

## 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.”<sup>1,2</sup>

- Basic FGB structure, including pressurized volume

- Rendezvous and docking systems
- $\Delta V$  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.<sup>3,4</sup> 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

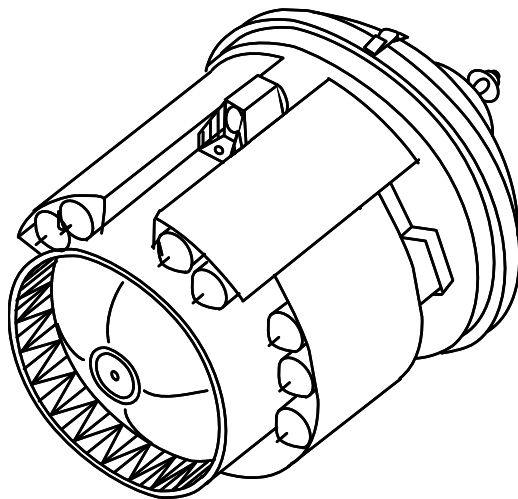


Figure 3-2. FGB. This is a simplified aft view of the propulsion/cargo module used in the TKS vehicles and as the basis for subsequent space station modules and tugs. Aft (left) details are conjectural. Solar arrays are omitted for clarity.

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

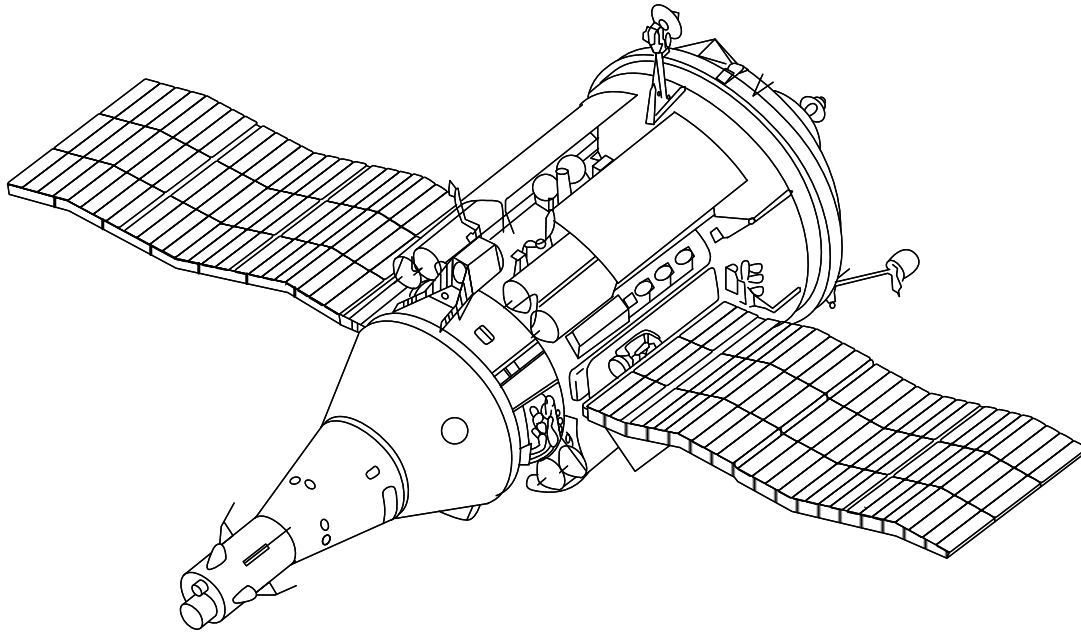


Figure 3-3. TKS. The FGB and Merkur vehicles were joined together aft end to aft end to form a TKS; thus, this is a front view of the conical Merkur capsule (left), and an aft view of the FGB (right).

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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.<sup>5,6</sup>

### 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

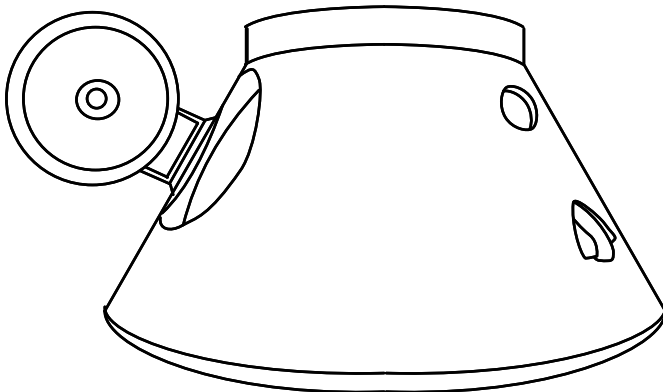


Figure 3-4. Merkur capsule.

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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.<sup>7</sup> 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 identified 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.<sup>8</sup> 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.<sup>9</sup> 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.<sup>10</sup>

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.<sup>11</sup>

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.<sup>12</sup>

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.<sup>13</sup>

### 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 <sup>3</sup>
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 compart-

ment. 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.

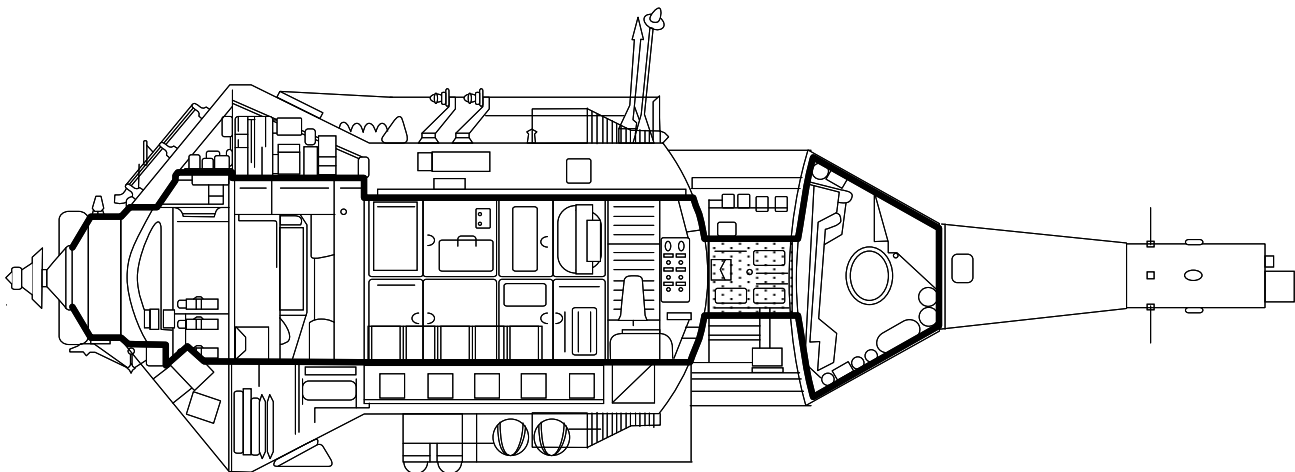


Figure 3-5. Cutaway of TKS vehicle. Details are conjectural. The broad black line outlines the vehicle's pressurized compartments. A tunnel (stippled) connects the FGB and Merkur capsule.

- 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

<b>Cosmos 881-882</b>	December 15, 1976
<p>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.</p>	
<b>Cosmos 929</b>	July 17, 1977-February 2, 1978
<p>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.</p>	
<b>Launch failure</b>	August 4, 1977
<p>The launch escape system rescued the top Merkur capsule for reuse after its Proton booster malfunctioned. The bottom capsule was destroyed.</p>	
<b>Cosmos 997-998</b>	March 30, 1978
<p>Dual test of Merkur capsules.</p>	
<b>Cosmos 1100-1101</b>	May 22-23, 1979
<p>Dual test of Merkur capsules.</p>	
<b>Cosmos 1267</b>	April 25, 1981-July 29, 1982
<p>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.</p>	

**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

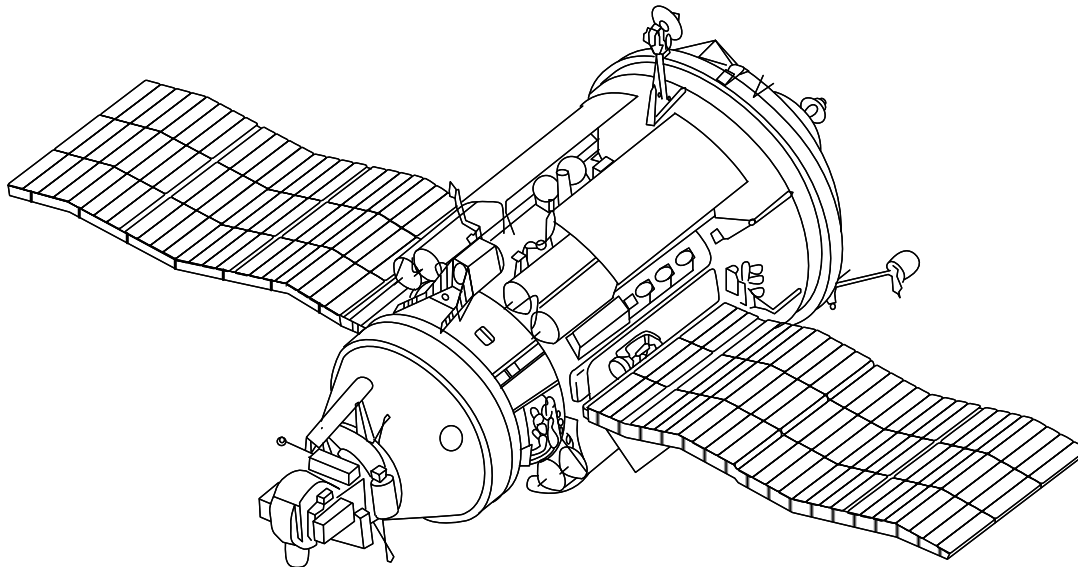


Figure 3-6. Cosmos 1686. Note the Merkur capsule (left), heavily modified to house scientific instruments.

