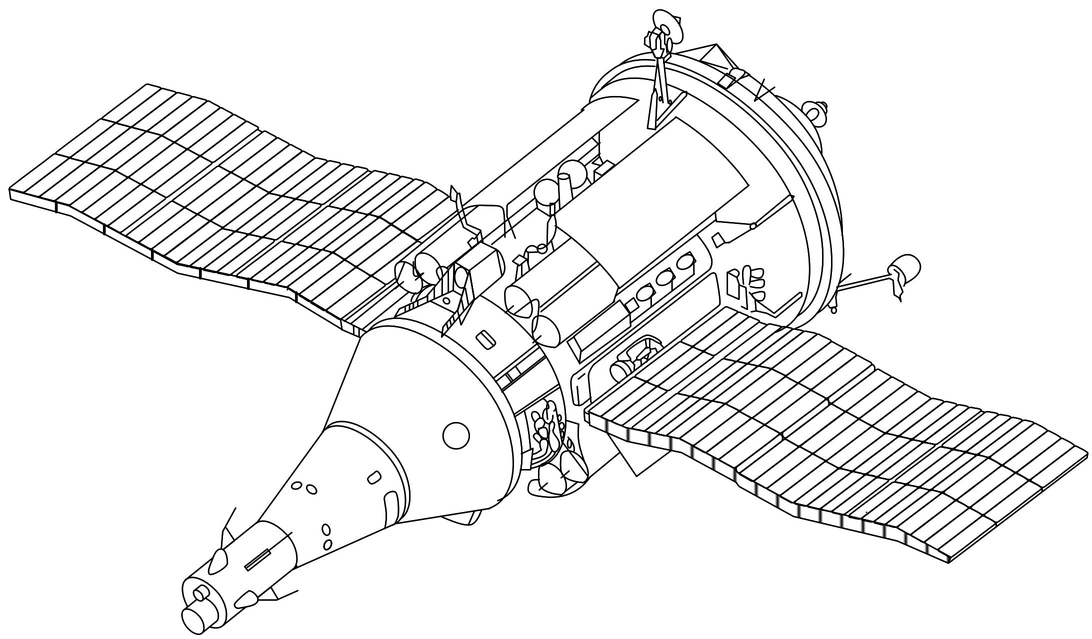

Figure 3-3. TKS. The FGB and Merkur vehicles were joined together aft end to aft end to form a TKS; thus, this is a front view of the conical Merkur capsule (left), and an aft view of the FGB (right).

by the main OKB-52 organization. OKB-52's Branch No. 1 (ancestor of the KB Salyut organization) was charged with developing the FGB component of the TKS. The station, spacecraft, and launcher would all be built at the Krunichev Machine Building Plant. This was the same plant which built much OKB-1 hardware.[5, 6]

3.2.2 TKS (1970-1978)

In February 1970, the Soviet Ministry of Machine Building ordered transfer of all completed Almaz hardware from the Chelomei bureau to the Korolev bureau. In cooperation with OKB-52 Branch No. 1, Korolev's bureau was able to build the first Long-Duration Orbital Station (DOS-1) within a year of the transfer. This marriage of Korolev Soyuz and Chelomei Almaz hardware was dubbed Salyut 1. It was launched on a three-stage Proton in April 1971.

Chelomei's bureau continued work on Almaz and the TKS. In December 1976, two TKS Merkur capsules were launched atop a Proton booster under the moniker Cosmos 881-882. This, and three additional dual capsule flights, were long misinterpreted as tests of subscale lifting bodies as part of the Soviet shuttle effort. The first complete TKS (a Merkur and an FGB), Cosmos 929, reached orbit unmanned in July 1977. Its Merkur capsule was successfully recovered in August 1977, and the FGB orbited until February 1978.

About 1980, the Soviet government decided to concentrate all manned

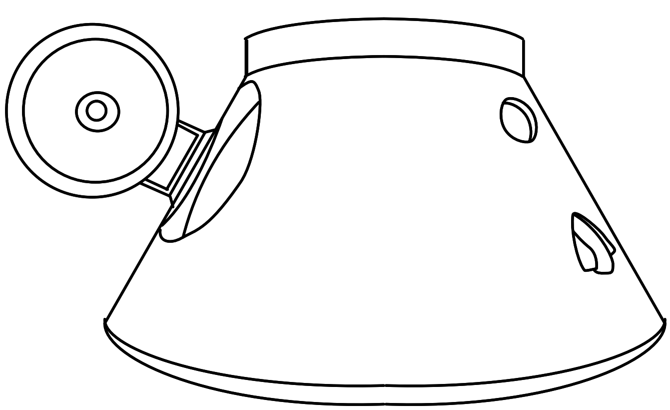

Figure 3-4. Merkur capsule.

spaceflight activity at NPO Energia. One Soviet source states that Soviet Defense Minister Dmitri Ustinov "wound down" the TKS program by 1982, an assertion which seems to match the schedule of the final two TKS test flights.[7] Cosmos 1267's Merkur capsule reentered on May 24, 1981. Its FGB docked with the unmanned Salyut 6 station on June 19, 1981. Cosmos 1443 docked with the unmanned Salyut 7 station in March 1983. The Soviets idenified it as a cargo transport. The Salyut 7 Principal Expedition 2 crew unloaded cargo from Cosmos 1443 in July-August 1983. By this time NPO Energia's efforts to reapply the Mashinostroyeniye TKS designs to its DOS multimodular station program were well advanced.

3.2.3 Space Station Modules (1985-Present)

Cosmos 1686 was a transitional vehicle reflecting the decision to convert the 20-ton TKS vehicles into space station modules. It had an FGB very similar to the ones used in the Cosmos 929, Cosmos 1267, and Cosmos 1443 TKS vehicles. However, its Merkur capsule was heavily modified to house scientific instruments and remained attached to the FGB throughout its flight. Cosmos 1686 delivered 4500 kg of cargo to Salyut 7 on October 2, 1985, though this cannot be taken as evidence that it was primarily a cargo TKS, like Cosmos 1443; the Mir space station modules Kvant, Kvant 2, and Kristall all delivered cargo as well. At the time of its launch, Soviet sources stated that it had no Merkur capsule, though later Russian sources stated that it had a capsule not designed to return to Earth, which was to have been detached manually by the Chegets in January 1986.[8] Cosmos 1686 was left attached to Salyut 7 in a long-duration test of critical systems after the last crew left the station (1986). Cosmos 1686 underwent uncontrolled reentry with Salyut 7 in February 1991.

The decision to adapt TKS hardware to serve the multimodular space station program affected Mir, the first multimodular station. It was originally meant to receive 7-ton modules based on the Progress design at its lateral ports. Such modules appeared often in Soviet conceptual artwork depicting multimodular stations. The first Progress-based station module was to have been the Gamma astrophysical research module. In the event, it flew as an independent unmanned satellite.[9] Its main instrument was the Gamma-1 gamma-ray telescope. The docking unit which would have joined it to Mir was replaced in the flown version by a small compartment holding two additional telescopes.[10]

Kvant docked at Mir's aft port on March 31, 1987. It was delivered to Mir by a detachable FGB-based space tug. It was not itself based on the FGB or TKS. It was originally intended to dock with Salyut 7.[11]

Kvant 2 docked with Mir in November 1989. Kvant 2 was built around an FGB. Kristall, another FGB-based module, docked with Mir in June 1990.

3.2.4 Space Tugs (1987-Present)

In 1974, on the day the Soyuz 14 crew returned from their stay on Salyut 3, Academician Boris Petrov described space tugs in an interview with the newspaper *Izvestia*. He stated that space tugs would be ground-controlled vehicles capable of searching for, capturing, and propelling space station modules. They would be used to bring together modules independently placed in orbit, thereby assembling large space station complexes.[12]

The Functional Service Module (FSM) tug which delivered the Kvant module to Mir in April 1987 was a simplified FGB. It was launched docked to the module's aft port. The FSM detached after delivering Kvant to Mir's aft port.

In May 1987, the first Energia heavy-lift launch vehicle carried the 80-ton Polyus space platform. A modified FGB tug was integral to Polyus, providing it with attitude control and orbit maintenance propulsion. It was also meant to complete orbital insertion for Polyus, but attitude control failure thwarted the orbital insertion maneuver. Polyus fell into the Pacific Ocean.[13]

3.3 TKS (1976-1983)

3.3.1 TKS Specifications

Launch weight	about 19,000 kg
Length	17.51 m
Diameter	4.15 m
Span across solar arrays	16 m
Number of main engines	2
Main engine thrust (each)	400 kg
Habitable volume	about 60 m^3
Number of crew	3*
Capsule diameter	305 cm
Capsule height	206 cm

*Never launched carrying a crew.

3.3.2 TKS Notable Features

- Launched on a three-stage Proton launch vehicle.
- Had a unique configuration (figure 3-5). It can be thought of as two spacecraft (Merkur and FGB) joined aft to aft (figure 3-3). The Merkur capsule (figure 3-4), which up until reentry had a long, slender nose containing the capsule's propulsion system, was attached by its aft end (heat shield) to the aft end of the FGB (figure 3-2). The forward end of the FGB was the broad, conical end with its probe docking unit. At launch the forward end of the FGB was pointed down, toward the top of the Proton booster. This put the nose of the Merkur capsule at the top.
- Couches for three cosmonauts in the conical Merkur capsule.
- A hatch through the capsule's heat shield led through a tunnel into the FGB pressurized compartment. The hatch was reached from Merkur by removing the center couch.
- Capsule propulsion systems in module attached to the nose of the capsule. This permitted maneuvering in orbit independent of the FGB, and was also used for deorbit burns. It was discarded after completing the deorbit burn.
- Parachute module attached to the nose of the Merkur capsule.
- Capsule was designed to be reusable; its heat shield did not ablate during reentry.

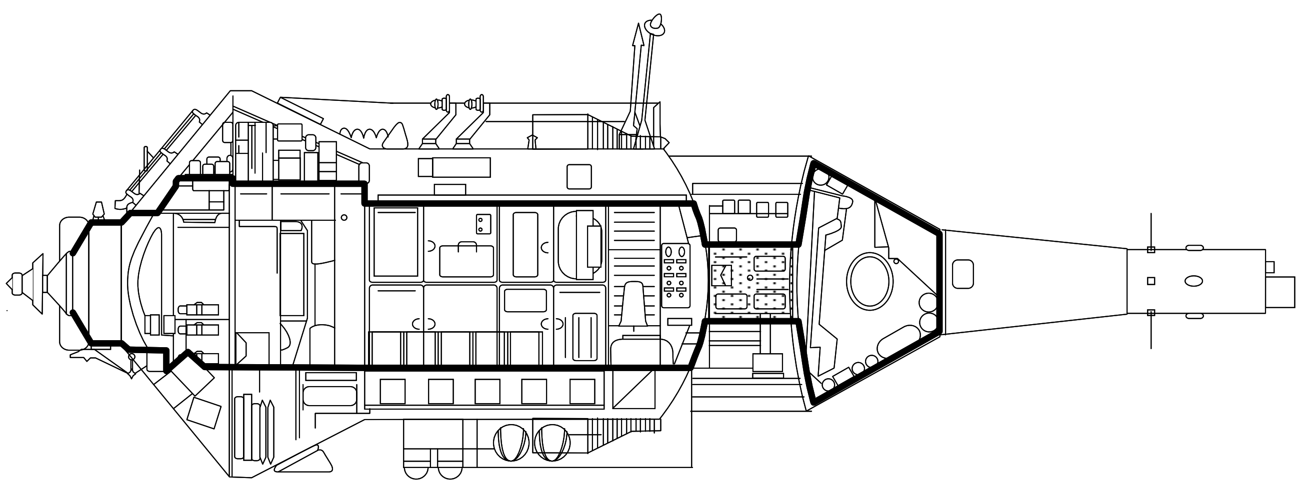

Figure 3-5. Cutaway of TKS vehicle. Details are conjectural. The broad black line outlines the vehicle's pressurized compartments. A tunnel (stippled) connects the FGB and Merkur capsule.

- During approach to a space station, cosmonauts piloted the TKS from a control post at the front of the FGB. The control post had a viewport overlooking the probe docking apparatus.
- FGB and capsule could be controlled independently from the ground. The capsule could detach from the FGB and return to Earth, leaving it in free flight or attached to a station. The FGB could be docked by ground control with a space station.
- TKS or FGB could remain docked to a station for months, providing it with attitude control, orbital maintenance, additional volume, and power from its solar arrays.

3.3.4 TKS Missions

Cosmos 881-882 December 15, 1976

For many years this and the other dual Cosmos flights were interpreted in the West as tests of pairs of small spaceplanes in support of the Soviet space shuttle program. In fact, they were tests of pairs of Merkur capsules. The capsules were stacked together atop a Proton rocket. Cosmos 881 reached a 198 km by 233 km orbit at 51.6° of inclination. Cosmos 882 reached a 189 km by 213 km orbit at the same inclination.

Cosmos 929 July 17, 1977-February 2, 1978

Tested the capsule and FGB together in space for the first time. Components of the FGB had already been tested on Salyuts 2, 3, and 5. The spacecraft made several small maneuvers in its first 30 days of operation. It may have simulated docking with a point in space. The capsule separated on August 18 and landed in central Asia. The FGB then carried out more maneuvers in orbit. Cosmos 929 was intentionally deorbited over the Pacific Ocean.

Launch failure August 4, 1977

The launch escape system rescued the top Merkur capsule for reuse after its Proton booster malfunctioned. The bottom capsule was destroyed.

Cosmos 997-998 March 30, 1978

Dual test of Merkur capsules.

Cosmos 1100-1101 May 22-23, 1979

Dual test of Merkur capsules.

Cosmos 1267 April 25, 1981-July 29, 1982

The spacecraft maintained a low orbit to permit study of its atmospheric drag characteristics, until Salyut 6's last crew (Salyut 6 Principal Expedition 6) returned to Earth. U.S. military sources claimed that the side-mounted propellant tanks were infrared homing antisatellite missiles. The capsule detached and landed on May 24. The FGB then docked with Salyut 6 on June 19. Cosmos 1267 boosted the orbit of Salyut 6 twice, then deorbited it over the Pacific.

Cosmos 1443 March 2-September 19, 1983

The Soviets called the Cosmos 1443 TKS a freighter module. On March 10 it docked with the forward port of the vacant Salyut 7 station. It carried 3600 kg of cargo. Soyuz T-9 docked with the Cosmos 1443-Salyut 7 complex on June 28. The cosmonauts began unloading Cosmos 1443 on June 30. In early August, the cosmonauts loaded the Merkur capsule with 317-350 kg of return cargo. Cosmos 1443 undocked from Salyut 7 on August 14. It had completed over 100 orbit adjustments and attitude changes for Salyut 7. The capsule landed on August 18, and the tug continued to orbit for another month before the Soviets commanded it to make a destructive reentry. In December 1993, Sotheby's of New York sold the Cosmos 1443 Merkur capsule to an anonymous American collector for $552,500.

3.4 Cosmos 1686

Salyut 7 module—Transitional vehicle (TKS to space station module)
October 2, 1985-February 7, 1991

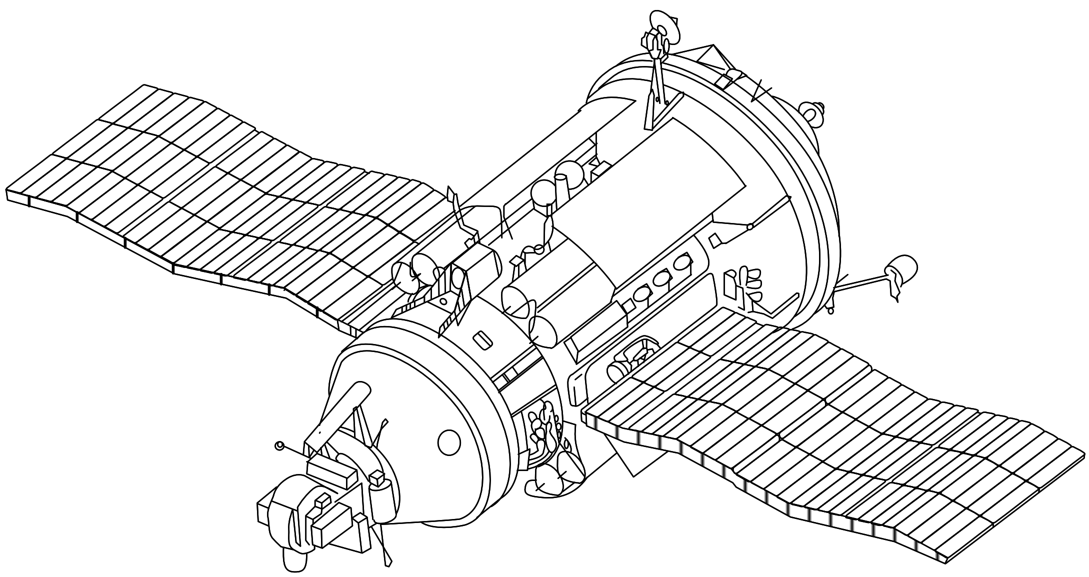

Figure 3-6. Cosmos 1686. Note the Merkur capsule (left), heavily modified to house scientific instruments.

3.4.1 Cosmos 1686 Specifications

Launch weight	about 20,000 kg
Length	15 m
Span across solar arrays	16 m
Maximum diameter	4.15 m
Propellant mass at launch	3000 kg

3.4.2 Cosmos 1686 Notable Features

- Closely resembled the TKS vehicles (figure 3-6).
- Merkur capsule was greatly modified to carry instruments. Basically, the retrorocket and parachute packages were replaced by scientific equipment, including an infrared telescope and the Ozon spectrometer.
- Tested systems planned for use on the Mir station base block.
- Docked with Salyut 7 on October 2, 1985, during the long-duration stay of the cosmonauts of its fifth Principal Expedition (the Cheget crew, which arrived on Soyuz-T 14).
- Salyut 7/Cosmos 1686 complex (figure 3-7) massed 43 tons. Cosmos 1686 delivered 4500 kg of cargo, and nearly doubled the volume available to the Chegets. Unfortunately, they were little able to use the supplies and experimental apparatus or the room because of Vasyutin's illness.
- On August 19-22, 1986, ground controllers boosted the vacant Salyut 7-Cosmos 1686 complex to a 474 km by 492 km orbit using engines on Cosmos 1686. This reduced the propellant supply of the complex to 70 kg (about 500 kg were required for controlled deorbit). In addition, Cosmos 1686 and Salyut 7 each suffered major systems breakdowns soon after they were abandoned, making the complex impossible to control.
- All previous space stations over which the Soviets maintained control were intentionally deorbited after their last cosmonaut crew departed. The Soviets estimated that the reboost gave the complex an 8-yr lifetime in orbit. They considered recovering the station using the Buran shuttle.
- Cosmos 1686 underwent uncontrolled reentry with Salyut 7 on February 11, 1991.

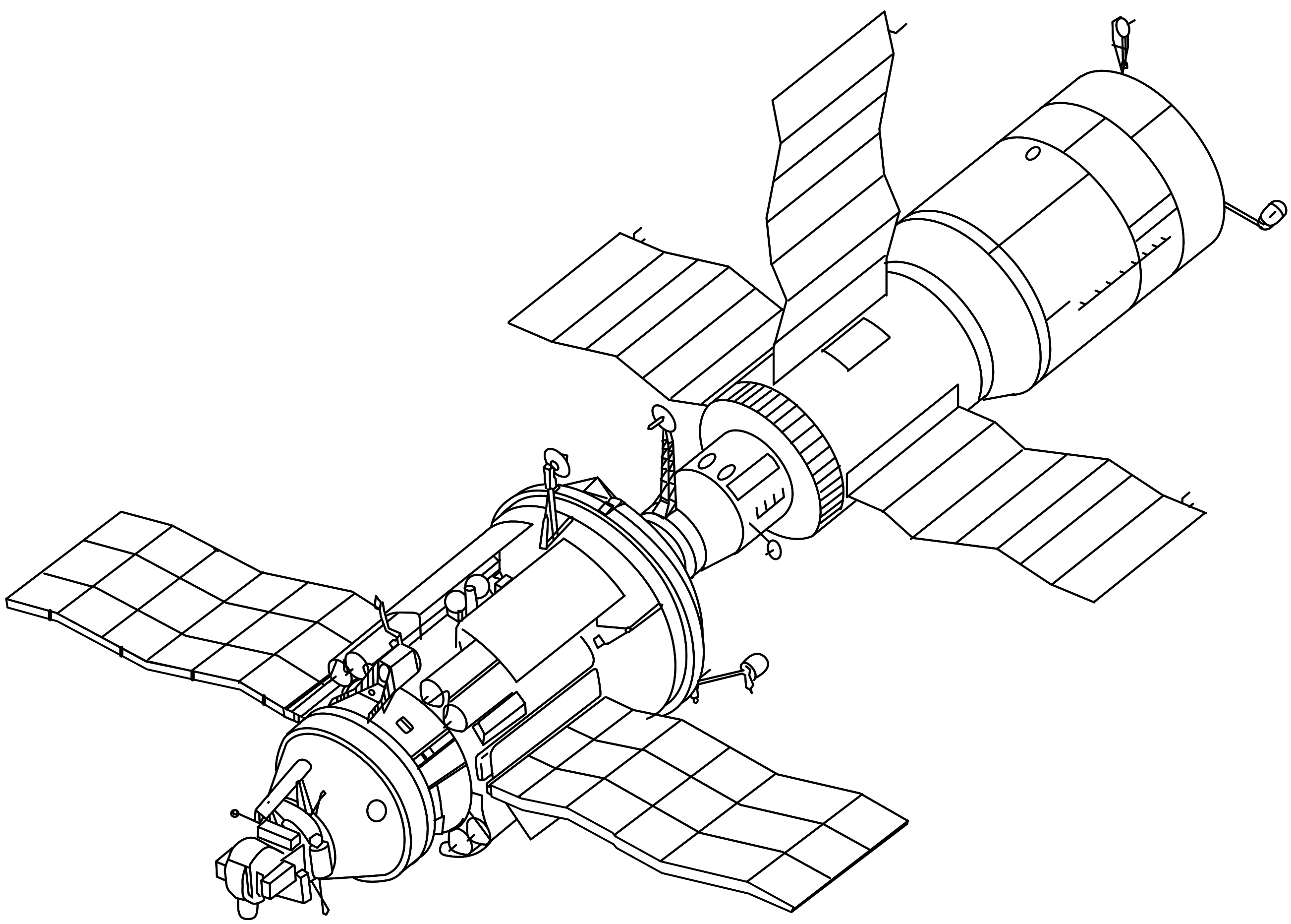

Figure 3-7. Cosmos 1686 and Salyut 7.

3.5 Kvant

Mir module—astrophysics and
attitude control
March 31, 1987-present

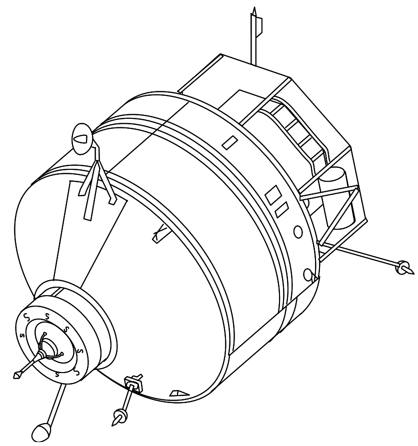

Figure 3-8. Kvant module.

3.5.1 Kvant Specifications

Total launch weight .... 20,600 kg
Mir module weight .... 11,000 kg
Functional Service Module (FSM)
weight .... 9,600 kg
Length... 5.8 m
Maximum diameter .... 4.15 m
Habitable volume .... 40 m^3
Anticipated lifetime at launch .... 5 yr

3.5.2 Kvant Notable Features

- Kvant (figure 3-8) was originally designed for use with Salyut 7, but launch was delayed past the endurance of that station.[14]
- Only space station module to dock at the rear port of a Salyut-type space station.
- Two pressurized living and working compartments and an unpressurized (20 cu/m) experiment compartment.
- Absence of an integral propulsion system. Delivered to Mir by FSM tug (figure 3-14).
- Absence of a power generation system. Kvant relies on the Mir base block's solar arrays for electricity. The Kristall module arrays are scheduled to be moved to Kvant in 1994, prior to the docking by Space Shuttle Atlantis with Mir in 1995. EVAs in 1991, 1993, and 1994, prepared the way for the transfer of the Kristall solar arrays to Kvant.
- Plumbing for transferring fuel from a Progress M spacecraft arriving at Kvant's rear port to propellant tanks for attitude thrusters in the Mir base block. Plumbing also transfers other fluids.
- Rear port features Igla and Kurs rendezvous and docking systems. Front port features Igla only; it was used for initial docking with the rear port of the Mir base block. After docking in 1987, the front port Kvant antenna was folded down, its work done.
- Module blocks the main engines at the rear of the Mir base block. Since Kvant docked, all orbital maintenance maneuvers have been carried out by docked spacecraft.
- Six control moment gyros (gyrodynes), with a total mass of 990 kg, which permit extremely accurate pointing of the complex (necessary for astronomical observations). The gyrodynes reduce the amount of attitude control propellant needed by the Mir base block's control thrusters. They do, however, use a great

deal of electricity. The gyrodynes can be reached from inside Kvant's pressurized volume for servicing. Up to the end of 1989, Kvant's gyrodynes saved the complex 15 tons of attitude control propellant.[15] Kvant also augments the complex's attitude control system with two infrared Earth sensors, two star sensors, three star trackers (two of which were added in January 1990), sun sensors, and an optical sight. EVAs in 1991-1992 installed the 14.5-m tall Sofora girder, then topped it with the 700-kg VDU thruster unit, improving Mir's attitude control capability. The VDU is linked to Kvant by control cables, but relies on an internal propellant supply.

- Elektron electrolytic oxygen production unit.
- Equipment for extracting carbon dioxide and harmful trace gases from the station's atmosphere. The system is rated for use by up to three cosmonauts. The filtration system is "renewed in the vacuum of space." Nonrenewable filtration cartridges are used only when more than three cosmonauts reside on Mir (i.e., when a guest crew visits). Operational experience indicates that up to five cosmonauts can rely on the renewable system.
- Scientific gear (800 kg) includes the Roentgen X-ray telescope suite (four instruments) and the Glazar ultraviolet telescope. They were developed in cooperation with the Netherlands, the U.K., ESA, and Germany. The Roentgen suite comprises the Dutch/British TTM wide-angle camera with coded-aperture mask, ESA's Sirene 2 gas-scintillation proportional counter, German HEXE high-energy X-ray experiment, and the Pulsar X-1 high-energy X-ray/gamma ray detector, contributed by the Soviet Union.
- Also carries the Svetlana electrophoresis unit.
- Small airlock permits the cosmonauts to change film in the Glazar telescope from inside Kvant.
- Astronomical instruments can only be aimed by orienting the entire Mir complex.
- Delivered 2500 kg of cargo, including a 22 m^2 solar array for attachment to a fixture atop the Mir base block.
- Equipped with the Sofora beam in 1991, to which the VDU thruster package was attached in 1992. The system is designed to enhance Mir attitude control.

3.6 Kvant 2

Mir module—augmentation of base block's capabilities, EVA airlock
November 26, 1989–present

3.6.1 Kvant 2 Specifications

Launch weight	19,565 kg
Length	13.73 m
Diameter	4.35 m
Habitable volume	61.3 m^3
Span across solar arrays	24 m
Solar array capacity	~7 kW
Anticipated lifetime at launch	3 yr

3.6.2 Kvant 2 Notable Features

- Referred to as D-module (Dushnashcheniye module) or augmentation module prior to launch (figure 3-9).
- First module to be put in place at one of the Mir base block's four lateral ports.
- Three compartments, including specialized EVA airlock compartment, central instrument and cargo compartment, and instrument and experiment compartment.
- Central instrument and cargo compartment can be sealed and depressurized, serving as either an airlock compartment extension or a backup to the EVA airlock compartment.
- Solar arrays of a design similar to those on the Mir base block.
- 1-m EVA hatch, first Soviet spacecraft hatch designed to open outward.
- Kurs rendezvous and docking system for docking with Mir's front port.
- Delivered the Soviet "flying armchair" manned maneuvering unit (Russian acronym YMK) and advanced new Orlan-DMA EVA suits.
- Lyappa arm (figure 3-10) attached to a fixture in the Mir base block's multiport docking node and pivoted Kvant 2 from the front longitudinal port to its assigned lateral port (figure 3-11). Kristall, Priroda, and Spektr also carry the Lyappa arm.
- Delivered the Salyut 5B computer, which was designed to take over from the Argon 16B computer in the Mir base block. Salyut 5B is faster and has more memory than the older computer, and thus is more capable of managing the expanding Mir complex.
- System for regenerating water from urine. The water produced is electrolyzed to produce oxygen in an Elektron system similar to the one on Kvant.
- Shower cabinet for personal hygiene, a metal compartment through which warm air circulates. Water is supplied through a sprayer. A "gas-liquid separator" siphons used shower water to a regenerator, which processes the water for reuse (the latter is part of the dehumidifier system which recycles water from the air). In practice this system has not worked as well as hoped. Water adheres to the user and the sides of the cabinet, making drying and cleanup difficult.
- Rodnik ("spring") water system launched with 300 liters/420 kg of water in external tanks.
- Launched with other cargo, including 600 kg of propellant; 285 kg of food; 28 kg of air; and 200 kg of experimental equipment.
- Scientific equipment includes the Priroda 5 high-resolution camera, MKF-6MA multispectral Earth resources camera, MKS-M2 optical spectrometer on the ASPG-M platform, ITS-7D infrared spectrometer on the ASPG-M platform, ARIS X-ray sensor on the ASPG-M platform, Inkubator-2 unit for hatching and raising Japanese quail, VEP-3 and VEP-4 panels for monitoring

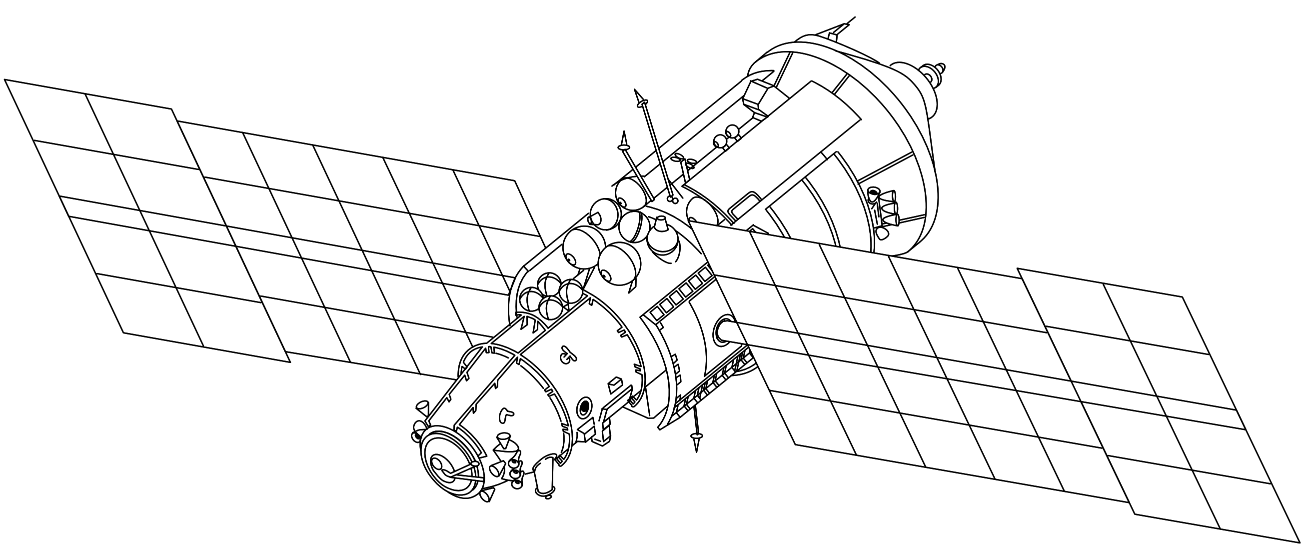

Figure 3-9. Kvant 2 module. Kvant 2 houses an EVA airlock (hatch visible at left).

conditions outside Mir, and Volna 2 fluid flow experiment.