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**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.

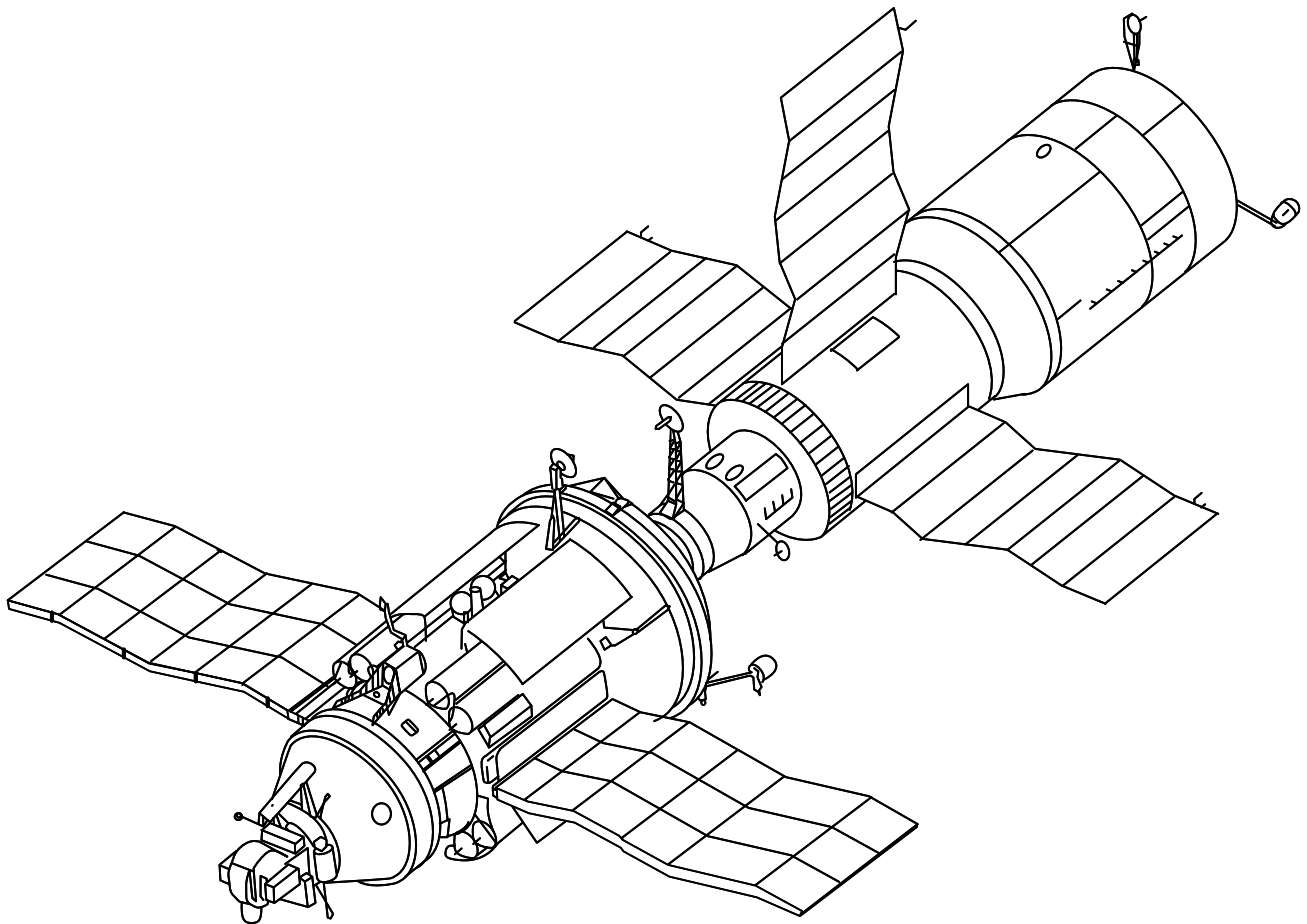


Figure 3-7. Cosmos 1686 and Salyut 7.

### 3.5 Kvant

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

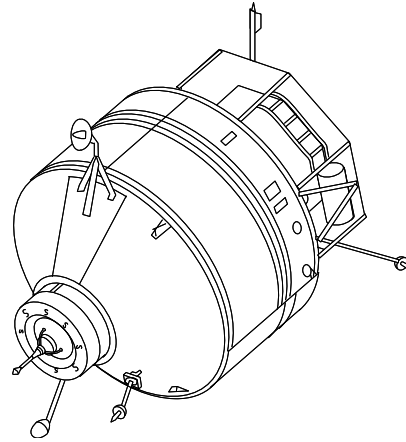


Figure 3-8. Kvant module.

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#### 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 <sup>3</sup>
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.<sup>14</sup>
- 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.<sup>15</sup> 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<sup>2</sup> 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 <sup>3</sup>
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

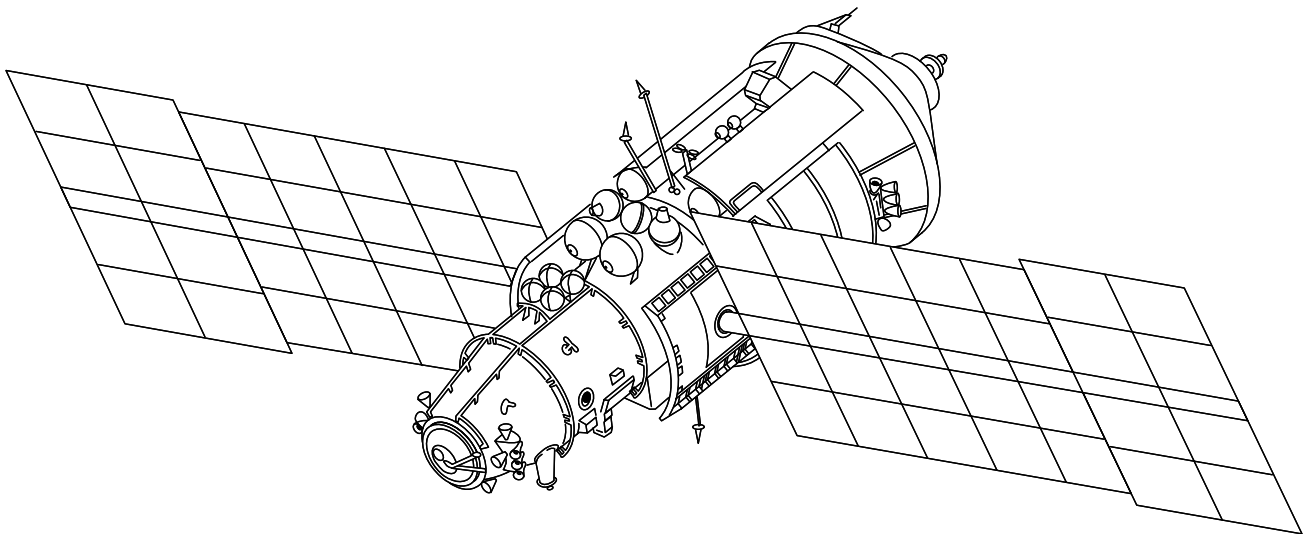


Figure 3-9. Kvant 2 module. Kvant 2 houses an EVA airlock (hatch visible at left).

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 multi-spectral 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.

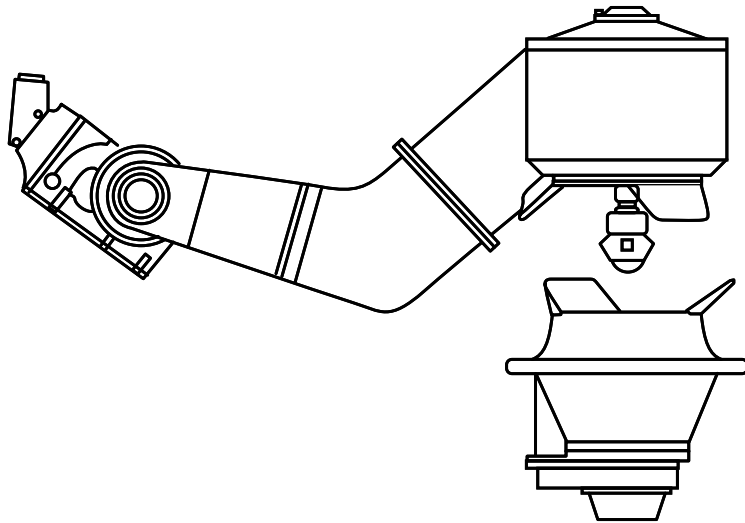


Figure 3-10. Lyappa arm. Modules for Mir's lateral ports first dock at the front longitudinal port. Each module carries a Lyappa arm (top), which attaches to a socket (bottom) on the outside of the Mir multiport node. The arm then pivots the module to the proper lateral berthing port.