- The Czechoslovak-built ASPG-M independent (stabilized) instrument platform attached to airlock compartment hull can be operated from Earth without disturbing the cosmonauts. The ITS-7D infrared spectrometer, MKS-M2 multispectral spectrometer, and ARIS X-ray sensor are all mounted on the platform, which resembles those carried by the two Vega (Venus-Halley's Comet) probes in 1985-1986. It launched with three television cameras and had room for two more.
- Six additional gyrodynes and 32 attitude control thrusters to augment Mir base block-Kvant attitude control capability.

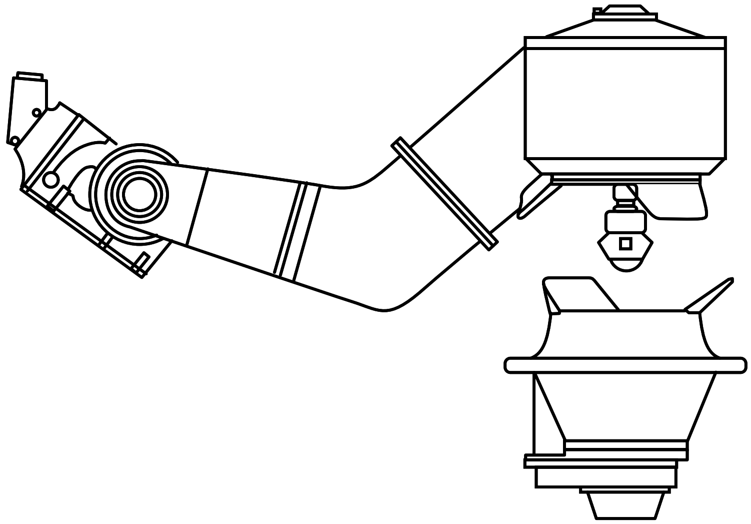

Figure 3-10. Lyappa arm. Modules for Mir's lateral ports first dock at the front longitudinal port. Each module carries a Lyappa arm (top), which attaches to a socket (bottom) on the outside of the Mir multiport node. The arm then pivots the module to the proper lateral berthing port.

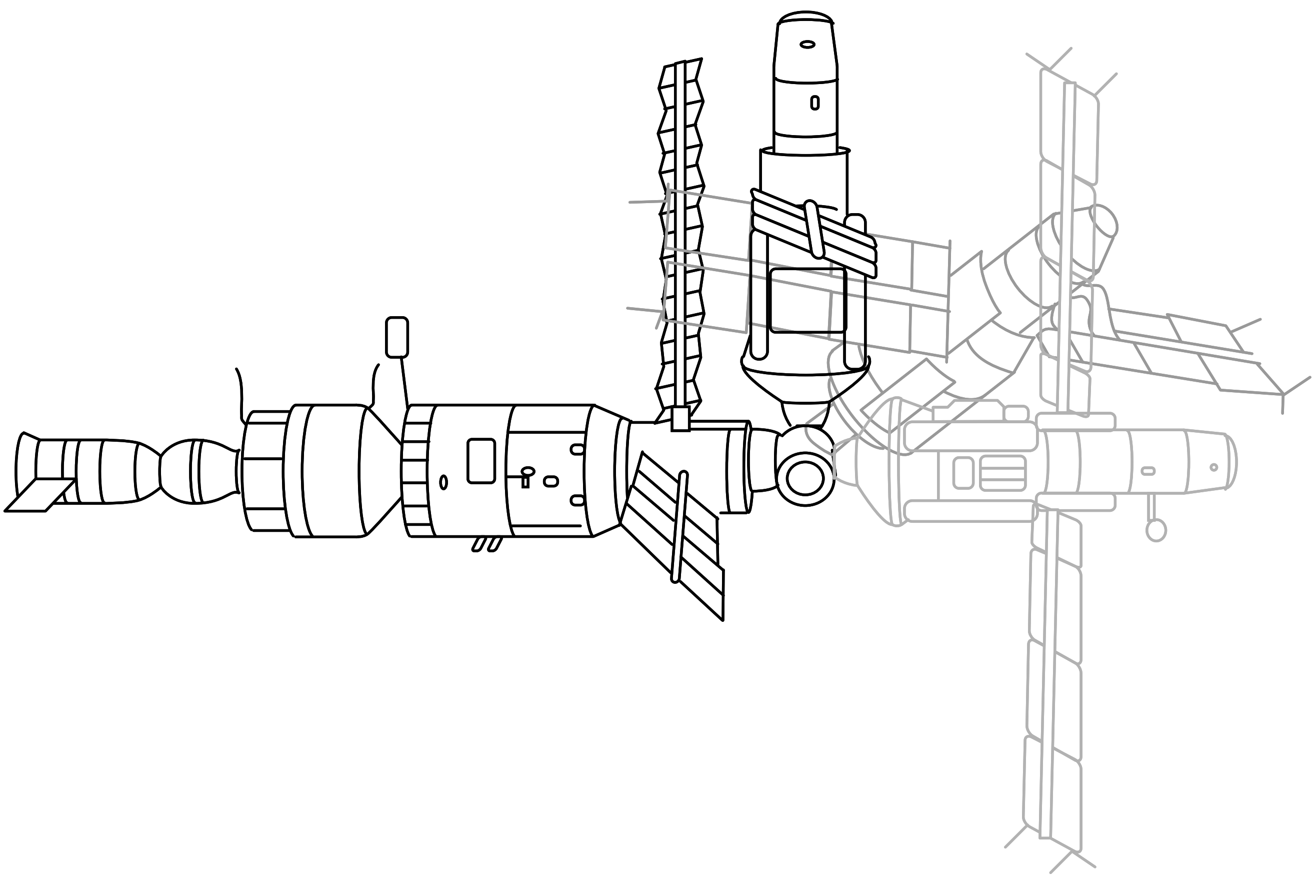

Figure 3-11. Repositioning Kvant module using Lyappa arm.

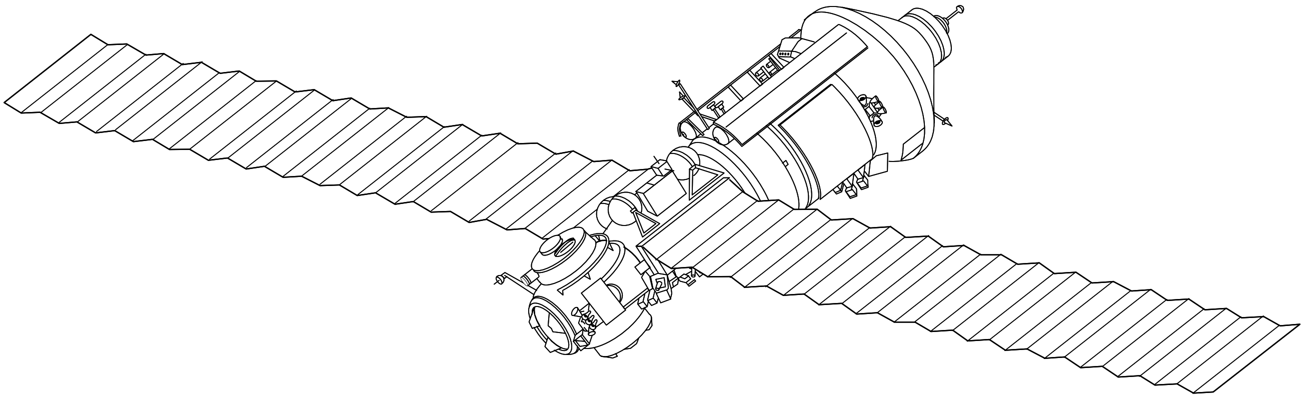

Figure 3-12. Kristall module. Kristall joined Mir in 1990. It carries two APAS-89 docking units (left).

3.7 Kristall

Mir module—Shuttle docking, materials processing, and Earth observation
May 31, 1990–present

3.7.1 Kristall Specifications

Launch weight	19,640 kg
Length	13.73 m
Diameter	4.35 m
Habitable volume	60.8 m^3
Span across solar arrays	about 36 m (maximum)

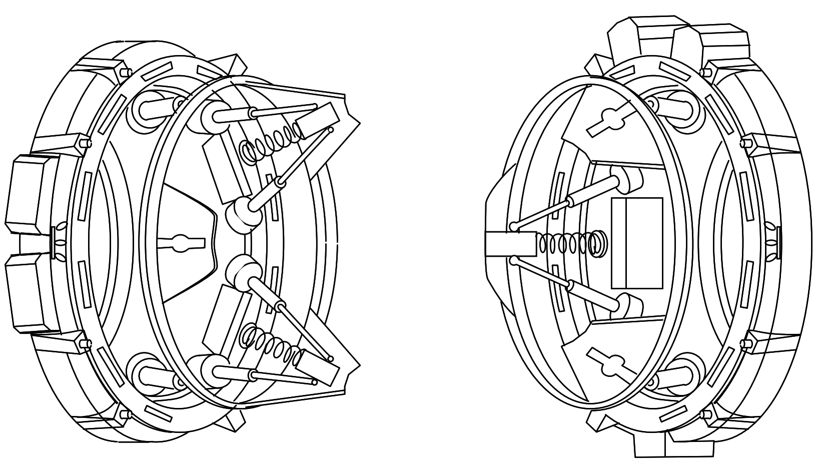

Figure 3-13. APAS-89 androgynous docking unit.

3.7.2 Kristall Notable Features

- Kristall (figure 3-12) referred to as the T-module (Teknologia module) or Kvant 3 prior to launch.
- At aft end is a node with two ports, each fitted with APAS-89 androgynous docking apparatus (figure 3-13). APAS-89 is similar to the APAS-75 docking unit (see section 1.9.2) jointly developed by the U.S. and Soviet Union for ASTP (1975). The chief difference is APAS-89's inward-facing spade-shaped guides. The guides were turned inward to be placed outside the pressurized tunnel

linking the two spacecraft electrical and fluid connections running through the docking collar. Conversely, this placed mechanical systems located outside the collar on the APAS-75 inside the APAS-89 collar. APAS-89 was tested in space by the Soyuz-TM 16 spacecraft, which docked at the lateral APAS-89 Kristall port in 1993. Originally built for a Soyuz-class vehicle as part of the Mir-2 space station program, a modified version was prepared for Buran shuttle/Mir dockings, but never used in that capacity. It is expected to be used in further modified form by U.S. Shuttle Orbiters beginning in 1995. Atlantis will use one of these to dock with Mir for the first time on the STS-71 mission in 1995. Seven U.S. Shuttle visits to this port are planned through 1997.[16]

- Materials processing furnaces (Krater 5, Optizon 1, Zona 2, and Zona 3) and biotechnology experiment apparatus (Ainur electrophoresis unit) weighing 500 kg, which are capable of generating 100 kg of material per year for industrial use on Earth.
- Priroda 5 Earth resources cameras in the docking node.
- Svet "hothouse" for growing radishes and leaf lettuce.
- Folding "collapsible" solar arrays weighing 500 kg. The arrays are designed to be transferred to the Kvant module, where they will be shaded less frequently.
- Six gyrodynes for attitude control.
- Glazar 2 ultraviolet telescope, augmenting the Glazar ultraviolet telescope on Kvant (together the two instruments swept areas of the sky 90° apart); Mariya magnetic spectrometer; Marina gamma ray telescope; Buket gamma spectrometer; and Granat astrophysical spectrometer.

3.8 Space Tugs

3.8.1 Kvant Functional Service Module (1987-1988)

Probably the "purest" space tug of the Soviet/Russian program was the Kvant Functional Service Module (FSM) (figure 3-14). The FSM was a stripped-down FGB. Presumably it was thus launched "tail-up" like the TKS spacecraft, an idea supported by the streamlined structure covering the FSM's aft, where the Merkur capsule would be located on a TKS. It was launched docked with Kvant's aft port on March 31, 1987. This would have placed the Kvant module with the probe docking unit meant to attach it to Mir pointed downwards at launch, against the top of the Proton booster. Kornilov's article about the Polyus spacecraft (see below) contains information on Polyus' design which adds credence to this suggestion. Together the module and FSM formed an integrated spacecraft, with navigation data from antennas at Kvant's front fed to the attitude control system in the FSM. The first attempt to dock Kvant failed; the second was successful, but only after an EVA to remove a foreign object from the docking mechanism. The Kvant FSM undocked from the Kvant aft port on April 13, and boosted to a storage orbit with a mean altitude only 41 km higher than that of Mir. The FSM underwent uncontrolled reentry on August 25, 1988.

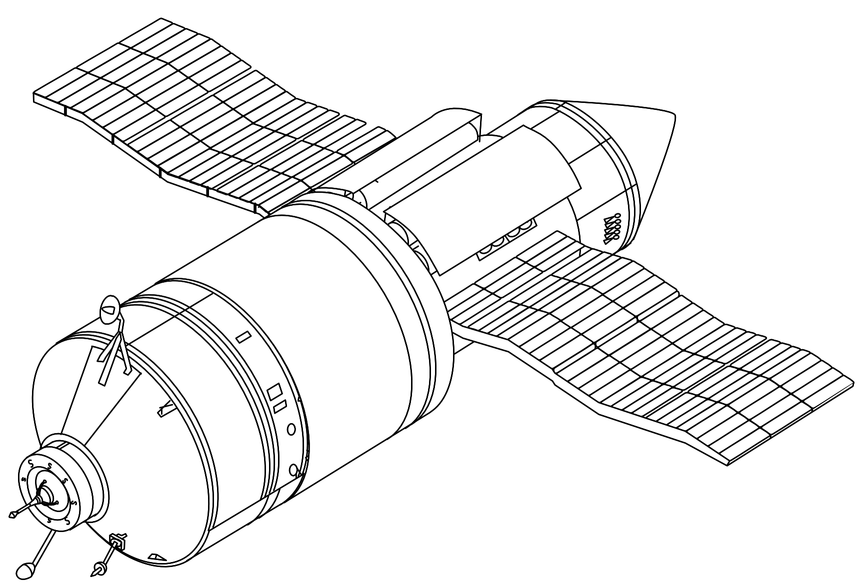

Figure 3-14. Kvant and FSM. The streamlined fairing covering the aft end of the FSM (right) pointed upwards at liftoff, and formed the nose of the launch stack.

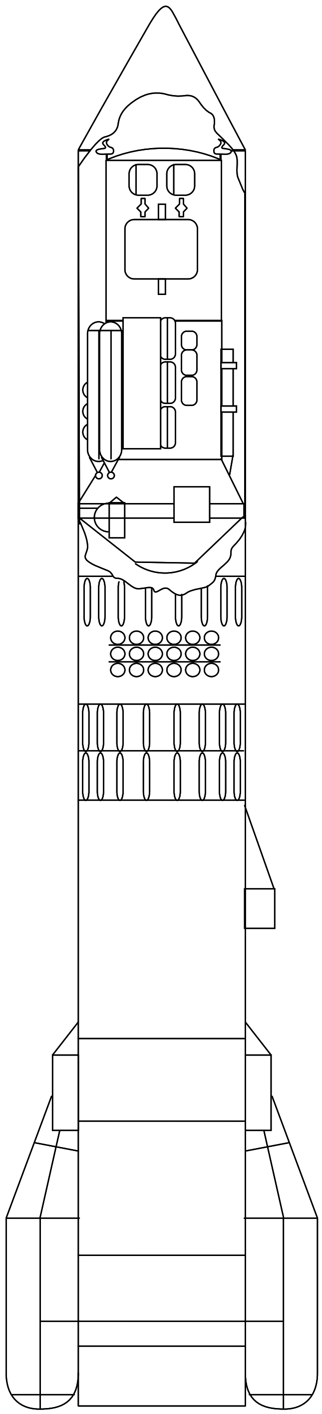

Figure 3-15. Polyus cutaway. Displays the FGB-based service/propulsion module. Note that, like other FGB-based vehicles, it launched aft end up. This places Polyus' front end at the bottom. The streamlined projections on Polyus' sides were dispensers for experimental tracking targets.