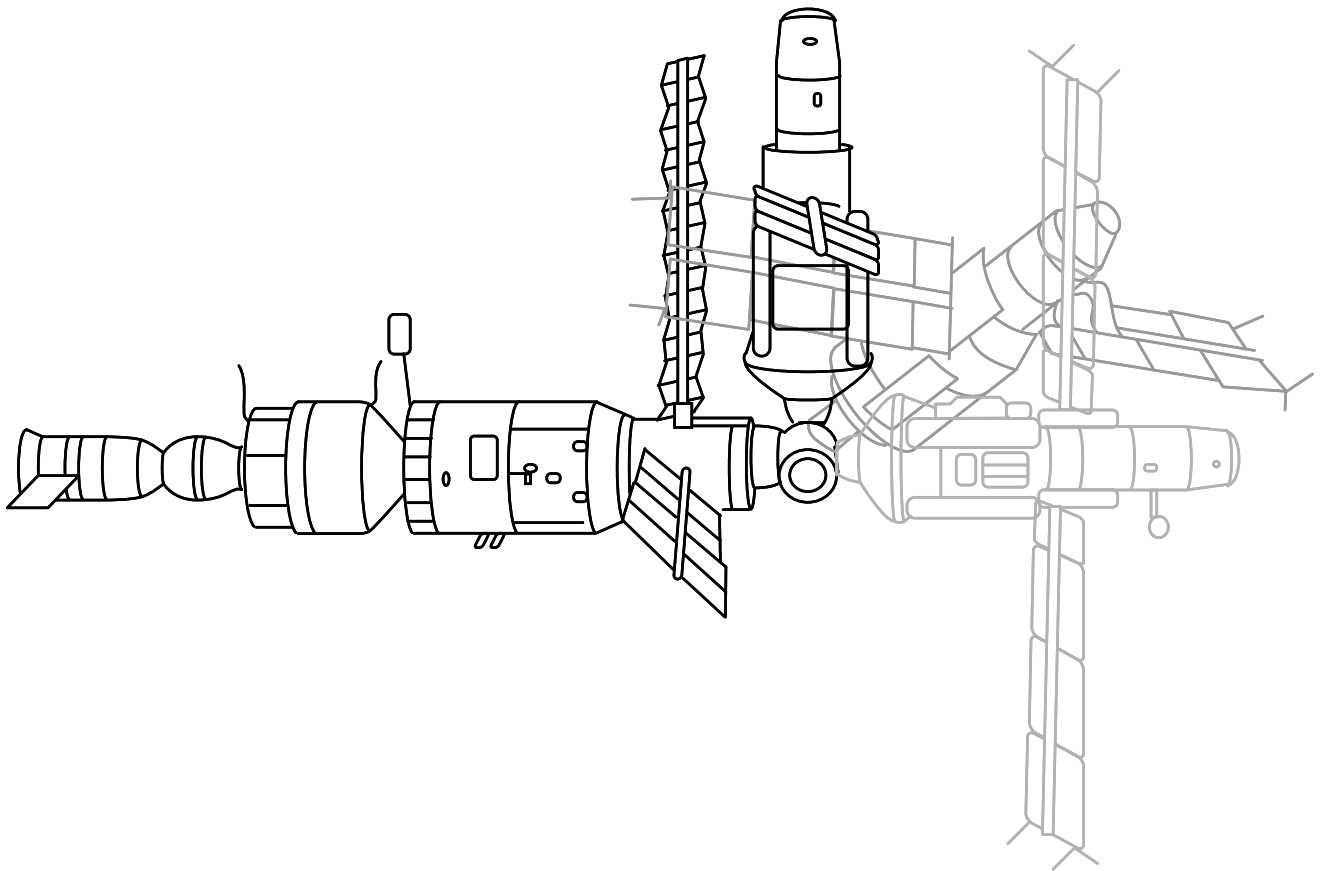


Figure 3-11. Repositioning Kvant module using Lyappa arm.

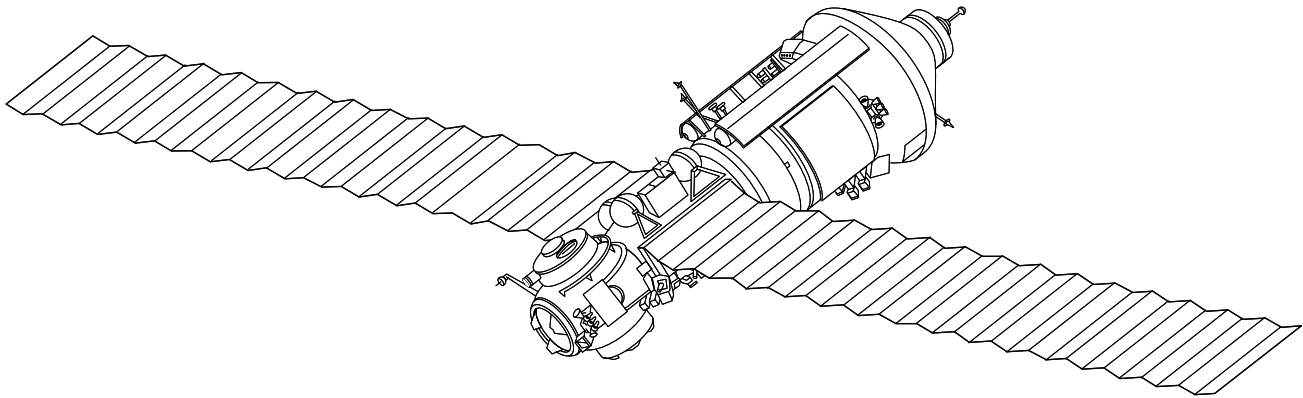


Figure 3-12. Kristall module. Kristall joined Mir in 1990. It carries two APAS-89 docking units (left).

### 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 <sup>3</sup>
Span across solar arrays .....	about 36 m (maximum)

#### 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

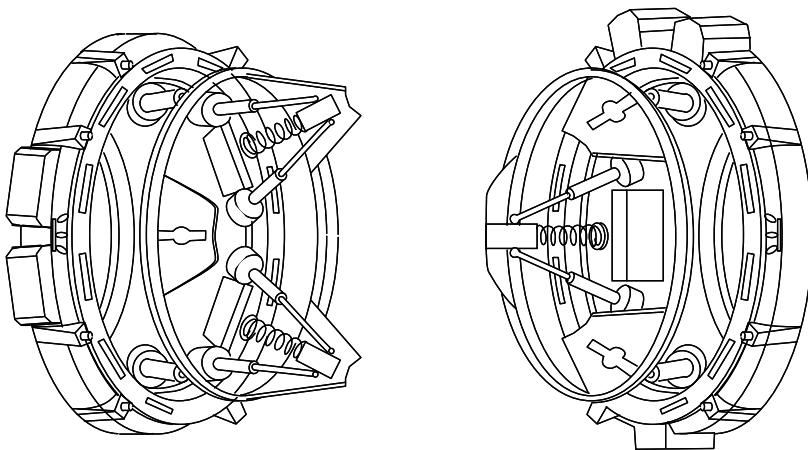


Figure 3-13. APAS-89 androgynous docking unit.

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 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.<sup>16</sup>

- 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.

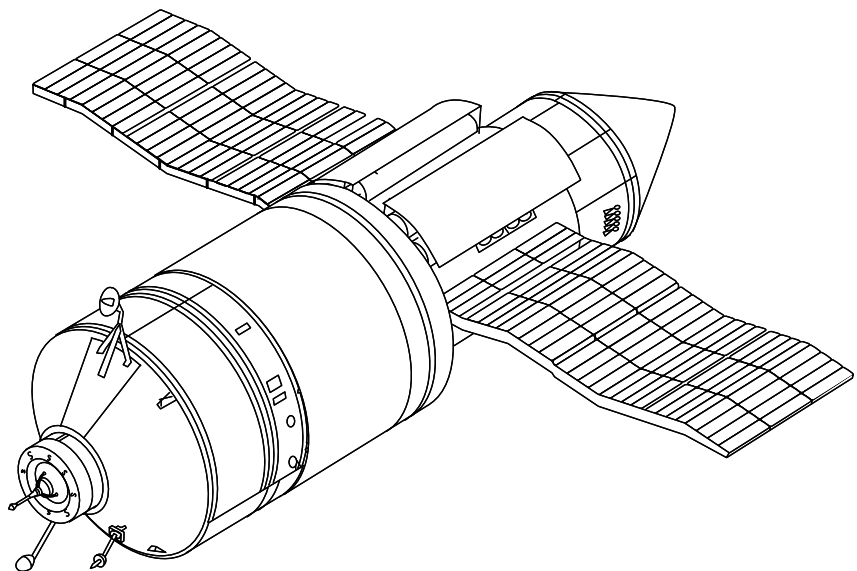


Figure 3-14. Kvant and FSM. The streamlined fairing covering the aft end of the FSM (right) pointed upwards at liftoff, and formed the nose of the launch stack.