3.8.2 Polyus Service Module (1987)

In July-August 1992, Yu. P. Kornilov, chief lead designer at Salyut Design Bureau, described in an article the Polyus spacecraft (figure 3-15).[17] Polyus ("pole of the Earth") was the payload of the first Energia rocket flight (May 15, 1987) (figure 3-16). In July 1985, the Ministry of General Machine Building ordered the Salyut Design Bureau to create a new spacecraft for the first Energia test flight, then scheduled for autumn 1986. The short lead time forced novel approaches to management and construction. Existing hardware, including systems developed for the Buran shuttle program, was used whenever possible. The final configuration had the following attributes:

- Length: 37 m.
- Diameter: 4.1 m.
- Approximate weight: 80,000 kg.
- Two modules: a small operations/service module and a large special-purpose module.
- Nose fairing made of "carbon-filled plastic." This was the first nonmetallic fairing used in the Soviet space program.
- Used Buran ground support equipment; also originally designed for Buran were the supports linking Polyus to Energia and the system for separating Polyus from Energia.

The new spacecraft's operations/service module was based on an FGB with the following attributes:

- Contained all Polyus attitude control and internal systems control equipment, the telemetry system, the power supply system (twin solar arrays, as on the TKS vehicle), the fairing jettison system, antennas, and the scientific experiment control systems.
- Polyus electronic systems unable to withstand hard vacuum were placed in the FGB's pressurized compartment.
- Propulsion system had 4 sustainer engines, 20 attitude control thrusters, and 16 vernier engines.
- Approximate weight: 20,000 kg.
- To meet deadline imposed on Polyus development, the FGB used was one which had exceeded its planned "shelf-life."

According to Kornilov, Polyus had the following mission objectives:

- Test feasibility of launching heavy (100-ton) side-mounted (asymmetrically positioned) payloads on the Energia rocket such as would be used in planned advanced space station programs (primary objective).
- Test future systems, including a docking system. The docking approach radio and optical systems would be tested using reflectors—small inflatable spheres and angled reflectors released from "side units" located on either side of the front of the Polyus spacecraft. The streamlined "side units" were sometimes mistaken for orbit insertion engines in early Western analyses.
- Study interaction of gas and plasma produced by Polyus with natural ionospheric plasma. Polyus contained 420 kg of xenon and krypton in 42 tanks, each with a capacity of 36 liters.

Polyus was launched backwards, with its engines pointing upward and its front end pointed down, toward the Energia launch pad's flame pit. This configuration was dictated by the FGB heritage of its aft-mounted operations/service module. The FGB-based module was launched with its broad front end down, and its engines pointed up, just as it would have been had it been launched atop a Proton. When the FGB was part the TKS, this arrangement put the Merkur capsule at the top of the Proton booster stack, where it could easily be plucked free of the booster by the launch escape system. According to Kornilov, this unorthodox configuration proved to be Polyus' undoing. After separating from Energia's second stage, Polyus had to flip 180° in order to use its service module engines to complete orbital insertion. An attitude control system failure caused Polyus to tumble end over end. When the service module engines fired for the first of two planned orbit insertion burns, they could not boost Polyus into orbit. The spacecraft, probably the heaviest Soviet payload ever, reentered over the South Pacific Ocean within minutes of its launch.

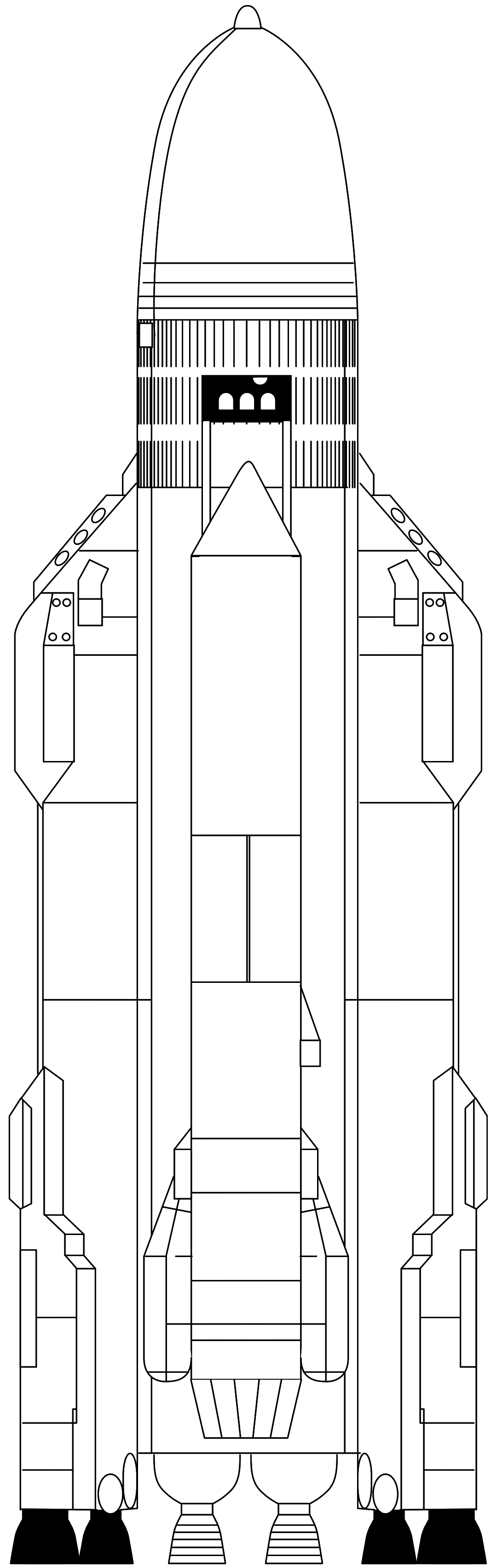

Figure 3-16. Polyus satellite on Energia launch vehicle.

3.9 References for Part 3

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Part 4 Comparative Chronology of U.S. and Soviet/Russian Manned Spaceflight

This chronology is included to serve as a reference for the main body of this work, permitting the reader to place hardware evolution in historical context. For brevity's sake, the chronology is incomplete up to 1970. Soviet missions are set apart by bold dates and names. Joint U.S.-Soviet/ Russian missions are italicized.

1961	**April 12**	**Vostok 1**—Yuri Gagarin completes one orbit of the Earth in 108 min. First manned spaceflight.
	May 5	Mercury-Redstone 3 (Freedom 7)—Alan Shepard completes a 297-mile suborbital flight lasting 14 min.
1962	February 20	Mercury-Atlas 6 (Friendship 7)—John Glenn becomes the first American to orbit Earth.
1963	**June 14-19**	**Vostok 5**—Valeri Bykovski spends nearly 5 days in space. This remains a record for the longest single-person flight. During his flight, Valentina Tereshkova, the first woman in space, passes within 10 km in Vostok 6. This is not an active rendezvous—close approach occurs because Vostok 6 was launched into an orbit which closely matched that of Vostok 5.
1964	**October 12-13**	**Voskhod 1**—Vladimir Komarov, Konstantin Feoktistov, and Boris Yegerov make up the crew of the first spacecraft capable of carrying more than one person. Voskhod 1 is a modified Vostok spacecraft.
1965	**March 18-19**	**Voskhod 2**—Pavel Belyayev and Alexei Leonov spend 26 hr in orbit aboard a modified Vostok. Leonov conducts humanity's first EVA. EVA duration—24 min.
	March 23	Gemini 3—Virgil Grissom and John Young complete three orbits. Gemini is the first manned spacecraft capable of orbit changes.
	December 4-18	Gemini 7—Frank Borman and James Lovell spend nearly 14 days (longer than typical lunar mission duration) orbiting the Earth. Walter Schirra and Thomas Stafford ride Gemini 6 into orbit on December 15. Gemini 6 and Gemini 7 achieve the first active rendezvous between manned spacecraft, coming to within 30 cm of each other.
1966	March 16	Gemini 8—Neil Armstrong and David Scott dock with an unmanned Agena target vehicle. This is the first docking between vehicles in orbit. Shortly after docking, a stuck thruster on Gemini 8 forces an emergency splashdown.
	November 28-30	**Cosmos 133**—Unmanned first test of Original Soyuz.

	December	**Launch failure**—A Soyuz launch vehicle carrying an unmanned Original Soyuz explodes, destroying its launch pad. The Soyuz orbital and descent modules are dragged to safety by the launch escape system.
1967	January 27	AS-204—Fire aboard the first Apollo CSM spacecraft scheduled for manned flight kills Virgil Grissom, Edward White, and Roger Chaffee during a rehearsal on the launch pad.
	February 7-9	**Cosmos 140**—Unmanned Original Soyuz test.
	March 10-18	**Cosmos 146**—Unmanned first flight of a simplified L1 (Zond). The flight is primarily intended to test the Block D fourth stage of the Proton. The Block D restarts twice.
	April 8-10	**Cosmos 154**—Unmanned L1 test. It fails to test the high-velocity reentry characteristics of the L1 because the Block D fourth stage fails to restart.
	April 23-24	**Soyuz 1**—At the end of a trouble-plagued flight, Vladimir Komarov dies when his descent module parachute system fails.
	September 28	**Launch failure**—An L1 ejects from its four-stage Proton launch vehicle when one of the six engines in the rocket's first stage fails to operate. The launch escape system rescues the descent module.
	October 27-November 2	**Cosmos 186** and **Cosmos 188** are unmanned Soyuz spacecraft. They carry out the first automatic docking on October 30.
	November 9	Apollo 4—First flight of the Saturn V booster. It carries no crew. NASA declares the flight a complete success.
	November 22	**Launch failure**—An L1 ejects when the second stage of its Proton rocket fails.
1968	January 22	Apollo 5—An uprated Saturn I rocket launches the first Apollo lunar module (LM) on a successful unmanned test flight.
	March 2-9	**Zond 4** reaches an apogee of 400,000 km, but is lost.
	April 4	Apollo 6—Second unmanned test of the Saturn V rocket. The second stage shuts down prematurely after undergoing excessive vibration. The third stage refuses to restart once in orbit. Portions of the shroud linking the Apollo CSM and the third stage rip loose during ascent.
	April 14-20	**Cosmos 212** and **Cosmos 213** are unmanned Soyuz craft. They dock on April 15.
	April 23	**Launch failure**—An L1 escape system triggers inadvertently during second stage operation of its Proton rocket.
	August 28-September 1	**Cosmos 238** is a successful unmanned Original Soyuz test.

	September 14-21	**Zond 5** ends its unmanned circumlunar flight by making an unplanned splashdown in the Indian Ocean.
	October 11-22	Apollo 7—Wally Schirra, Donn Eisele, and Walter Cunningham are the first astronauts to fly in an Apollo spacecraft. They spend nearly 11 days in Earth orbit testing the Apollo CSM.
	October 25-30	**Soyuz 2** and **Soyuz 3**—Georgi Beregevoi, in Soyuz 3, twice approaches the unmanned Soyuz 2 spacecraft, but is unable to dock.
	November 10-17	**Zond 6** flies around the Moon. It crashes after reentry, but its film cassettes are recovered.
	December 21-27	Apollo 8—Frank Borman, James Lovell, and William Anders complete ten lunar orbits. It is the first manned flight of a Saturn V rocket.
1969	**January 14-18**	**Soyuz 4** and **Soyuz 5** perform the first docking between two manned spacecraft. Alexei Yeliseyev and Yevgeny Khrunov conduct a spacewalk between the docked craft, leaving Boris Volynov at the controls of Soyuz 5. Vladimir Shatalov welcomes them aboard Soyuz 4. The spacecraft then return separately to the Soviet Union.
	January 20	**Launch failure**—A four-stage Proton launch vehicle malfunctions. Its L1 payload ejects.
	February 20	**N-1 test—**The first test of the Soviet equivalent of the Saturn V ends in an explosion 70 sec after launch. Its simplified L1 payload ejects and is recovered downrange **(**figure 4-1**)**.
	March 3-13	Apollo 9—David Scott, James McDivitt, and Russell Schweickart test the LM *Spider* in Earth orbit. First manned flight of the LM.
	July 3	An **N-1 test** ends as the rocket falls on its launch pad, destroying its launch complex.
	July 16-24	Apollo 11—Neil Armstrong and Edwin Aldrin become the first humans on the Moon. LM *Eagle* lands on July 20. Michael Collins remains in orbit aboard the CSM *Columbia*.
	August 7-14	**Zond 7** carries out an unmanned circumlunar flight. It is the most successful of the L1 missions.
	October 11-18	**Soyuz 6, Soyuz 7,** and **Soyuz 8**—Soyuz 6 tests space station-related hardware. Soyuz 7 and 8 rendezvous, but do not dock. The crew of Soyuz 6 is Georgi Shonin and Valeri Kubasov; Soyuz 7, Anatoli Filipchenko, Viktor Gorbatko, and Vladislav Volkov; and Soyuz 8, Vladimir Shatalov and Alexei Yeliseyev.
	November 14-24	Apollo 12—LM *Intrepid* lands on Oceanus Procellarum on November 19. *Intrepid*'s crew is Pete Conrad and Alan Bean. Richard Gordon remains in lunar orbit in *Yankee Clipper*.
1970	April 11-17	Apollo 13—CSM *Odyssey* is disabled by an onboard explosion, scrubbing the third U.S. lunar landing attempt. *Aquarius*, the LM, serves as a lifeboat for James Lovell, Fred Haise, and Jack Swigert.

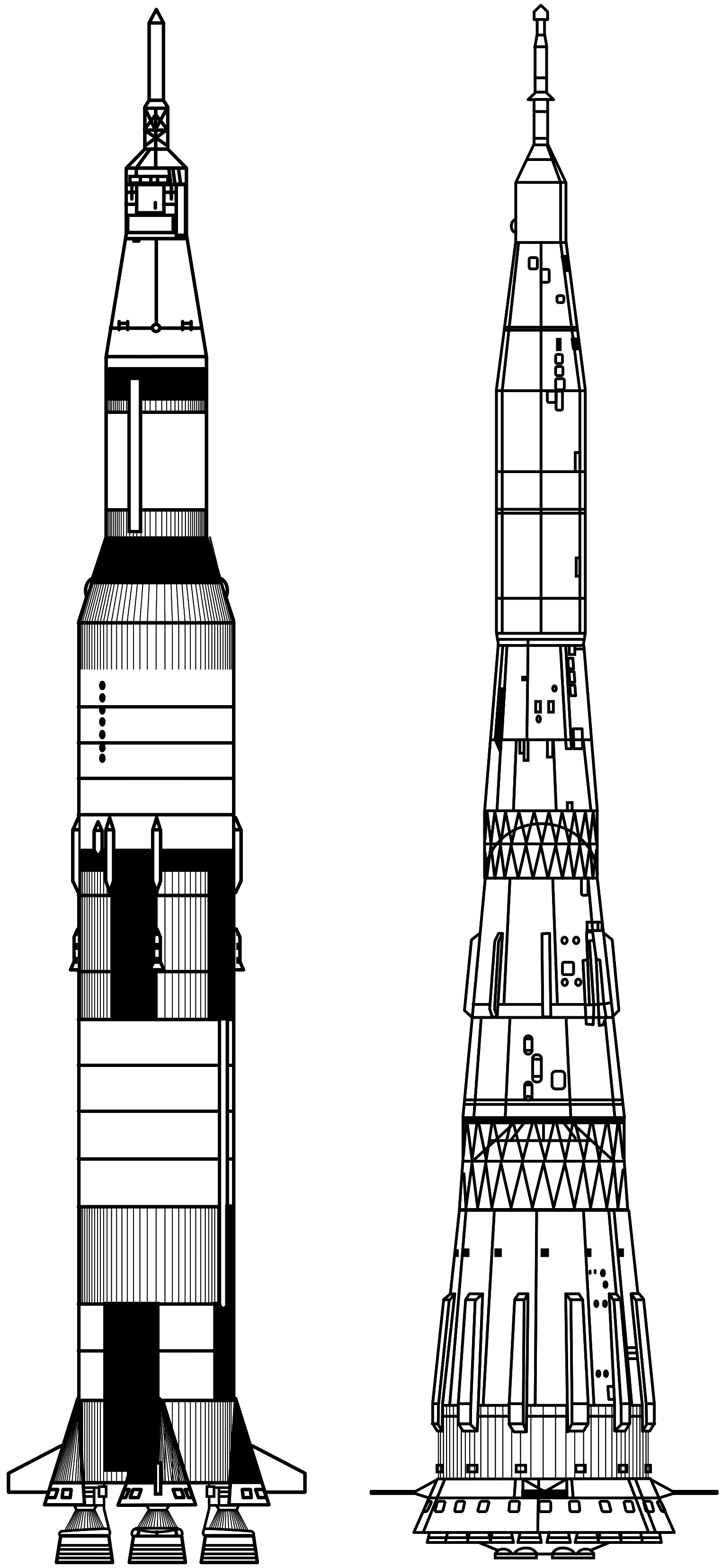

Figure 4-1. Saturn V (left) and N-1 (drawn to scale). Manned Moon rockets.