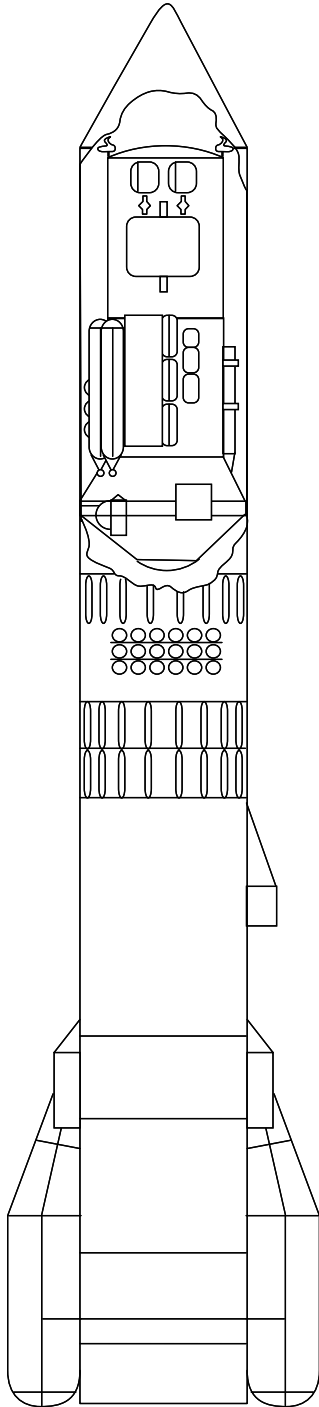


Figure 3-15. Polyus cutaway. Displays the FGB-based service/propulsion module. Note that, like other FGB-based vehicles, it launched aft end up. This places Polyus' front end at the bottom. The streamlined projections on Polyus' sides were dispensers for experimental tracking targets.

### 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).<sup>17</sup> 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.

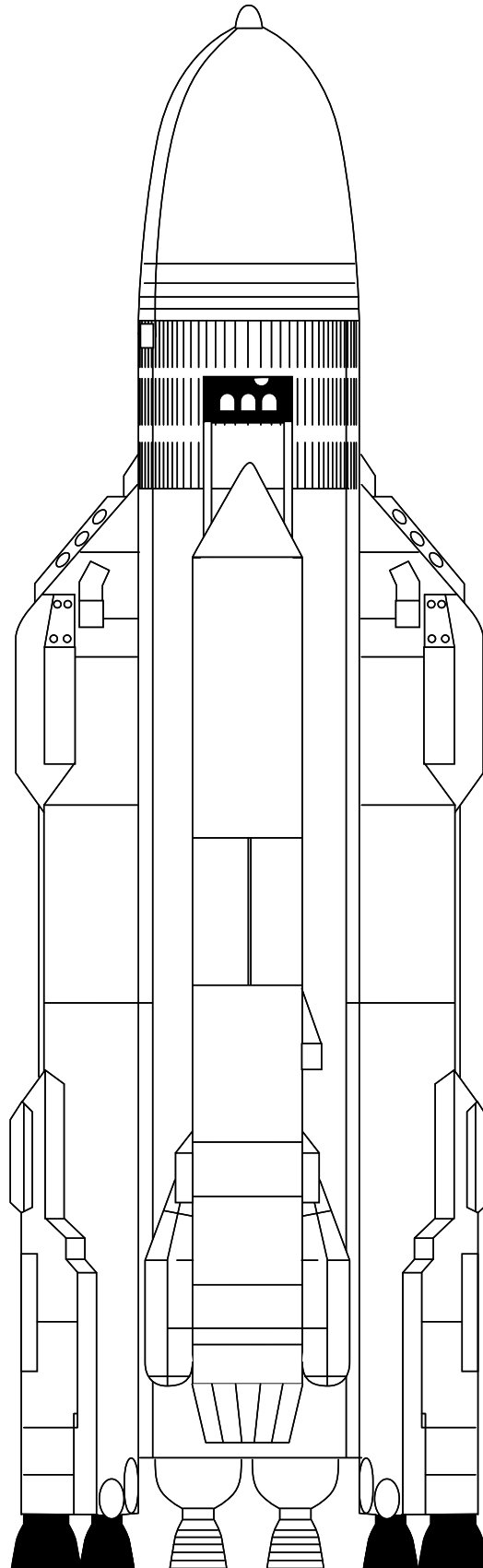


Figure 3-16. Polyus satellite on Energia launch vehicle.

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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.

<b>1961</b>	<b>April 12</b>	<b>Vostok 1</b> —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.
<b>1962</b>	February 20	Mercury-Atlas 6 (Friendship 7)—John Glenn becomes the first American to orbit Earth.
<b>1963</b>	<b>June 14-19</b>	<b>Vostok 5</b> —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.
<b>1964</b>	<b>October 12-13</b>	<b>Voskhod 1</b> —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.
<b>1965</b>	<b>March 18-19</b>	<b>Voskhod 2</b> —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.
<b>1966</b>	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.
	<b>November 28-30</b>	<b>Cosmos 133</b> —Unmanned first test of Original Soyuz.

	<b>December</b>	<b>Launch failure</b> —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.
<b>1967</b>	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.
	<b>February 7-9</b>	<b>Cosmos 140</b> —Unmanned Original Soyuz test.
	<b>March 10-18</b>	<b>Cosmos 146</b> —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.
	<b>April 8-10</b>	<b>Cosmos 154</b> —Unmanned L1 test. It fails to test the high-velocity reentry characteristics of the L1 because the Block D fourth stage fails to restart.
	<b>April 23-24</b>	<b>Soyuz 1</b> —At the end of a trouble-plagued flight, Vladimir Komarov dies when his descent module parachute system fails.
	<b>September 28</b>	<b>Launch failure</b> —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.
	<b>October 27- November 2</b>	<b>Cosmos 186</b> and <b>Cosmos 188</b> 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.
	<b>November 22</b>	<b>Launch failure</b> —An L1 ejects when the second stage of its Proton rocket fails.
<b>1968</b>	January 22	Apollo 5—An uprated Saturn I rocket launches the first Apollo lunar module (LM) on a successful unmanned test flight.
	<b>March 2-9</b>	<b>Zond 4</b> 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.
	<b>April 14-20</b>	<b>Cosmos 212</b> and <b>Cosmos 213</b> are unmanned Soyuz craft. They dock on April 15.
	<b>April 23</b>	<b>Launch failure</b> —An L1 escape system triggers inadvertently during second stage operation of its Proton rocket.
	<b>August 28- September 1</b>	<b>Cosmos 238</b> is a successful unmanned Original Soyuz test.

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<b>September 14-21</b>	<b>Zond 5</b> 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.
<b>October 25-30</b>	<b>Soyuz 2</b> and <b>Soyuz 3</b> —Georgi Beregevoi, in Soyuz 3, twice approaches the unmanned Soyuz 2 spacecraft, but is unable to dock.
<b>November 10-17</b>	<b>Zond 6</b> 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.

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<b>1969</b>	<b>January 14-18</b>	<b>Soyuz 4</b> and <b>Soyuz 5</b> 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.
	<b>January 20</b>	<b>Launch failure</b> —A four-stage Proton launch vehicle malfunctions. Its L1 payload ejects.
	<b>February 20</b>	<b>N-1 test</b> —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 <i>Spider</i> in Earth orbit. First manned flight of the LM.
	<b>July 3</b>	An <b>N-1 test</b> 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 <i>Eagle</i> lands on July 20. Michael Collins remains in orbit aboard the CSM <i>Columbia</i> .
	<b>August 7-14</b>	<b>Zond 7</b> carries out an unmanned circumlunar flight. It is the most successful of the L1 missions.
	<b>October 11-18</b>	<b>Soyuz 6</b> , <b>Soyuz 7</b> , and <b>Soyuz 8</b> —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 <i>Intrepid</i> lands on Oceanus Procellarum on November 19. <i>Intrepid's</i> crew is Pete Conrad and Alan Bean. Richard Gordon remains in lunar orbit in <i>Yankee Clipper</i> .

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<b>1970</b>	April 11-17	Apollo 13—CSM <i>Odyssey</i> is disabled by an onboard explosion, scrubbing the third U.S. lunar landing attempt. <i>Aquarius</i> , the LM, serves as a lifeboat for James Lovell, Fred Haise, and Jack Swigert.
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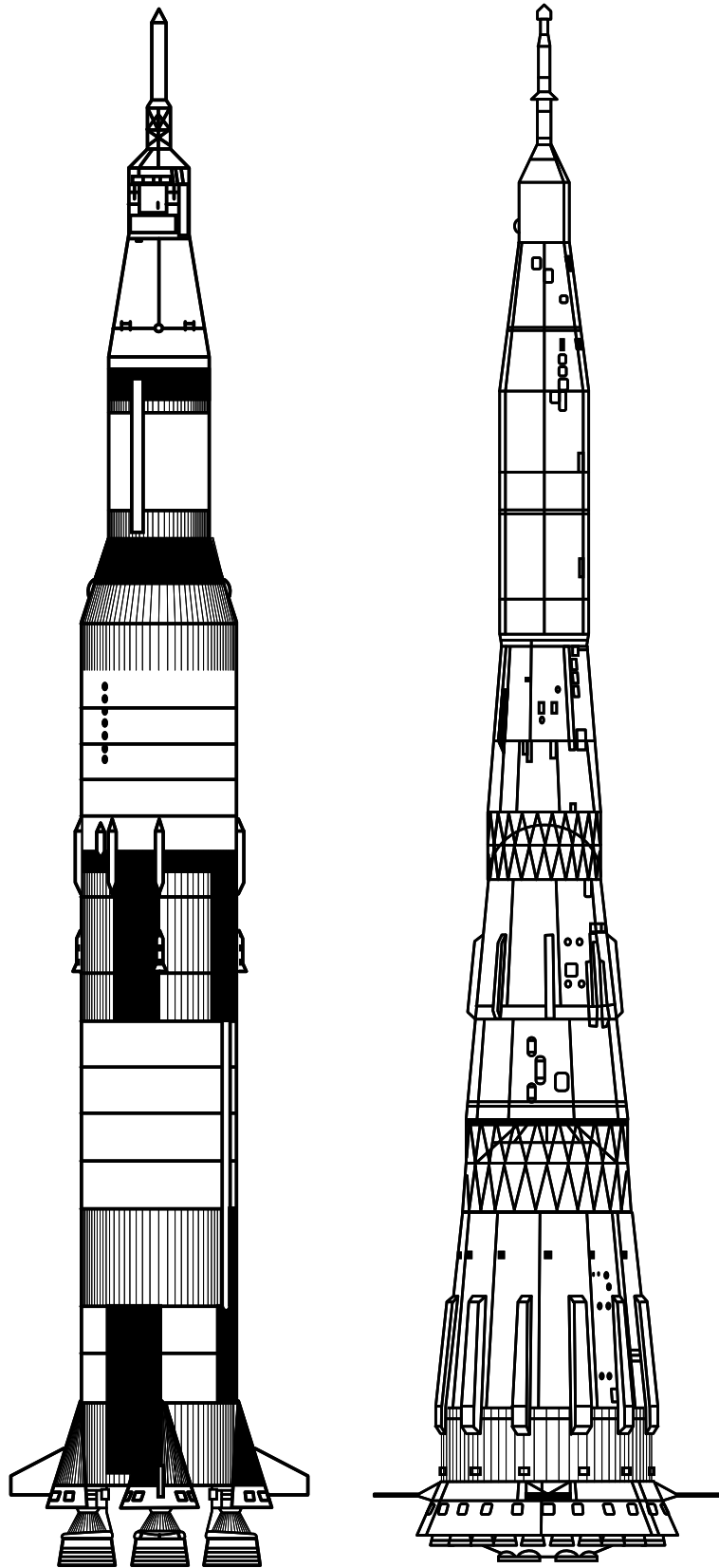


Figure 4-1. Saturn V (left) and N-1 (drawn to scale).  
Manned Moon rockets.

- 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.

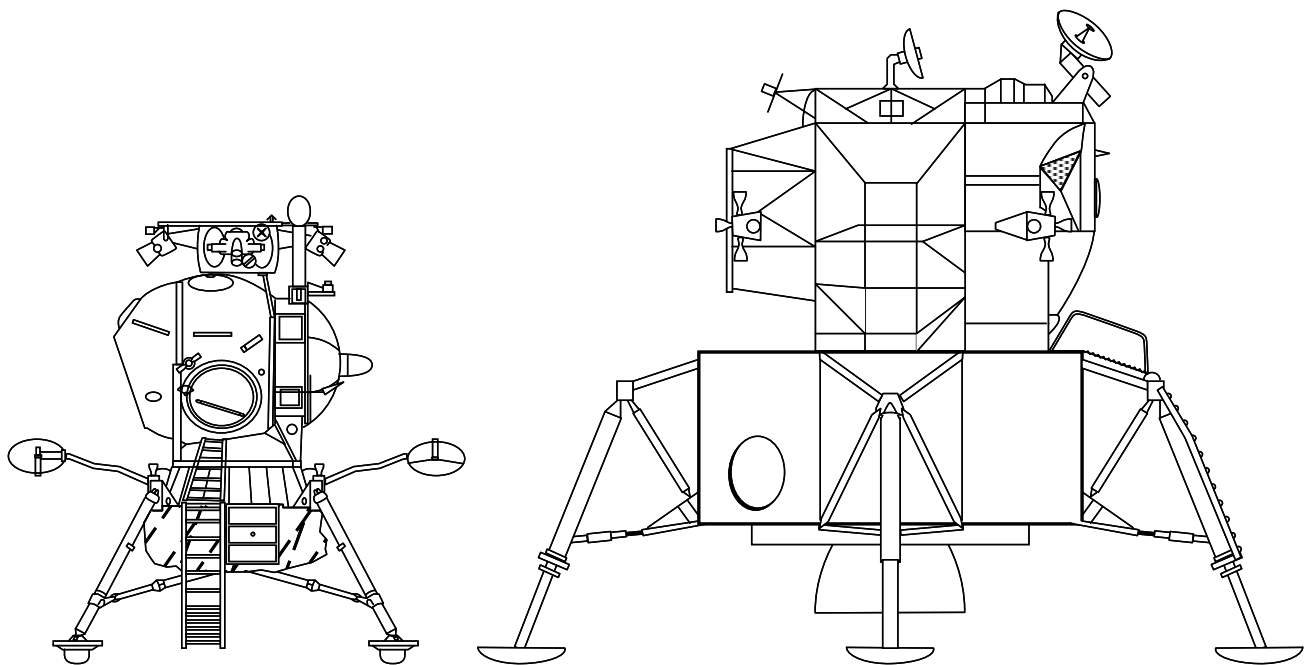


Figure 4-2. L3 (left) and Apollo LM (drawn to scale). Manned Moon landers.

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.

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**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.

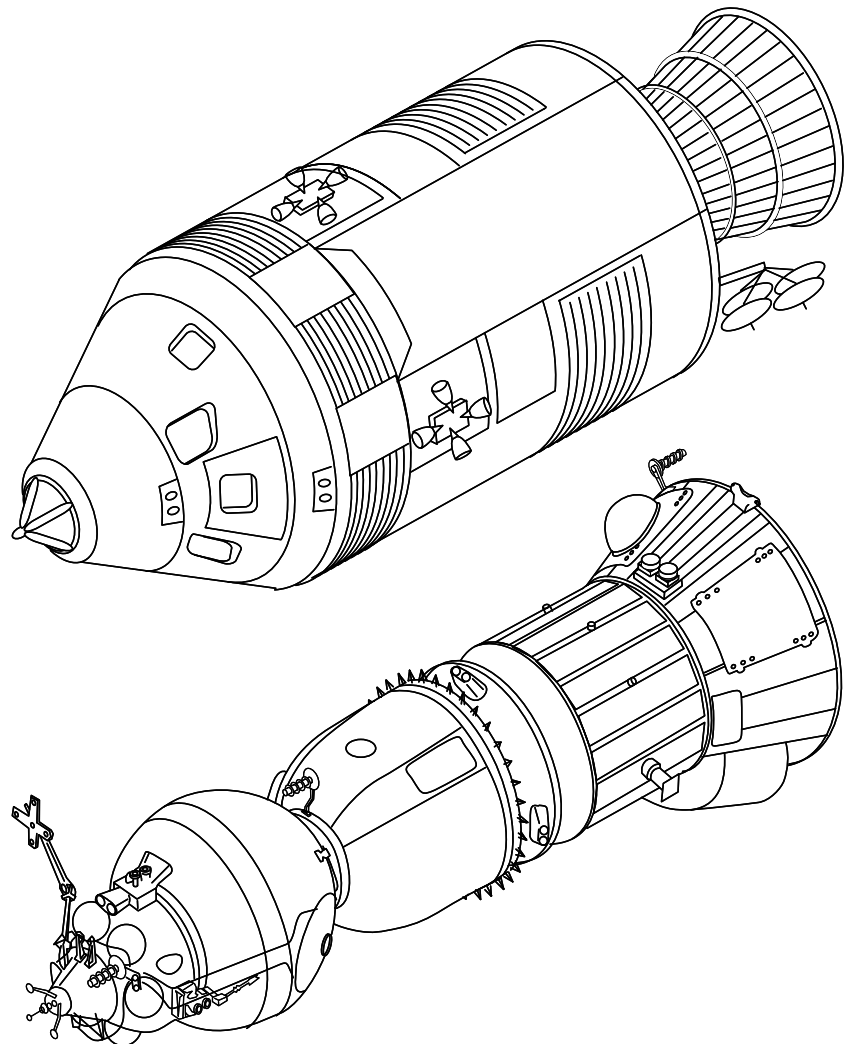


Figure 4-3. Apollo CSM (top) and L2 (drawn to scale).  
Command ships for the Moon voyage.

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<b>November 23</b>	<b>N-1 test</b> 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 <i>Challenger</i> 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 <i>America</i> in orbit. This is the last human flight beyond low Earth orbit and the last flight of the successful LM spacecraft.
<b>1973</b>	
<b>April 3-May 28</b>	<b>Salyut 2/Almaz 1 launch</b> —First of the primarily military Almaz-type Salyuts. Salyut 2 breaks up soon after reaching orbit.
<b>May 11-22</b>	<b>Cosmos 557/DOS-3 launch</b> —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.
<b>June 15-17</b>	<b>Cosmos 573</b> 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.
<b>September 27-29</b>	<b>Soyuz 12</b> —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).
<b>November 30-January 29, 1974</b>	<b>Cosmos 613</b> is an unmanned test of the Soyuz Ferry vehicle in long-duration orbital storage.
<b>December 18-26</b>	<b>Soyuz 13</b> —Valentin Lebedev and Pyotr Klimuk use the Soyuz orbital module as a laboratory for conducting experiments of the kind planned for future space stations.
<b>1974</b>	
<b>April 3-13</b>	<b>Cosmos 638</b> is the first unmanned test of the Soyuz modified for ASTP. The spacecraft carries the APAS-75 androgynous docking system.
<b>June 24</b>	<b>Salyut 3/Almaz 2 launch.</b>
<b>July 3-19</b>	<b>Soyuz 14</b> —Pavel Popovich and Yuri Artyukhin live aboard the Salyut 3 station for 16 days.
<b>August 12-18</b>	<b>Cosmos 672</b> is the second unmanned test of the ASTP Soyuz.
<b>August 26-28</b>	<b>Soyuz 15</b> —Gennadi Sarafanov and Lev Demin fail to dock with Salyut 3.