June 1-19 — **Soyuz 9** orbits Earth for 17 days, 17 hr, the longest manned spaceflight up to this time. Andrian Nikolayev and Vitali Sevastyanov test space station equipment, observe Earth, and carry out medical tests related to long-duration spaceflight.

October 20-27 — **Zond 8** conducts an unmanned circumlunar flight. This is the last L1 mission.

November 24 — **Cosmos 379 launch**—First unmanned test of the T2K version of the L3 manned lunar lander in Earth orbit (figure 4-2).

1971

January 31-February 9 — Apollo 14—LM *Antares* lands at Fra Mauro on February 5. Alan Shepard and Edward Mitchell walk on the Moon and Stuart Roosa remains in lunar orbit aboard the CSM *Kitty Hawk.*

February 26 — **Cosmos 398 launch**—Unmanned test in orbit of the T2K version of the Soviet L3 manned lunar lander. It maneuvered under remote control until March 3.

April 19 — **Salyut 1/DOS-1 launch** on a three-stage Proton. First space station.

April 22-24 — **Soyuz 10**—Vladimir Shatalov, Alexei Yeliseyev, and Nikolai Rukavishnikov are unable to enter Salyut 1.

June 6-29 — **Soyuz 11—**Cosmonauts Georgi Dobrovolski, Viktor Patseyev, and Vladislav Volkov set a new space endurance record by spending 22 days aboard Salyut 1, the longest stay by humans in space up to this time. During reentry the air escapes from their descent module. They do not wear pressure suits, so they are killed.

June 27 — **N-1 test**—The rocket undergoes structural failure. L2 (first launched) (figure 4-3) and L3 test articles crash near the pad, and the rocket impacts downrange.

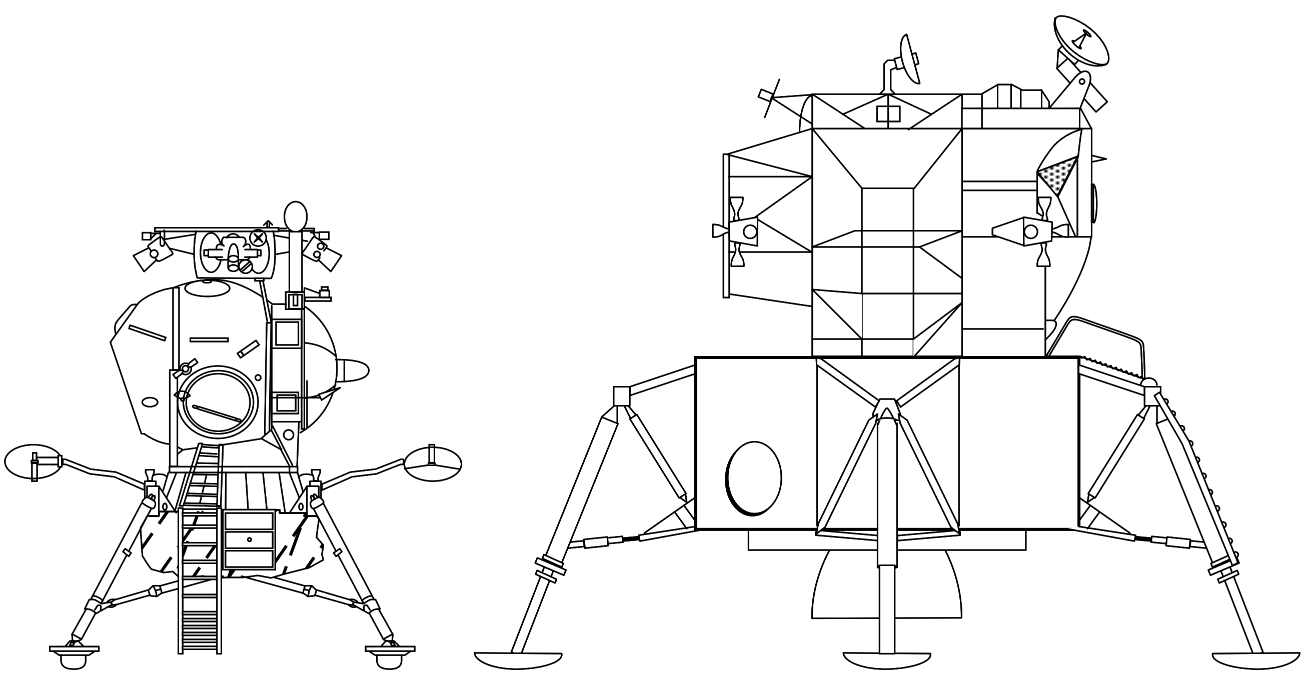

Figure 4-2. L3 (left) and Apollo LM (drawn to scale). Manned Moon landers.

	July 26- August 7	Apollo 15—LM *Falcon* lands at Hadley Rille on July 30. David Scott and James Irwin cover 27 km on their lunar roving vehicle (LRV). Alfred Worden orbits the Moon 74 times in the CSM *Endeavour*.
	August 12	**Cosmos 434**—This is the last of three successful unmanned tests of the T2K version of the L3 lunar lander in Earth orbit.
1972	April 16-27	Apollo 16—LM *Orion* lands at Descartes on April 20. John Young and Charles Duke drive an LRV on the surface while Kenneth Mattingly orbits the Moon in CSM *Casper*.
	June 26-July 2	**Cosmos 496** is an unmanned test of the Soyuz space station ferry.
	July 29	**Salyut launch failure**—The second DOS-type space station fails to reach orbit.

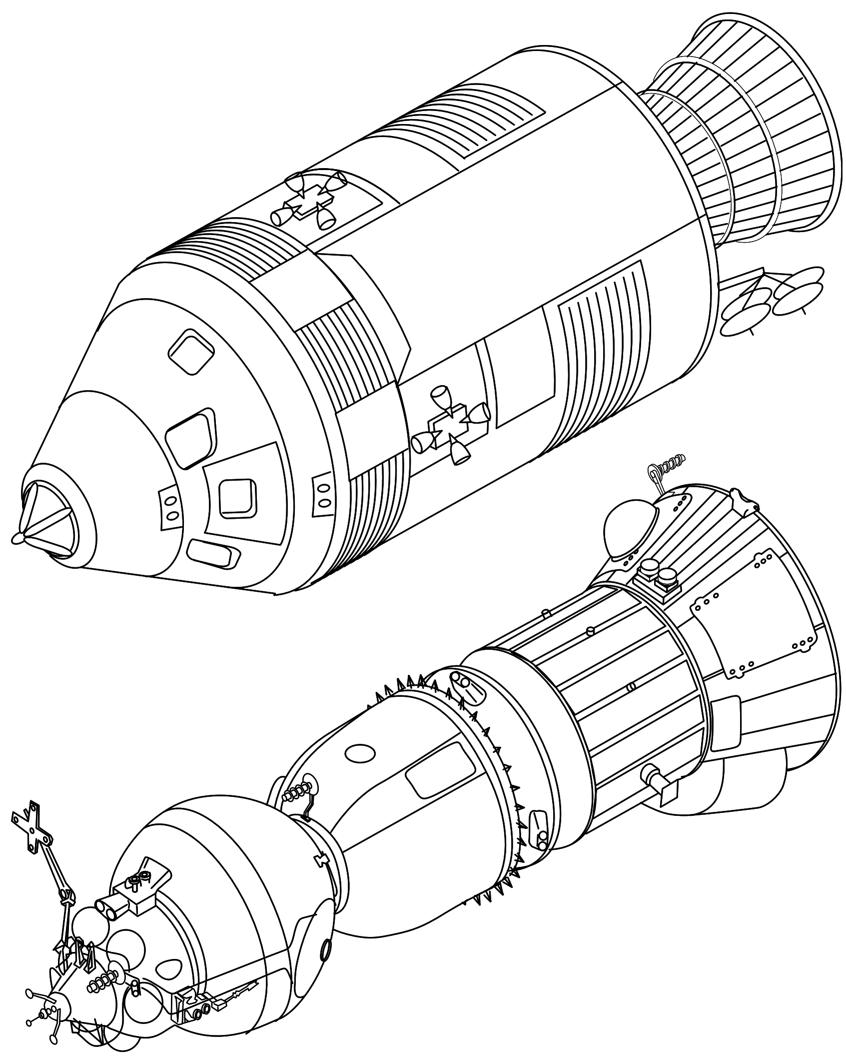

Figure 4-3. Apollo CSM (top) and L2 (drawn to scale). Command ships for the Moon voyage.

	November 23	**N-1 test** ends in a first stage explosion at 40 km altitude. The descent and orbital modules of the L2 are plucked free of the rocket by the launch escape system. This is the fourth and final N-1 test.
	December 7-19	Apollo 17—LM *Challenger* sets down at Taurus-Littrow on December 11. Harrison Schmitt and Eugene Cernan are the last men on the Moon. Ronald Evans remains in the CSM *America* in orbit. This is the last human flight beyond low Earth orbit and the last flight of the successful LM spacecraft.
1973	**April 3-May 28**	**Salyut 2/Almaz 1 launch**—First of the primarily military Almaz-type Salyuts. Salyut 2 breaks up soon after reaching orbit.
	May 11-22	**Cosmos 557/DOS-3 launch—**Fails shortly after reaching orbit.
	May 14	Skylab 1—The first U.S. space station is damaged during launch atop the last Saturn V to fly.
	May 25-June 22	Skylab 2—Pete Conrad, Joseph Kerwin, and Paul Weitz travel to the Skylab 1 station aboard their Skylab 2 Apollo CSM. They spend part of their 28 days in orbit repairing the station, yet still manage to complete their experimental program.
	June 15-17	**Cosmos 573** is an unmanned test of the Soyuz Ferry.
	July 28- September 25	Skylab 3—Alan Bean, Jack Lousma, and Owen Garriott spend 56 days in the Skylab Orbital Workshop.
	September 27-29	**Soyuz 12**—Vasili Lazarev and Oleg Makarov conduct the first manned test of the Soyuz Ferry.
	November 16- February 8, 1974	Skylab 4—Gerald Carr, Edward Gibson, and William Pogue are the last U.S. crew to date to live aboard a space station. This is the longest U.S. space mission to date (84 days).
	November 30- January 29, 1974	**Cosmos 613** is an unmanned test of the Soyuz Ferry vehicle in long-duration orbital storage.
	December 18-26	**Soyuz 13**—Valentin Lebedev and Pyotr Klimuk use the Soyuz orbital module as a laboratory for conducting experiments of the kind planned for future space stations.
1974	**April 3-13**	**Cosmos 638** is the first unmanned test of the Soyuz modified for ASTP. The spacecraft carries the APAS-75 androgynous docking system.
	June 24	**Salyut 3/Almaz 2 launch.**
	July 3-19	**Soyuz 14**—Pavel Popovich and Yuri Artyukhin live aboard the Salyut 3 station for 16 days.
	August 12-18	**Cosmos 672** is the second unmanned test of the ASTP Soyuz.
	August 26-28	**Soyuz 15—**Gennadi Sarafanov and Lev Demin fail to dock with Salyut 3.

	September 23	**Salyut 3/Almaz 2 capsule reenters, is recovered.** The station reenters on January 24, 1975.
	December 2-8	**Soyuz 16**—Anatoli Filipchenko and Nikolai Rukavishnikov test the ASTP Soyuz.
	December 26	**Salyut 4/DOS-4 launch.**
1975	**January 10-February 9**	**Soyuz 17**—Alexei Gubarev and Georgi Grechko live aboard Salyut 4.
	April 5	**"The April 5 Anomaly"** is the Soviet name for the only suborbital manned flight of the Soviet space program. A problem develops in the booster carrying the Soyuz 18a (Western designation) spacecraft, necessitating an abort late in the ascent phase of the mission. Vasili Lazarev and Oleg Makarov land unhurt 1800 km east of the Baikonur Cosmodrome.
	May 24-July 26	**Soyuz 18**—Pyotr Klimuk and Vitali Sevastyanov live for 62 days aboard Salyut 4. Called Soyuz 18b in the West.
	July 15-July 24	*Apollo Soyuz Test Project (ASTP)—Alexei Leonov and Valeri Kubasov, aboard Soyuz 19, dock in low Earth orbit with the last U.S. Apollo CSM. Soyuz 19 lands on July 21. Tom Stafford, Vance Brand, and Donald Slayton are the last U.S. astronauts in space until 1981.*
	November 17-February 16, 1976	**Soyuz 20—**Unmanned Progress-related test. Docks with Salyut 4.
1976	**June 22**	**Salyut 5/Almaz 3 launch.**
	July 6-August 24	**Soyuz 21**—Boris Volynov and Vitali Zholobov spend 49 days on Salyut 5.
	September 15-23	**Soyuz 22**—Valeri Bykovskii and Vladimir Aksyonov conduct an Earth observation mission using the backup ASTP Soyuz.
	October 14-16	**Soyuz 23—**Vyacheslav Zudov and Valeri Rozhdestvenski are unable to dock with Salyut 5.
	November 29-December 17	**Cosmos 869—**Unmanned test of Soyuz-T.
	December 15	**Cosmos 881** and **Cosmos 882** are two Transport Logistics Spacecraft (TKS) capsules (Merkur capsules) launched atop a Proton rocket. They reenter and are recovered the same day.
1977	**February 7-25**	**Soyuz 24**—Viktor Gorbatko and Yuri Glazkov are the last crew to stay aboard Salyut 5.
	February 26	**Salyut 5 capsule reenters—**The last Almaz Salyut station reenters on August 8, 1977.

	July 17- February 2, 1978	**Cosmos 929** is the first flight of a TKS. It is put through unmanned maneuvering and propulsion system tests. The Merkur capsule lands in the Soviet Union after a month in orbit. The FGB is guided to destructive reentry on February 2, 1978.
	August 4	**Launch failure** destroys one Merkur capsule (the lower one) of a Proton-launched dual Merkur capsule test. The top capsule is plucked free by the launch escape system.
	September 29	**Salyut 6/DOS-5 launch.**
	October 9-11	**Soyuz 25**—Vladimir Kovalyonok and Valeri Ryumin are unable to hard dock with the front port of Salyut 6.
	December 10	**Soyuz 26**—Yuri Romanenko and Georgi Grechko dock at the rear port of Salyut 6.
1978	**January 10**	**Soyuz 27 launch**—Vladimir Dzhanibekov and Oleg Makarov dock with the Salyut 6 front port on January 10. They return to Earth in the **Soyuz 26** spacecraft on January 16.
	January 20- February 8	**Progress 1**—The unmanned, Soyuz-based space station logistics support craft delivers supplies to Salyut 6. It docks at the aft port on January 22.
	March 2-10	**Soyuz 28**—Vladimir Remek (Czechoslovakia) becomes the first non-U.S., non-Soviet space traveler. Remek and Soviet cosmonaut Alexei Gubarev visit Salyut 6. This is the first flight in the Intercosmos program, which involved joint flights by Soviet cosmonauts and guest cosmonauts from countries with ties to the U.S.S.R.
	March 16	**Soyuz 27 reentry**—Grechko and Romanenko return to Earth after 96 days in space. This beats the 84-day space endurance record held by the U.S. Skylab 4 astronauts since early 1974.
	March 30	**Cosmos 997** and **Cosmos 998** are two Merkur capsules launched on a single three-stage Proton rocket. They reenter and are recovered the same day.
	April 4-15	**Cosmos 1001**—Unmanned test of Soyuz-T.
	June 15	**Soyuz 29 launch**—Vladimir Kovalyonok and Alexander Ivanchenkov travel to Salyut 6.
	July 7- August 4	**Progress 2**.
	June 27-July 5	**Soyuz 30**—Miroslaw Hermaszewski (Poland) and Pyotr Klimuk visit Salyut 6.
	August 7-23	**Progress 3**.
	August 26	**Soyuz 31 launch**—Sigmund Jahn (East Germany) and Valeri Bykovski visit Salyut 6. They return to Earth aboard **Soyuz 29** on September 3.
	October 3-26	**Progress 4**.