	<b>September 23</b>	<b>Salyut 3/Almaz 2 capsule reenters, is recovered.</b> The station reenters on January 24, 1975.
	<b>December 2-8</b>	<b>Soyuz 16</b> —Anatoli Filipchenko and Nikolai Rukavishnikov test the ASTP Soyuz.
	<b>December 26</b>	<b>Salyut 4/DOS-4 launch.</b>
<b>1975</b>	<b>January 10-February 9</b>	<b>Soyuz 17</b> —Alexei Gubarev and Georgi Grechko live aboard Salyut 4.
	<b>April 5</b>	<b>“The April 5 Anomaly”</b> 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.
	<b>May 24-July 26</b>	<b>Soyuz 18</b> —Pyotr Klimuk and Vitali Sevastyanov live for 62 days aboard Salyut 4. Called Soyuz 18b in the West.
	<i>July 15-July 24</i>	<i>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.</i>
	<b>November 17-February 16, 1976</b>	<b>Soyuz 20</b> —Unmanned Progress-related test. Docks with Salyut 4.
<b>1976</b>	<b>June 22</b>	<b>Salyut 5/Almaz 3 launch.</b>
	<b>July 6-August 24</b>	<b>Soyuz 21</b> —Boris Volynov and Vitali Zholobov spend 49 days on Salyut 5.
	<b>September 15-23</b>	<b>Soyuz 22</b> —Valeri Bykovskii and Vladimir Aksyonov conduct an Earth observation mission using the backup ASTP Soyuz.
	<b>October 14-16</b>	<b>Soyuz 23</b> —Vyacheslav Zudov and Valeri Rozhdestvenski are unable to dock with Salyut 5.
	<b>November 29-December 17</b>	<b>Cosmos 869</b> —Unmanned test of Soyuz-T.
	<b>December 15</b>	<b>Cosmos 881</b> and <b>Cosmos 882</b> are two Transport Logistics Spacecraft (TKS) capsules (Merkur capsules) launched atop a Proton rocket. They reenter and are recovered the same day.
<b>1977</b>	<b>February 7-25</b>	<b>Soyuz 24</b> —Viktor Gorbato and Yuri Glazkov are the last crew to stay aboard Salyut 5.
	<b>February 26</b>	<b>Salyut 5 capsule reenters</b> —The last Almaz Salyut station reenters on August 8, 1977.



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<b>July 17- February 2, 1978</b>	<b>Cosmos 929</b> 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.
<b>August 4</b>	<b>Launch failure</b> 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.
<b>September 29</b>	<b>Salyut 6/DOS-5 launch.</b>
<b>October 9-11</b>	<b>Soyuz 25</b> —Vladimir Kovalyonok and Valeri Ryumin are unable to hard dock with the front port of Salyut 6.
<b>December 10</b>	<b>Soyuz 26</b> —Yuri Romanenko and Georgi Grechko dock at the rear port of Salyut 6.
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<b>1978</b>	
<b>January 10</b>	<b>Soyuz 27 launch</b> —Vladimir Dzhaniybekov and Oleg Makarov dock with the Salyut 6 front port on January 10. They return to Earth in the <b>Soyuz 26</b> spacecraft on January 16.
<b>January 20- February 8</b>	<b>Progress 1</b> —The unmanned, Soyuz-based space station logistics support craft delivers supplies to Salyut 6. It docks at the aft port on January 22.
<b>March 2-10</b>	<b>Soyuz 28</b> —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.
<b>March 16</b>	<b>Soyuz 27 reentry</b> —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.
<b>March 30</b>	<b>Cosmos 997</b> and <b>Cosmos 998</b> are two Merkur capsules launched on a single three-stage Proton rocket. They reenter and are recovered the same day.
<b>April 4-15</b>	<b>Cosmos 1001</b> —Unmanned test of Soyuz-T.
<b>June 15</b>	<b>Soyuz 29 launch</b> —Vladimir Kovalyonok and Alexander Ivanchenkov travel to Salyut 6.
<b>July 7- August 4</b>	<b>Progress 2.</b>
<b>June 27-July 5</b>	<b>Soyuz 30</b> —Miroslaw Hermaszewski (Poland) and Pyotr Klimuk visit Salyut 6.
<b>August 7-23</b>	<b>Progress 3.</b>
<b>August 26</b>	<b>Soyuz 31 launch</b> —Sigmund Jahn (East Germany) and Valeri Bykovski visit Salyut 6. They return to Earth aboard <b>Soyuz 29</b> on September 3.
<b>October 3-26</b>	<b>Progress 4.</b>

	<b>November 2</b>	<b>Soyuz 31 reentry</b> —Kovalyonok and Ivanchenkov return to Earth after 139 days on Salyut 6.
<b>1979</b>	<b>January 31-April 1</b>	<b>Cosmos 1074</b> is an unmanned long-duration test flight of the Soyuz-T spacecraft.
	<b>February 25</b>	<b>Soyuz 32 launch</b> —Vladimir Lyakhov and Valeri Ryumin travel to Salyut 6.
	<b>March 12-April 5</b>	<b>Progress 5.</b>
	<b>April 10-12</b>	<b>Soyuz 33</b> —A main engine malfunction forces Nikolai Rukavishnikov and Georgi Ivanov (Bulgaria) to abort docking with Salyut 6.
	<b>May 13-June 9</b>	<b>Progress 6.</b>
	<b>May 22-23</b>	<b>Cosmos 1100-1101</b> —The last dual Merkur capsule test.
	<b>June 6</b>	<b>Soyuz 34 launch</b> —The spacecraft, which carries no crew, is intended to replace the aging <b>Soyuz 32</b> spacecraft. <b>Soyuz 32</b> 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.
	<b>June 28-July 20</b>	<b>Progress 7.</b>
	<b>July 11</b>	Skylab reenters over Australia.
	<b>August 19</b>	<b>Soyuz 34 reentry</b> —Lyakhov and Ryumin return to Earth after 175 days in space.
	<b>December 16-March 25, 1980</b>	<b>Soyuz-T 1</b> docks automatically with Salyut 6 in the third unmanned test of the new Soyuz derivative.
<b>1980</b>	<b>March 27-April 26</b>	<b>Progress 8.</b>
	<b>April 9</b>	<b>Soyuz 35 launch</b> —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.
	<b>April 27-May 22</b>	<b>Progress 9.</b>
	<b>May 26</b>	<b>Soyuz 36 launch</b> —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 <b>Soyuz 35</b> .
	<b>June 5-9</b>	<b>Soyuz-T 2</b> —First manned test flight of Soyuz-T. Yuri Malyshev and Vladimir Aksyonov spend 2 days on Salyut 6 before returning to Earth.
	<b>June 29-July 19</b>	<b>Progress 10.</b>

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

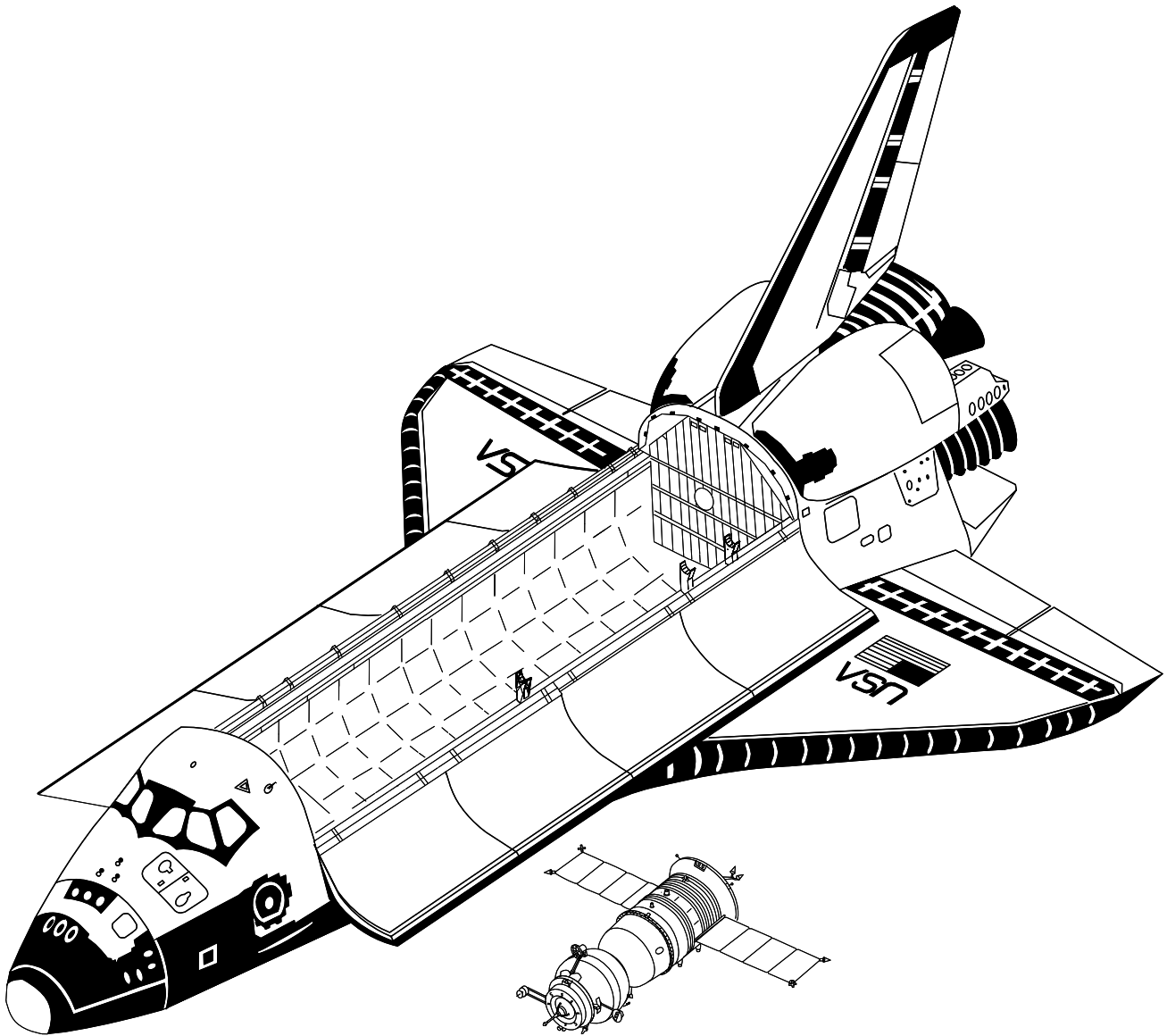


Figure 4-4. Space Shuttle Orbiter and Soyuz-TM (drawn to scale). Current spacecraft used by humans to travel in space.