	November 2	**Soyuz 31 reentry**—Kovalyonok and Ivanchenkov return to Earth after 139 days on Salyut 6.
1979	**January 31-April 1**	**Cosmos 1074** is an unmanned long-duration test flight of the Soyuz-T spacecraft.
	February 25	**Soyuz 32 launch**—Vladimir Lyakhov and Valeri Ryumin travel to Salyut 6.
	March 12-April 5	**Progress 5**.
	April 10-12	**Soyuz 33**—A main engine malfunction forces Nikolai Rukavishnikov and Georgi Ivanov (Bulgaria) to abort docking with Salyut 6.
	May 13-June 9	**Progress 6**.
	May 22-23	**Cosmos 1100-1101**—The last dual Merkur capsule test.
	June 6	**Soyuz 34 launch**—The spacecraft, which carries no crew, is intended to replace the aging **Soyuz 32** spacecraft. **Soyuz 32** undocks unmanned on June 13 and returns 280 kg of experiment results and disused equipment to the Soviet Union. Ryumin and Lyakhov continue work in orbit.
	June 28-July 20	**Progress 7.**
	July 11	Skylab reenters over Australia.
	August 19	**Soyuz 34 reentry**—Lyakhov and Ryumin return to Earth after 175 days in space.
	December 16-March 25, 1980	**Soyuz-T 1** docks automatically with Salyut 6 in the third unmanned test of the new Soyuz derivative.
1980	**March 27-April 26**	**Progress 8.**
	April 9	**Soyuz 35 launch**—Leonid Popov and Valeri Ryumin (making his second long-duration flight in less than a year) lift off for the Salyut 6 station. They dock on April 10.
	April 27-May 22	**Progress 9.**
	May 26	**Soyuz 36 launch**—This joint Soviet-Hungarian mission marks the resumption of international flights to Salyut 6 following the Soyuz 33 main engine malfunction. Valeri Kubasov and Bertalan Farkas (Hungary) return to Earth aboard **Soyuz 35**.
	June 5-9	**Soyuz-T 2**—First manned test flight of Soyuz-T. Yuri Malyshev and Vladimir Aksyonov spend 2 days on Salyut 6 before returning to Earth.
	June 29-July 19	**Progress 10.**

	July 23	**Soyuz 37 launch**—Pham Tuan (Vietnam) and Viktor Gorbatko travel to Salyut 6. The cosmonauts return to the Soviet Union in the **Soyuz 36** spacecraft on July 31.
	September 18-26	**Soyuz 38**—Arnaldo Tamayo-Mendez (Cuba) and Yuri Romanenko visit Salyut 6.
	September 28-December 11	**Progress 11.**
	October 11	**Soyuz 37 reentry—**Valeri Ryumin and Leonid Popov return to Earth after 185 days in space.
	November 27-December 10	**Soyuz-T 3**—Leonid Kizim, Oleg Makarov, and Gennadi Strekalov spend 13 days refurbishing the aging Salyut 6 station.
1981	**January 24-March 20**	**Progress 12.** Last Progress to visit Salyut 6.
	March 12	**Soyuz-T 4 launch**—Vladimir Kovalyonok and Viktor Savinykh arrive at the Salyut 6 station.
	March 22-30	**Soyuz 39**—Vladimir Dzhanibekov and Judgerdemidiyin Gurragcha (Mongolia) visit the Salyut 6 station.
	April 12-14	STS-1—On the first Space Shuttle mission, astronauts John Young and Robert Crippen spend 2 days testing Space Shuttle Columbia in orbit. This is the first flight by U.S. astronauts since 1975 (figure 4-4).
	April 25	**Cosmos 1267**, a TKS, is launched from Baikonur Cosmodrome atop a Proton rocket. On May 26 its Merkur capsule separates and lands in the Soviet Union.
	May 14-22	**Soyuz 40**—Leonid Popov and Dumitru Prunariu (Romania) fly the last of the Soyuz ferries to Salyut 6.
	May 26	**Soyuz-T 4 reentry—**Kovalyonok and Savinykh are the last cosmonauts to leave Salyut 6.
	June 19	The **Cosmos 1267** FGB docks with **Salyut 6**.
	November 12-14	STS-2—Richard Truly and Joe Engle are forced to cut their planned 5-day Space Shuttle test mission by 3 days because of a fuel cell problem.
1982	March 22-30	STS-3—Jack Lousma and Gordon Fullerton test Columbia.
	April 19	**Salyut 7 launch** atop a three-stage Proton rocket.
	May 13	**Soyuz-T 5 launch—**Anatoli Berezevoi and Valentin Lebedev become the first cosmonauts to dock with Salyut 7.
	May 23-June 6	**Progress 13.**

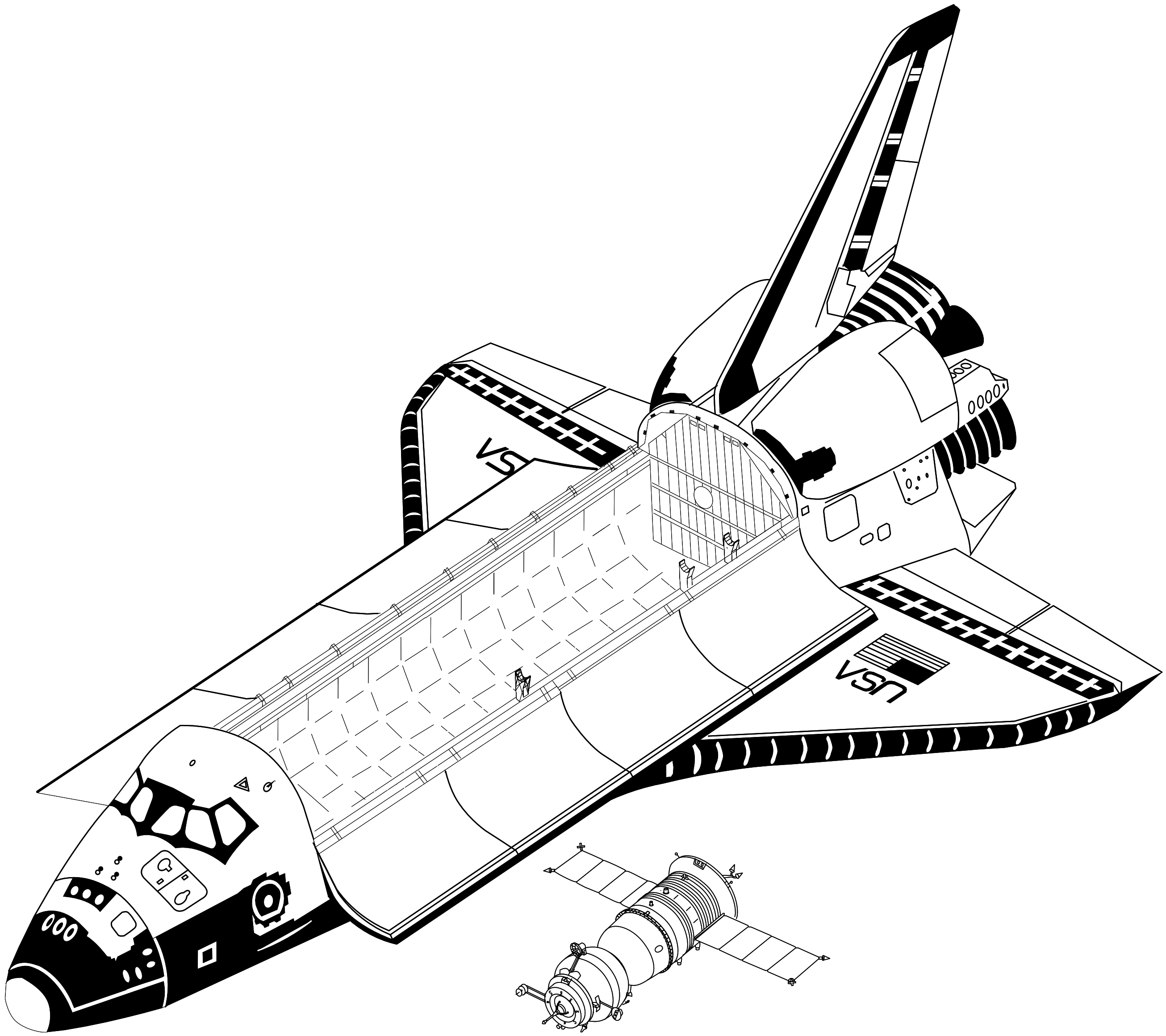

Figure 4-4. Space Shuttle Orbiter and Soyuz-TM (drawn to scale). Current spacecraft used by humans to travel in space.

June 24-July 2	**Soyuz-T 6**—Jean-Loup Chretien (France), Vladimir Dzhanibekov, and Alexander Ivanchenkov visit Salyut 7.
June 27-July 4	STS-4—Ken Mattingly and Henry Hartsfield carry out the fourth and last Space Shuttle test flight.
July 10-August 13	**Progress 14.**
July 29	The **Salyut 6/Cosmos 1267** complex deorbits using Cosmos 1267's engines.
August 19	**Soyuz-T 7**—Leonid Popov, Alexander Serebrov, and Svetlana Savitskaya visit the Salyut 7 station. They return to Earth in **Soyuz T-5** on August 27.

	September 18-October 16	**Progress 15.**
	October 31-December 14	**Progress 16.**
	November 11-16	STS-5—Vance Brand, Robert Overmyer, Joseph Allen, and William Lenoir fly Columbia on the first operational Shuttle mission.
	December 10	**Soyuz-T 7 reentry**—Lebedev and Berezevoi return to Earth after 211 days in space.
1983	**March 2-September 19**	**Cosmos 1443**, a TKS, reaches orbit atop a three-stage Proton rocket. It docks with Salyut 7 on March 10. It undocks on August 14, and its Merkur capsule lands on August 23. On September 19 the FGB is commanded to a destructive reentry.
	April 4-9	STS-6—Paul Weitz, Karol Bobko, Donald Peterson, and Story Musgrave are the crew for the first flight of the Space Shuttle Challenger.
	April 20-22	**Soyuz-T 8—**Vladimir Titov, Gennadi Strekalov, and Alexander Serebrov are unable to dock with Salyut 7.
	June 18-24	STS-7—Robert Crippen, Frederick Hauck, Sally Ride, John Fabian, and Norman Thagard are the crew for the second flight of the Space Shuttle Challenger.
	June 27	**Soyuz-T 9 launch—**Vladimir Lyakhov and Alexander Alexandrov fly to Salyut 7.
	August 17-September 18	**Progress 17.**
	August 30-September 5	STS-8—Richard Truly, Dan Brandenstein, Dale Gardner, Guion Bluford, and William Thornton are the crew of Challenger.
	September 26	**Pad Abort**—Vladimir Titov and Gennadi Strekalov narrowly escape death when fire and explosion destroy their booster on the launch pad seconds before planned liftoff. The explosion consumes the launch pad. Soyuz-T 10a (as it is known in the West) constitutes a Salyut 7 refurbishment mission.
	October 20-November 16	**Progress 18.**
	November 23	**Soyuz-T 9 reentry**—Lyakhov and Alexandrov return to the Soviet Union in Soyuz-T 9 after spending 149 days in space.
	November 28-December 8	STS-9—John Young, Brewster Shaw, Owen Garriott, Robert Parker, Ulf Merbold, and Byron Lichtenberg work inside the joint ESA-NASA Spacelab module in Columbia's cargo bay. Merbold is a European Space Agency astronaut from West Germany. During the flight, Columbia overflies Baikonur Cosmodrome, the Soviet manned spaceflight launch center, permitting Young to photograph the Energia launch vehicle on its launch pad at Baikonur Cosmodrome.

1984	February 3-11	STS 41-B—Challenger carries aloft astronauts Vance Brand, Robert Gibson, Robert Stewart. Bruce McCandless, and Ronald McNair for the tenth mission of the Shuttle series. On February 7 and February 9, McCandless and Stewart conduct test flights of the manned manuevering unit (MMU).
	February 8	**Soyuz-T 10 launch**—Leonid Kizim, Vladimir Solovyov, and Oleg Atkov lift off for Salyut 7. This mission is sometimes called Soyuz T-10b in the West.
	February 21-April 1	**Progress 19.**
	April 3	**Soyuz-T 11 launch**—The spacecraft docks at Salyut 7's aft port bearing Yuri Malyshev, Gennadi Strekalov, and Rakesh Sharma (India). They return to Earth in the **Soyuz-T 10** spacecraft on April 11.
	April 6-13	STS 41-C—Bob Crippen, Dick Scobee, Terry Hart, George Nelson, and James van Hoften reach orbit aboard Challenger. They deploy the Long Duration Exposure Facility (LDEF), a Salyut-sized passive satellite, and rendezvous with and repair the Solar Maximum Mission (Solar Max) satellite.
	April 15-May 7	**Progress 20.**
	May 7-May 26	**Progress 21.**
	May 28-July 15	**Progress 22.**
	July 17-29	**Soyuz-T 12—**Vladimir Dzhanibekov, Svetlana Savitskaya, and Igor Volk visit the Salyut 7 station. Volk is a Soviet space shuttle test pilot. Immediately after return to Earth, he conducts simulated shuttle landings in a training aircraft.
	August 14-August 28	**Progress 23.**
	August 30-September 5	STS 41-D—Henry Hartsfield, Michael Coats, Judith Resnik, Richard Mullane, Steven Hawley, and Charles Walker are the crew of the Space Shuttle Discovery on its maiden flight. They deploy a prototype space station solar array.
	October 2	**Soyuz-T 11 reentry—**Kizim, Solovyov, and Atkov return to Earth after 237 days in space.
	October 5-13	STS 41-G—Robert Crippen, Jon McBride, Sally Ride, Kathryn Sullivan, David Leestma, Marc Garneau, and Paul Scully-Power are Challenger's seven crew members.
	November 8-16	STS 51-A—Rick Hauck, David Walker, Joe Allen, Anna Fisher, and Dale Gardner ride Discovery. They recover two satellites launched on STS 41-B for resale.
1985	January 24-27	STS 51-C is the first U.S. Department of Defense-dedicated Space Shuttle flight. Discovery's crew is Thomas Mattingly, Loren Shriver, Ellison Onizuka, James Buchli, and Gary Payton.