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| <b>June 24-July 2</b>    | <b>Soyuz-T 6</b> —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.  |
| <b>July 10-August 13</b> | <b>Progress 14.</b>  |
| <b>July 29</b>           | The <b>Salyut 6/Cosmos 1267</b> complex deorbits using Cosmos 1267's engines.  |
| <b>August 19</b>         | <b>Soyuz-T 7</b> —Leonid Popov, Alexander Serebrov, and Svetlana Savitskaya visit the Salyut 7 station. They return to Earth in <b>Soyuz T-5</b> on August 27. |

	<b>September 18-October 16</b>	<b>Progress 15.</b>
	<b>October 31-December 14</b>	<b>Progress 16.</b>
	November 11-16	STS-5—Vance Brand, Robert Overmyer, Joseph Allen, and William Lenoir fly Columbia on the first operational Shuttle mission.
	<b>December 10</b>	<b>Soyuz-T 7 reentry</b> —Lebedev and Berezevoi return to Earth after 211 days in space.
<b>1983</b>	<b>March 2-September 19</b>	<b>Cosmos 1443</b> , 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.
	<b>April 20-22</b>	<b>Soyuz-T 8</b> —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.
	<b>June 27</b>	<b>Soyuz-T 9 launch</b> —Vladimir Lyakhov and Alexander Alexandrov fly to Salyut 7.
	<b>August 17-September 18</b>	<b>Progress 17.</b>
	August 30-September 5	STS-8—Richard Truly, Dan Brandenstein, Dale Gardner, Guion Bluford, and William Thornton are the crew of Challenger.
	<b>September 26</b>	<b>Pad Abort</b> —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.
	<b>October 20-November 16</b>	<b>Progress 18.</b>
	<b>November 23</b>	<b>Soyuz-T 9 reentry</b> —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.

<b>1984</b>	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 maneuvering unit (MMU).
	<b>February 8</b>	<b>Soyuz-T 10 launch</b> —Leonid Kizim, Vladimir Solovyov, and Oleg Atkov lift off for Salyut 7. This mission is sometimes called Soyuz T-10b in the West.
	<b>February 21- April 1</b>	<b>Progress 19.</b>
	<b>April 3</b>	<b>Soyuz-T 11 launch</b> —The spacecraft docks at Salyut 7's aft port bearing Yuri Malyshev, Gennadi Strekalov, and Rakesh Sharma (India). They return to Earth in the <b>Soyuz-T 10</b> 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.
	<b>April 15-May 7</b>	<b>Progress 20.</b>
	<b>May 7-May 26</b>	<b>Progress 21.</b>
	<b>May 28-July 15</b>	<b>Progress 22.</b>
	<b>July 17-29</b>	<b>Soyuz-T 12</b> —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.
	<b>August 14- August 28</b>	<b>Progress 23.</b>
	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.
	<b>October 2</b>	<b>Soyuz-T 11 reentry</b> —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.
<b>1985</b>	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.

<b>March 2</b>	<b>Salyut 7 career declared ended</b> —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.
<b>June 6</b>	<b>Soyuz-T 13 launch and Salyut 7 rescue</b> —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.
<b>June 21-July 15</b>	<b>Progress 24.</b>
<b>July 19-August 30</b>	<b>Cosmos 1669</b> —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.
<b>September 17</b>	<b>Soyuz-T 14 launch</b> —Carries Vladimir Vasyutin, Georgi Grechko, and Alexander Volkov to Salyut 7. Vladimir Dzhanibekov returns to Earth with Georgi Grechko in <b>Soyuz-T 13</b> on September 26. Vasyutin, Volkov, and Savinykh remain on the station.
<b>September 27</b>	<b>Cosmos 1686</b> 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 Pailles.

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.
<b>November 21</b>	<b>Soyuz-T 14 reentry</b> —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.
<b>1986</b>	
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 reseal 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.
<b>February 19</b>	<b>Mir launch.</b>
<b>March 13</b>	<b>Soyuz-T 15 launch</b> —Leonid Kizim and Vladimir Solovyov become the first cosmonauts to board Mir on March 15. They activate Mir's systems and commence systems checks.
<b>March 19-April 21</b>	<b>Progress 25</b> is the first Progress vehicle to service Mir. It incorporates improvements pioneered by Cosmos 1669.
<b>April 23-June 23</b>	<b>Progress 26.</b>
<b>May 5-June 25</b>	<b>Soyuz-T 15 transfer to Salyut 7</b> —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.
<b>May 21-30</b>	<b>Soyuz-TM 1</b> —First flight of the latest version of Soyuz. It docks unmanned with Mir on May 23, then undocks and returns to Earth.
<b>June 26-July 16</b>	<b>Soyuz-T 15 transfer to Mir and reentry</b> —Kizim and Solovyov deliver to Mir equipment recovered from Salyut 7. They then mothball the station and return to Earth.



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<b>1987</b>	<b>January 16-February 25</b>	<b>Progress 27.</b>
	<b>February 5</b>	<b>Soyuz-TM 2 launch</b> —Yuri Romanenko and Alexander Laveikin travel to Mir.
	<b>March 3-March 28</b>	<b>Progress 28.</b>
	<b>March 31</b>	<b>Kvant launch</b> —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.
	<b>April 21-May 11</b>	<b>Progress 29.</b>
	<b>May 15</b>	<b>Energia</b> —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.
	<b>May 19-July 19</b>	<b>Progress 30.</b>
	<b>July 22</b>	<b>Soyuz-TM 3 launch</b> —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 <b>Soyuz-TM 2</b> on July 30.
	<b>August 3-September 23</b>	<b>Progress 31.</b>
	<b>September 23-November 19</b>	<b>Progress 32.</b>
	<b>November 20-December 19</b>	<b>Progress 33.</b>
	<b>December 21</b>	<b>Soyuz-TM 4 launch</b> —Anatoli Levchenko, Musa Manarov, and Vladimir Titov arrive at Mir. Levchenko, a pilot for the Soviet space shuttle, returns to Earth in <b>Soyuz-TM 3</b> 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.
<b>1988</b>	<b>January 20-March 4</b>	<b>Progress 34.</b>
	<b>March 23-May 5</b>	<b>Progress 35.</b>
	<b>May 13-June 5</b>	<b>Progress 36.</b>

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<b>June 7</b>	<b>Soyuz-TM 5 launch</b> —Bulgarian cosmonaut Alexandr Alexandrov and Russian cosmonauts Viktor Savinykh and Anatoli Solovyov travel to the Mir station. They return to Earth in <b>Soyuz-TM 4</b> on June 17, leaving Soyuz-TM 5 for Manarov and Titov.
<b>July 18- August 12</b>	<b>Progress 37.</b>
<b>August 29</b>	<b>Soyuz-TM 6</b> 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 <b>Soyuz-TM 5</b> 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.
<b>September 9- November 23</b>	<b>Progress 38.</b>
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.
<b>November 15</b>	<b>Buran</b> —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).
<b>November 26- December 21</b>	<b>Soyuz-TM 7 launch</b> —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.
<b>December 25- February 7, 1989</b>	<b>Progress 39.</b>
<hr/> <b>1989</b>	
<b>February 10- March 5</b>	<b>Progress 40.</b>
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.
<b>March 16- April 25</b>	<b>Progress 41.</b>

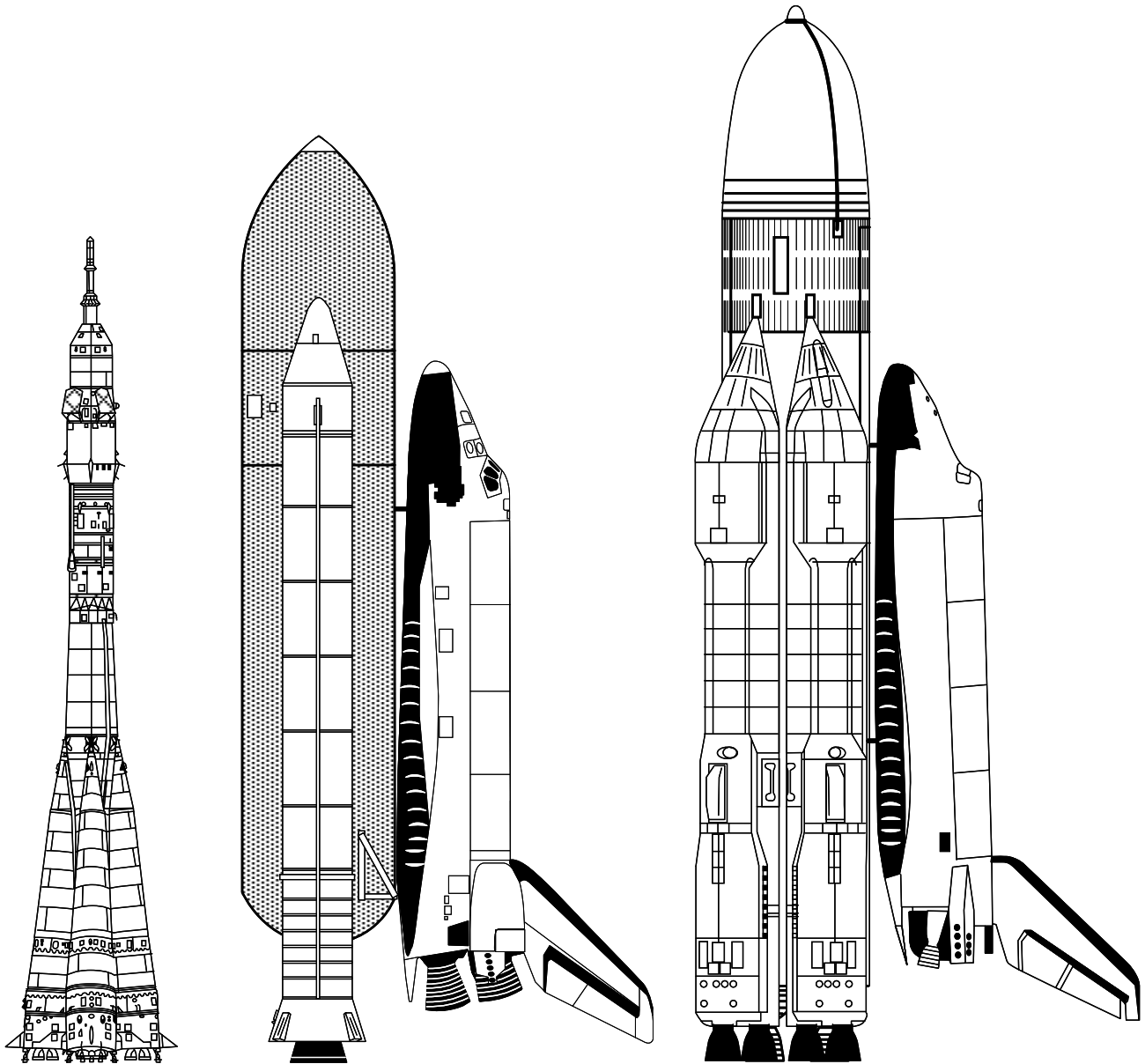


Figure 4-5. Soyuz rocket (left), Space Shuttle (center), and Energia-Buran (right) (drawn to scale). Rockets currently used to launch manned spacecraft into orbit.

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| April 27    | <b>Soyuz-TM 7 reentry</b> —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.                           |

<b>August 23- December 1</b>	<b>Progress-M 1</b> —First flight of an advanced Progress incorporating many Soyuz-TM features.
<b>September 5</b>	<b>Soyuz-TM 8 launch</b> —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.
<b>November 26</b>	<b>Kvant 2 launch</b> atop a Proton rocket. It docks with Mir’s front port on December 6, and is berthed at a lateral port on December 8.
<b>December 20- February 9, 1990</b>	<b>Progress-M 2.</b>
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<b>1990</b>	
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.
<b>February 11</b>	<b>Soyuz-TM 9 launch</b> —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.
<b>February 28- April 28</b>	<b>Progress-M 3.</b>
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.
<b>May 5-May 27</b>	<b>Progress 42.</b>
<b>May 31</b>	<b>Kristall launch</b> —The module docks with Mir’s forward port on June 10, and is berthed at a lateral port the following day.
<b>August 1</b>	<b>Soyuz-TM 10 launch</b> —The transport spacecraft docks with Mir on August 3 carrying cosmonauts Gennadi Manakov and Gennadi Strekalov.
<b>August 9</b>	<b>Soyuz-TM 9 reentry</b> —Balandin and Solovyov return to Earth after about 6 months in space.
<b>August 15- September 20</b>	<b>Progress-M 4.</b>

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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.
<b>September 27- November 28</b>	<b>Progress-M 5</b> —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.
<b>December 2</b>	<b>Soyuz-TM 11 launch</b> —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 <b>Soyuz-TM 10</b> on December 10.
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<b>1991</b>	<b>January 14- March 16</b>
	<b>Progress-M 6.</b>
	<b>February 7</b>
	<b>Salyut 7/Cosmos 1686</b> reenters over Argentina.
	<b>March 19-May 7</b>
	<b>Progress-M 7</b> 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.
	<b>April 5-11</b>
	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.
	<b>April 28-May 6</b>
	STS-39—Michael Coats, L. Blaine Hammond, Gregory Harbaugh, Donald McMonagle, Guion Bluford, Lacy Veach, and Richard Hieb are Discovery's crew.
	<b>May 7</b>
	<b>Progress-M 7</b> 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.
	<b>May 18</b>
	<b>Soyuz-TM 12 launch</b> —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 <b>Soyuz-TM 11</b> with Sharman on May 26.
	<b>May 30-August 16</b>
	<b>Progress-M 8.</b>
	<b>June 5-14</b>
	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.
<b>August 20-September 30</b>	<b>Progress-M 9.</b> 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.
<b>October 2</b>	<b>Soyuz-TM 13 launch</b> —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 <b>Soyuz-TM 12</b> , leaving Soyuz TM-13, Volkov, and Sergei Krikalev at the Mir station.
<b>October 17-January 20, 1992</b>	<b>Progress-M 10.</b> 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.
<b>1992</b>	
January 22-30	STS-42—Discovery carries International Microgravity Laboratory 1. Its crew is Ronald Grabe, Stephen Oswald, David Hilmers, Norman Thagard, William Raddy, Ulf Merbold, and Roberta Bondar.
<b>January 25-March 13</b>	<b>Progress-M 11.</b>
<b>March 17</b>	<b>Soyuz-TM 14 launch</b> —Alexandr Viktorenko, Alexandr Kaleri, and Klaus-Dietrich Flade (Germany) leave Kazakh territory for Mir (Russian territory). Flade returns to Earth in <b>Soyuz TM-13</b> 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.
<b>April 19-June 27</b>	<b>Progress-M 12.</b>
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.
<b>June 30-July 24</b>	<b>Progress-M 13.</b>

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<b>July 27</b>	<b>Soyuz-TM 15</b> 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 <b>Soyuz-TM 14</b> . 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.	
<b>August 15- October 20</b>	<b>Progress-M 14</b> 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. <b>Progress-M 14</b> '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.	
<b>October 27- February 7, 1993</b>	<b>Progress-M 15</b> . 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.	
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<b>1993</b>	January 13-19	STS-54—John Casper, Donald McMonagle, Mario Runco, Gregory Harbaugh, and Susan Helms deploy a TDRS from Endeavour.
	<b>January 24</b>	<b>Soyuz-TM 16 launch</b> —Docks with the APAS-89 androgynous port on Mir's Kristall module to test it in preparation for U.S. Shuttle (and possible <b>Buran</b> shuttle) visits to Mir. Its crew is Gennadi Manakov and Alexandr Poleshchuk. They replace Solovyov and Avdeyev, who return to Earth in <b>Soyuz-TM 15</b> on February 1.
	<b>February 21- March 27</b>	<b>Progress-M 16</b> .
	<b>March 31</b>	<b>Progress-M 17 launch</b> . 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.
<b>May 22-July 4</b>	<b>Progress-M 18.</b> 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.
<b>July 1</b>	<b>Soyuz-TM 17 launch</b> —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 Haignere in <b>Soyuz-TM 16</b> on July 22.
<b>August 10-October 13</b>	<b>Progress-M 19</b> —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.
<b>September 13</b>	<b>Progress-M 17 undocks</b> —The spacecraft moves to a storage orbit 10 km below Mir.
<b>October 11-November 21</b>	<b>Progress-M 20</b> —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.
<b>1994</b>	
<b>January 8</b>	<b>Soyuz-TM 18 launch</b> —Yuri Usachyov, Viktor Afanaseyev, and Valeri Polyakov dock with Mir on January 10. Usachyov and Afanaseyev replace Serebrov and Tsibliyev, who undock in <b>Soyuz-TM 17</b> 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. <b>Soyuz-TM 17</b> 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.
<b>January 28-March 23</b>	<b>Progress-M 21.</b>
<i>February 3-11</i>	<i>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.</i>



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<b>March 3</b>	<b>Progress-M 17</b> , 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.
<b>March 22-May 23</b>	<b>Progress-M 22.</b>
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.
<b>May 22-July 2</b>	<b>Progress-M 23</b> —Deploys a Raduga capsule.
<b>July 1</b>	<b>Soyuz-TM 19 launch</b> —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).
<b>July 9</b>	<b>Soyuz-TM 18 landing</b> —Usachyov and Afanaseyev return to Earth, leaving Polyakov aboard with Malenchenko and Musabayev.
<b>August 25-October 4</b>	<b>Progress-M 24.</b> 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.
<b>October 3</b>	<b>Soyuz-TM 20 launch.</b> Docking takes place early on October 6. The spacecraft 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.