March 2	**Salyut 7 career declared ended**—The Soviets announce unexpectedly that the station is no longer to be staffed. They lost contact with the station in early February. By the end of March they change their minds and decide to attempt a repair mission.
April 12-19	STS 51-D—Karol Bobko, Don Williams, Rhea Seddon, David Griggs, Jeff Hoffman, Charles Walker, and Jake Garn are the crew of Discovery.
April 29-May 6	STS 51-B—Robert Overmyer, Frederick Gregory, Don Lind, Norman Thagard, William Thornton, Taylor Wang, and Lodewijk van den Berg fly Challenger on the STS 51-B mission. Spacelab 3 is the primary payload.
June 6	**Soyuz-T 13 launch and Salyut 7 rescue**—Vladimir Dzhanibekov and Viktor Savinykh lift off for Salyut 7. They dock June 8. Salyut 7 is rolling, with its solar arrays pointing at random. The interior of the station is covered with frost. All of its batteries are depleted, and two are ruined. The cosmonauts determine that a sun sensor failure prevented Salyut 7 from recharging its batteries. They restore power, thaw out the station, and find that the attitude control system is still functional. This permits Progress 24 to dock on June 23, with a badly-needed cargo of replacement parts and fuel for Salyut 7.
June 17-24	STS 51-G—Dan Brandenstein, John Creighton, Steve Nagel, John Fabian, Shannon Lucid, Sultan Salman Abdul Aziz Al Sa'ud (Saudi Arabia), and Patrick Baudry (France) launch three satellites and conduct proximity operations with Spartan 1. Discovery also participates in a Strategic Defense Initiative (SDI) test.
June 21-July 15	**Progress 24.**
July 19-August 30	**Cosmos 1669**—This is a test flight of Progress upgraded to service Mir. It delivers cargo to Salyut 7.
July 29-August 6	STS 51-F—Gordon Fullerton, Roy Bridges, Story Musgrave, Karl Henize, Anthony England, Loren Acton, and John-David Bartoe make up Challenger's crew. A main engine sensor problem during ascent forces the crew to execute Abort-to-Orbit contingency procedures. The low orbit reached by the Shuttle has only a minor impact on Spacelab 3's astronomy-focused science program.
August 27- September 3	STS 51-I—Joe Engle, Dick Covey, Mike Lounge, James van Hoften, and Bill Fisher make up the crew of the Space Shuttle Discovery. They rendezvous with the Leasat 3 satellite, stranded in low Earth orbit since its kick motor malfunctioned after deployment on STS 51-D. Bill Fisher and James van Hoften successfully repair the Leasat.
September 17	**Soyuz-T 14 launch**—Carries Vladimir Vasyutin, Georgi Grechko, and Alexander Volkov to Salyut 7. Vladimir Dzhanibekov returns to Earth with Georgi Grechko in **Soyuz–T 13** on September 26. Vasyutin, Volkov, and Savinykh remain on the station.
September 27	**Cosmos 1686** is a transitional vehicle between the TKS and dedicated space station modules. It docks at Salyut 7's front port on October 2. It is an FGB with a Merkur capsule heavily modified to house scientific instruments.
October 3-7	STS 51-J is a dedicated Department of Defense mission. It is the first flight of the fourth orbiter, Atlantis, and the twenty-first flight of the Shuttle program. Its crew was Karol Bobko, Ronald Grabe, David Hilmers, Robert Stewart and William Pailes.

	October 30-November 6	STS 61-A is the fourth Spacelab mission, and the first chartered by another country (West Germany). Ernst Messerschmid and Reinhard Furrer, from West Germany, Wubbo Ockels, representing the European Space Agency, and Americans Henry Hartsfield, Steve Nagel, Bonnie Dunbar, James Buchli, and Guion Bluford make up Challenger's eight-person crew, the largest ever to fly into space on a single spacecraft.
	November 26-December 3	STS 61-B—Brewster Shaw, Bryan O'Connor, Sherwood Spring, Mary Cleave, Jerry Ross, Charles Walker, and Mexican astronaut Rodolfo Neri-Vela make up the crew of Atlantis. During EVAs, Spring and Ross conduct space structure assembly exercises.
	November 21	**Soyuz-T 14 reentry**—Mission commander Vladimir Vasyutin became seriously ill aboard Salyut 7 in late October. On this date Vasyutin, Volkov, and Savinykh return to Earth, cutting short their mission, which had been planned to continue until at least January 1986. Savinykh spent 216 days in space; the others, 65 days.
1986	January 12-18	STS 61-C—Columbia makes the twenty-fourth flight of the Space Shuttle program. Its crew is Robert Gibson, Charles Bolden, George Nelson, Steven Hawley, Franklin Chang-Diaz, Robert Cenker, and Bill Nelson.
	January 28	STS 51-L—At liftoff on an unusually cold Florida morning, an O-ring in the right solid rocket booster (SRB) of Space Shuttle Challenger is crushed when SRB segments shift at main engine ignition. This is not unusual, but the unusually low temperatures mean that the O-ring fails to reseat itself to form a seal against the SRB's hot exhaust gases. Flames open and rapidly expand a hole in the O-ring seal. About 70 sec after liftoff, the booster stack—SRBs and external tank—begins to disintegrate. About 73 sec after liftoff, Space Shuttle Challenger breaks up. Challenger lacks escape systems. Dick Scobee, Michael Smith, Judith Resnik, Ellison Onizuka, Ron McNair, Christa McAuliffe, and Gregory Jarvis perish. This is the last U.S. manned spaceflight until September 1988.
	February 19	**Mir launch.**
	March 13	**Soyuz-T 15 launch**—Leonid Kizim and Vladimir Solovyov become the first cosmonauts to board Mir on March 15. They activate Mir's systems and commence systems checks.
	March 19-April 21	**Progress 25** is the first Progress vehicle to service Mir. It incorporates improvements pioneered by Cosmos 1669.
	April 23-June 23	**Progress 26.**
	May 5-June 25	**Soyuz-T 15 transfer to Salyut 7**—Kizim and Solovyov undock from Mir on May 5. They dock their Soyuz T-15 spacecraft with the rear port of the Salyut 7-Cosmos 1686 complex on May 6. They salvage equipment from Salyut 7 for use on Mir. They also perform two EVAs to assemble a 12-m beam. They undock from Salyut 7 on June 25 and fly back to Mir.
	May 21-30	**Soyuz-TM 1**—First flight of the latest version of Soyuz. It docks unmanned with Mir on May 23, then undocks and returns to Earth.
	June 26-July 16	**Soyuz-T 15 transfer to Mir and reentry**—Kizim and Solovyov deliver to Mir equipment recovered from Salyut 7. They then mothball the station and return to Earth.

1987	**January 16-February 25**	**Progress 27.**
	February 5	**Soyuz-TM 2 launch**—Yuri Romanenko and Alexander Laveikin travel to Mir.
	March 3-March 28	**Progress 28.**
	March 31	**Kvant launch**—The Soviets launch Kvant, the first Mir space station module, atop a Proton rocket. Kvant fails to dock with Mir on April 5 because of a docking transponder problem. On April 9 it achieves soft dock, but cannot make hard dock. Laveikin and Romanenko perform an unrehearsed EVA to investigate the problem. They discover a foreign object jammed in the docking mechanism. Kvant achieves hard dock April 12. Its FSM detaches on April 13 and undergoes uncontrolled reentry on August 25, 1988.
	April 21-May 11	**Progress 29.**
	May 15	**Energia**—The Soviets launch the first Energia rocket. It carries the unmanned 80-ton Polyus space platform. An FGB-based propulsion/service module is designed to complete orbital insertion and provide attitude control and orbit maintenance. An attitude control problem prevents the orbital insertion burn.
	May 19-July 19	**Progress 30.**
	July 22	**Soyuz-TM 3 launch**—Alexander Viktorenko, Alexander Alexandrov, and Mohammed Faris (Syria) dock at the Kvant port on July 24. Alexandrov remains onboard Mir, and Laveikin returns to Earth with Victorenko and Faris in **Soyuz-TM 2** on July 30.
	August 3-September 23	**Progress 31.**
	September 23-November 19	**Progress 32.**
	November 20-December 19	**Progress 33.**
	December 21	**Soyuz-TM 4 launch**—Anatoli Levchenko, Musa Manarov, and Vladimir Titov arrive at Mir. Levchenko, a pilot for the Soviet space shuttle, returns to Earth in **Soyuz-TM 3** on December 29 with Alexandrov and Romanenko. Within half an hour of touchdown, Levchenko takes the controls of a Tu-154 aircraft to test whether his flight proficiency has been hampered by spending a week in space. Romanenko spent 326 days in space. Manarov and Titov remain on Mir, beginning a 365-day stay in space.
1988	**January 20-March 4**	**Progress 34.**
	March 23-May 5	**Progress 35.**
	May 13-June 5	**Progress 36.**

	June 7	**Soyuz-TM 5 launch**—Bulgarian cosmonaut Alexandr Alexandrov and Russian cosmonauts Viktor Savinykh and Anatoli Solovyov travel to the Mir station. They return to Earth in **Soyuz-TM 4** on June 17, leaving Soyuz-TM 5 for Manarov and Titov.
	July 18- **August 12**	**Progress 37.**
	August 29	**Soyuz-TM 6** delivers Vladimir Lyakhov, Valeri Polyakov, and Abdul Ahad Mohmand (Afghanistan) to the Mir station. Polyakov remains on Mir with Manarov and Titov, while Mohmand and Lyakhov depart in **Soyuz-TM 5** on September 6. They discard the orbital module before firing the main engine, a practice begun with the early flights of the Soyuz-T. This practice permits the spacecraft to burn more fuel for orbital maneuvers; with no orbital module to deorbit, less fuel need be retained for the deorbit burn at the end of the mission. Orientation sensor and software problems force them to remain aloft an extra day in their cramped descent capsule with neither docking apparatus nor sanitary facilities. After this the orbital module is retained until after a successful deorbit burn.
	September 9- **November 23**	**Progress 38.**
	September 29- October 3	STS-26—Frederick Hauck, Richard Covey, John Lounge, George Nelson, and David Hilmers reach orbit aboard the Space Shuttle Discovery. They deploy a Tracking and Data Relay Satellite (TDRS). This is the first launch of American astronauts since January 1986. Return-to-flight modifications include more stringent launch-commit criteria, SRB redesign, and escape apparatus.
	November 15	**Buran—**The first Buran reusable space shuttle lifts off on an Energia launch vehicle. The test flight carries no crew. Touchdown is on a runway at Baikonur Cosmodrome, a few km from its launch pad **(**figure 4-5**)**.
	November 26- **December 21**	**Soyuz-TM 7 launch**—Alexander Volkov, Sergei Krikalev, and Jean-Loup Chretien (France) arrive at Mir aboard Soyuz-TM 7. The French spationaute spends 25 days on Mir before returning to Earth with Manarov and Titov in Soyuz-TM 6 on December 21. Polyakov remains behind with Volkov and Krikalev.
	December 2-6	STS-27 is a Department of Defense Space Shuttle mission. The crew of Atlantis for this flight is Robert Gibson, Guy Gardner, Richard Mullane, Jerry Ross, and William Shepherd.
	December 25- **February 7, 1989**	**Progress 39.**
1989	**February 10-** **March 5**	**Progress 40.**
	March 12-18	STS-29**—**Michael Coats, John Blaha, James Buchli, Robert Springer, and James Bagian are the crew of the Space Shuttle Discovery. They deploy a TDRS.
	March 16- **April 25**	**Progress 41.**

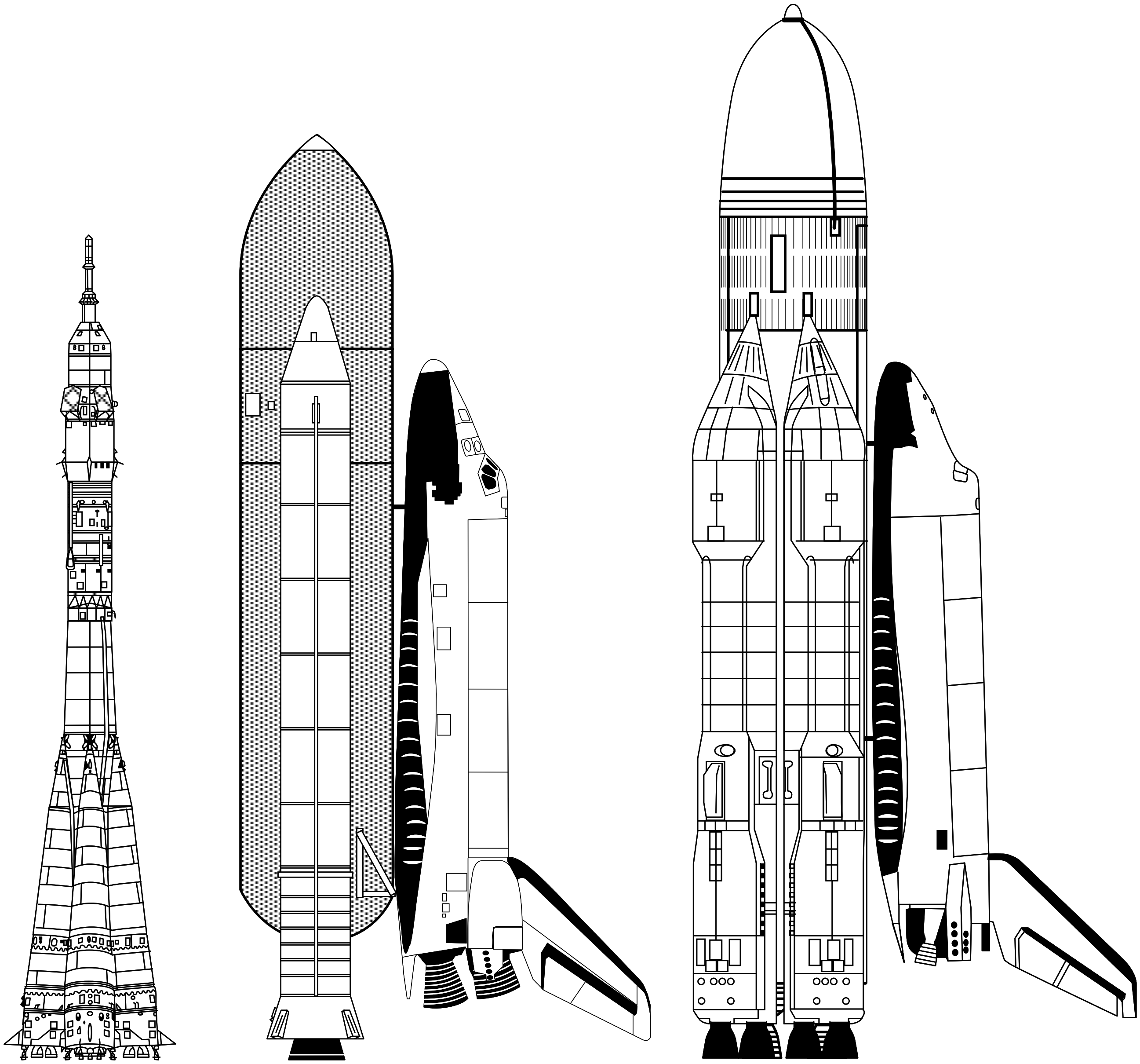

Figure 4-5. Soyuz rocket (left), Space Shuttle (center), and Energia-Buran (right) (drawn to scale). Rockets currently used to launch manned spacecraft into orbit.

April 27	**Soyuz-TM 7 reentry**—Polyakov, Krikalev, and Volkov return to Earth. Mir is left unmanned because of delays in the arrival of expansion modules for its lateral ports.
May 4-8	STS-30—David Walker, Ronald Grabe, Norman Thagard, Mary Cleave, and Mark Lee launch the Venus-bound Magellan interplanetary probe from Atlantis's payload bay.
August 8-13	STS-28—Brewster Shaw, Richard Richards, David Leestma, James Adamson, and Mark Brown are the crew of Columbia for a Department of Defense mission.

	August 23-December 1	**Progress-M 1**—First flight of an advanced Progress incorporating many Soyuz-TM features.
	September 5	**Soyuz-TM 8 launch**—The spacecraft docks with Mir's aft port with cosmonauts Alexandr Serebrov and Alexandr Viktorenko aboard.
	October 18-23	STS-34—Donald Williams, Michael McCulley, Shannon Lucid, Ellen Baker, and Franklin Chang-Diaz deploy the Galileo Jupiter probe from the cargo bay of Atlantis.
	November 22-27	STS-33—Frederick Gregory, John Blaha, Story Musgrave, Kathryn Thornton, and Manley Carter are the crew of Discovery for this Department of Defense mission.
	November 26	**Kvant 2 launch** atop a Proton rocket. It docks with Mir's front port on December 6, and is berthed at a lateral port on December 8.
	December 20-February 9, 1990	**Progress-M 2.**
1990	January 9-20	STS-32—Columbia recovers the LDEF, which was launched on STS 41-C in 1984. Its crew is Daniel Brandenstein, James Wetherbee, Bonnie Dunbar, G. David Low, and Marsha Ivins.
	February 11	**Soyuz-TM 9 launch**—Carries cosmonauts Anatoli Solovyov and Alexandr Balandin. They relieve Serebrov and Viktorenko, who depart in Soyuz TM-8 on February 19. During approach, Serebrov and Viktorenko spotted damage to the thermal blankets on Soyuz-TM 9. Balandin and Solovyov make an unscheduled EVA to repair their spacecraft on July 17.
	February 28-March 4	STS-36 is a Department of Defense mission using Atlantis. Its crew is John Creighton, John Casper, David Hilmers, Richard Mullane, and Pierre Thuot.
	February 28-April 28	**Progress-M 3.**
	April 24-29	STS-31—Loren Shriver, Charles Bolden, Steven Hawley, Bruce McCandless, and Kathryn Sullivan are the crew of the Space Shuttle Discovery. They deploy the Hubble Space Telescope.
	May 5-May 27	**Progress 42.**
	May 31	**Kristall launch**—The module docks with Mir's forward port on June 10, and is berthed at a lateral port the following day.
	August 1	**Soyuz-TM 10 launch**—The transport spacecraft docks with Mir on August 3 carrying cosmonauts Gennadi Manakov and Gennadi Strekalov.
	August 9	**Soyuz-TM 9 reentry**—Balandin and Solovyov return to Earth after about 6 months in space.
	August 15-September 20	**Progress-M 4.**

	October 6-10	STS-41—Richard Richards, Robert Cabana, Bruce Melnick, William Shepherd, and Thomas Akers deploy the Ulysses solar polar probe from Discovery's cargo bay.
	November 15-20	STS-38—For this Department of Defense mission, Atlantis's crew is Richard Covey, Frank Culbertson, Robert C. Springer, Carl Meade, and Charles Gemar.
	September 27-November 28	**Progress-M 5—**After undocking from Mir and completing its deorbit burn, it detaches a Raduga recoverable capsule. The capsule, the first of its kind, carries 100 kg of space-made materials and experiment results from the Mir station. Progress-M 5 burns up as planned, and the capsule is recovered in the Soviet Union.
	December 2-10	STS-35—Vance Brand, Guy Gardner, Jeffrey Hoffman, John Lounge, Robert Parker, Samuel Durrance, and Ronald Parise operate a payload of astronomy instruments in Columbia's cargo bay.
	December 2	**Soyuz-TM 11 launch**—It docks with Mir on December 4 carrying cosmonauts Musa Manarov and Viktor Afanaseyev, and Japanese journalist Toyohiro Akiyama. Akiyama returns to Earth with Manakov and Strekalov aboard **Soyuz-TM 10** on December 10.
1991	**January 14-March 16**	**Progress-M 6.**
	February 7	**Salyut 7/Cosmos 1686** reenters over Argentina.
	March 19-May 7	**Progress-M 7** nearly collides with Mir during two docking attempts at the aft port on March 21. Manarov and Afanaseyev dock manually at Mir's aft port on March 26, permitting Progress-M 7 to dock at the front port on March 28. On April 25 they perform an EVA to repair the damaged aft rendezvous antenna.
	April 5-11	STS-37—Atlantis carries the Gamma Ray Observatory into space. Its crew consists of Steven Nagel, Kenneth Cameron, Jerry Ross, Jerome Apt, and Linda Godwin. Ross and Apt perform an EVA to free a stuck antenna on the Gamma Ray Observatory.
	April 28-May 6	STS-39—Michael Coats, L. Blaine Hammond, Gregory Harbaugh, Donald McMonagle, Guion Bluford, Lacy Veach, and Richard Hieb are Discovery's crew.
	May 7	**Progress-M 7** deorbits and detaches a recoverable capsule carrying 115 kg of space-made materials and experiment results from Mir. The capsule fails to operate correctly and is lost.
	May 18	**Soyuz-TM 12 launch—**The transport docks with Mir on May 20 carrying Sergei Krikalev, Anatoli Artsebarski, and British cosmonaut Helen Sharman. The two Soviet cosmonauts relieve Manarov and Afanaseyev, who return to Earth in **Soyuz-TM 11** with Sharman on May 26.
	May 30-August 16	**Progress-M 8.**
	June 5-14	STS-40 is the Spacelab Life Sciences 1 mission. Columbia carries Bryan O'Connor, Sidney Gutierrez, M. Rhea Seddon, James Bagian, Tamara Jernigan, F. Drew Gaffney, and Millie Hughes-Fulford into space.

	August 2-11	STS-43—John Blaha, Michael Baker, Shannon Lucid, G. David Low, and James C. Adamson are the crew of Atlantis.
	August 20-September 30	**Progress-M 9.** Deploys a recoverable capsule, which is successfully recovered.
	September 12-18	STS-48—John Creighton, Kenneth Reightler, James Buchli, Mark Brown, and Charles Gemar are the crew of Discovery. They deploy the Upper Atmosphere Research Satellite.
	October 2	**Soyuz-TM 13 launch**—Russian cosmonaut Alexandr Volkov, Kazakh cosmonaut Toktar Aubakirov, and Austrian cosmonaut Franz Viehboeck leave Earth for Mir. Aubakirov, Viehboeck, and Anatoli Artsebarski return to Earth on October 10 in **Soyuz-TM 12**, leaving Soyuz TM-13, Volkov, and Sergei Krikalev at the Mir station.
	October 17-January 20, 1992	**Progress-M 10.** Deploys a recoverable capsule.
	November 24-December 1	STS-44—Frederick Gregory, Terrence Henricks, Story Musgrave, Mario Runco, James Voss, and Thomas Hennen perform unclassified Department of Defense experiments aboard Atlantis.
1992	January 22-30	STS-42—Discovery carries International Microgravity Laboratory 1. Its crew is Ronald Grabe, Stephen Oswald, David Hilmers, Norman Thagard, William Readdy, Ulf Merbold, and Roberta Bondar.
	January 25-March 13	**Progress-M 11.**
	March 17	**Soyuz-TM 14 launch**—Alexandr Viktorenko, Alexandr Kaleri, and Klaus-Dietrich Flade (Germany) leave Kazakh territory for Mir (Russian territory). Flade returns to Earth in **Soyuz TM-13** with Krikalev and Volkov on March 25. Krikalev spent 311 days on Mir.
	March 24-April 2	STS-45—Charles Bolden, Brian Duffy, Kathryn Sullivan, David Leestma, C. Michael Foale, Dirk Frimout, and Byron Lichtenberg operate the Atmospheric Laboratory for Applications and Science (ATLAS) 1 payload in Atlantis's payload bay.
	April 19-June 27	**Progress-M 12.**
	May 7-16	STS-49 is the first flight of the Shuttle Endeavour. Its crew is Daniel Brandenstein, Kevin Chilton, Pierre Thuot, Kathryn Thornton, Richard Hieb, Thomas Akers, and Bruce Melnick. Thuot, Hieb, Thornton, and Akers perform a series of four EVAs to test space station assembly methods and to capture and repair the Intelsat VI satellite.
	June 25-July 9	STS-50—Columbia carries U.S. Microgravity Laboratory 1. Its crew is Richard Richards, Kenneth Bowersox, Bonnie Dunbar, Ellen Baker, Carl Meade, Lawrence DeLucas, and Eugene Trinh.
	June 30-July 24	**Progress-M 13.**

	July 27	**Soyuz-TM 15** launch—Docks with Mir on July 29 carrying cosmonauts Anatoli Solovyov, Sergei Avdeyev, and Michel Tognini (France). Tognini returns to Earth with Viktorenko and Kaleri on August 10 in **Soyuz-TM 14**. Their Earth-landing system malfunctions, so the capsule lands hard and comes to rest upside down, trapping the crew until it can be turned over.
	July 31-August 8	STS-46—Atlantis deploys the Italian-built Tethered Satellite System and ESA's EURECA experiment carrier on the STS-46 mission. Claude Nicollier (ESA), Franco Malerbo (Italy), Marsha Ivins, Franklin Chang-Diaz, Loren Shriver, Andrew Allen, and Jeffrey Hoffman are its crew.
	August 15-October 20	**Progress-M 14** carries in its modified tankage compartment the VDU thruster package, to be mounted at the end of the Sofora truss assembled in July 1991 by Krikalev and Artsebarski. **Progress-M 14**'s Raduga capsule is recovered on October 20.
	September 12-20	STS-47—Endeavour carries Spacelab-J into orbit. Mamoru Mohri (Japan), Mae Jemison, N. Jan Davis, Jerome Apt, Mark Lee, Curtis Brown, and Robert Gibson are its crew. This is the fiftieth Space Shuttle mission.
	October 22-November 1	STS-52—Lacy Veach, James Wetherbee, Steven MacLean (Canada), Michael Baker, Tamara Jernigan, and William Shepherd are the crew of Columbia. They deploy the LAGEOS 2 satellite atop an Italian Research Interim Stage and operate the Canadian Experiments (CANEX) 2 package.
	October 27-February 7, 1993	**Progress-M 15**. On February 4, 1993, the spacecraft backs away from Mir and deploys Znamya, a 20-m solar mirror, from its orbital module. The test lasts about 5 hr.
	December 2-9	STS-53 is the last largely Department of Defense-dedicated mission. David Walker, Robert Cabana, Guion Bluford, James Voss, and Michael Richard Clifford are its crew.
1993	January 13-19	STS-54—John Casper, Donald McMonagle, Mario Runco, Gregory Harbaugh, and Susan Helms deploy a TDRS from Endeavour.
	January 24	**Soyuz-TM 16 launch**—Docks with the APAS-89 androgynous port on Mir's Kristall module to test it in preparation for U.S. Shuttle (and possible **Buran** shuttle) visits to Mir. Its crew is Gennadi Manakov and Alexandr Poleshchuk. They replace Solovyov and Avdeyev, who return to Earth in **Soyuz-TM 15** on February 1.
	February 21-March 27	**Progress-M 16.**
	March 31	**Progress-M 17 launch**. Docks at Kvant port on April 2. Progress-M 17 is earmarked for a long-duration orbital experiment. See September 13, 1993 entry.
	April 8-17	STS-56—Ellen Ochoa, Steve Oswald, Kenneth Cameron, Michael Foale, and Kenneth Cockrell release and retrieve the SPARTAN 201 free-flying payload, and operate the ATLAS 2 package in Discovery's payload bay.

	April 26-May 6	STS-55 is the Spacelab D2 mission. Columbia's crew comprises German astronauts Ulrich Walter and Hans Schlegel, and U.S. astronauts Terrence Henricks, Jerry Ross, Steve Nagel, Bernard Harris, and Charles Precourt.
	May 22-July 4	**Progress-M 18.** Its Raduga capsule is successfully recovered.
	June 21-July 1	STS-57—Endeavour carries the first commercial Spacehab module. Its crew is Ron Grabe, Brian Duffy, David Low, Janice Voss, Nancy Sherlock, and Jerry Wisoff.
	July 1	**Soyuz-TM 17 launch**—Alexandr Serebrov, Vasili Tsibliyev, and Jean-Pierre Haignere (France) arrive at Mir on July 3. Tsibliyev and Serebrov spell Poleshchuk and Manakov, who return to Earth with Hagniere in **Soyuz-TM 16** on July 22.
	August 10-October 13	**Progress-M 19**—Carries a Raduga capsule.
	September 12-22	STS-51—Discovery deploys the Advanced Communication Technology Satellite. Its crew is Frank Culbertson, William Readdy, James Newman, Daniel Bursch, Carl Walz.
	September 13	**Progress-M 17 undocks**—The spacecraft moves to a storage orbit 10 km below Mir.
	October 11-November 21	**Progress-M 20**—Carries a Raduga capsule.
	October 18-November 1	STS-58 is the Spacelab Life Sciences 2 mission. Columbia's crew is John Blaha, M. Rhea Seddon, Shannon Lucid, Rick Searfoss, Bill MacArthur, David Wolf, and Martin Fettman.
	December 2-12	STS-61—Space Shuttle Endeavour makes rendezvous with the Hubble Space Telescope. Through a series of five space walks, astronauts Story Musgrave, Jeffrey Hoffman, Kathryn Thornton, and Tom Akers repair Hubble. Crew members also include Claude Nicollier (ESA), Richard Covey, and Kenneth Bowersox. STS-61 is the fifty-ninth flight of the Space Shuttle program.
1994	**January 8**	**Soyuz-TM 18 launch**—Yuri Usachyov, Viktor Afanaseyev, and Valeri Polyakov dock with Mir on January 10. Usachyov and Afanaseyev replace Serebrov and Tsibliyev, who undock in **Soyuz-TM 17** on January 14. They fly around Mir and inspect a NASA JSC-built rendezvous and docking target installed on Kristall in anticipation of Shuttle visits to Mir. **Soyuz-TM 17** accidentally strikes Kristall, causing no apparent damage. Usachyov and Afanaseyev were replaced aboard Mir by the Soyuz-TM 18 crew in July 1994. Polyakov, a medical doctor, is to live aboard Mir for 14 mo.
	January 28-March 23	**Progress-M 21.**
	February 3-11	*STS-60—N. Jan Davis, Charles Bolden, Ken Reightler, Franklin Chang-Diaz, Ron Sega, and Sergei Krikalev (Russia) are the crew of the first joint U.S.-Russian piloted mission. Krikalev is the first Russian since 1965 to reach space in a vehicle other than a Soyuz. Discovery carries Spacehab 2 and the Wake Shield Facility.*

March 3	**Progress-M 17,** in orbit since April 1993, reenters over South America.
March 4-18	STS-62—John Casper, Andrew Allen, Pierre Thuot, Charles Gemar, and Marsha Ivins are the crew of Columbia, which carries the second U.S. Microgravity Payload.
March 22-May 23	**Progress-M 22.**
April 9-20	STS-59—Endeavour carries the first Space Radar Laboratory. Its crew comprises Sidney Gutierrez, Kevin Chilton, Linda Godwin, Jay Apt, Michael Clifford, and Thomas Jones.
May 22-July 2	**Progress-M 23—**Deploys a Raduga capsule.
July 1	**Soyuz-TM 19 launch**—Docks with Mir on July 3 carrying rookies Yuri Malenchenko and Talgat Musabayev. Supplies and repair parts for the station fill its third seat.
July 8-23	STS-65—Space Shuttle Columbia carries the International Microgravity Laboratory-2 payload. Commander Robert Cabana speaks with the Russian cosmonauts on Mir by radio. Other crew members are James Halsell, Richard Hieb, Carl Walz, Leroy Chiao, Donald Thomas, and Chiaki Naito-Mukai (Japan).
July 9	**Soyuz-TM 18 landing—**Usachyov and Afanaseyev return to Earth, leaving Polyakov aboard with Malenchenko and Musabayev.
August 25-October 4	**Progress-M 24.** Malenchenko docks the cargo ship by remote control from a control post inside Mir after two failed automatic approaches. During the second approach, on August 30, the spacecraft struck Mir's forward docking port 2-4 times. No damage was discovered during a September 9 EVA.
September 9-20	STS-64—Richard Richards, L. Blaine Hammond, Jerry Linenger, Susan Helms, Carl Meade, and Mark Lee are Discovery's crew. They deploy and retrieve the Spartan 201 satellite and use lasers to study Earth's environment. Lee and Meade conduct a 6 hr, 51 min spacewalk to test SAFER, a self-rescue maneuvering unit.
September 30-October 11, 1994	STS-68—Endeavour, on the 65th flight of the Shuttle program, carries aloft the second Space Radar Laboratory. Michael Baker, Terrence Wilcutt, Steven Smith, Thomas Jones, Daniel Bursch, and Jeff Wisoff are its crew.
October 3	**Soyuz-TM 20 launch.** Docking takes place early on October 6. The space-craft carries four-time Mir visitor Alexandr Viktorenko, rookie Yelena Kondakova, and ESA cosmonaut Ulf Merbold. Kondakova is the third Russian woman in space, and the first scheduled for a long-duration flight. Merbold, a veteran of two Space Shuttle flights, is the first non-Russian/non-American to fly on both U.S. and Russian craft.

November 4	**Soyuz-TM 19 landing.** Malenchenko, Musabayev, and Merbold land uneventfully in northern Kazakhstan 3.5 hours after separating from the Mir station.
November 11-	**Progress-M 25.** Docking at the aft port on November 13 occurred without incident.

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