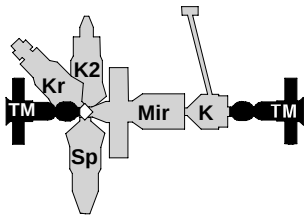
Mir Principal Expedition 20 and Euromir 95

Commander Yuriy Gidzenko (1st flight)
Flight Engineer Sergey Avdeyev (2nd)
ESA Cosmonaut Researcher/Flight Engineer
Thomas Reiter (1st)
Call name Uran
Launched and landed in Soyuz-TM 22,
September 3, 1995-February 27, 1996
179 days in space

Highlights. Mir 20 was a harbinger of the multinational missions that will be typical of International Space Station. It was the second Mir mission with a simultaneous Euromir designation, the second with an ESA astronaut as part of the crew. (Ulf Merbold, the first ESA astronaut aboard Mir, conducted Euromir 94 in October and November of 1994.) Thomas Reiter was the first non-Russian Mir crew member with the designation Flight Engineer. The scientific objectives of Euromir 95 were to study effects of microgravity on the human body, to experiment with the development on new materials in a space environment, to capture samples of cosmic dust and man-made particles in low Earth orbit, and to test new space equipment. Mir 20 was also the second Mir mission to include a U.S. Space Shuttle Orbiter docking. During that phase of the mission, the station complex housed crews from four countries, representing the Russian, Canadian, and U.S. space agencies as well as ESA.

Mir 20 and Euromir 95 crew launched. Soyuz-TM 22 was launched from Baikonur on September 3 at 08:58 UTC. Russian Space Forces controlled the launch, with a switchover to TsUP after separation of the manned capsule from the Soyuz-U launcher. ESA Director for Manned Spaceflight and Microgravity, Jorg Feustel-Büechl, said that the mission would "provide European scientists with unprecedented data on long duration spaceflight and further strengthen ESA's relationship with the Russian space programme."[97]

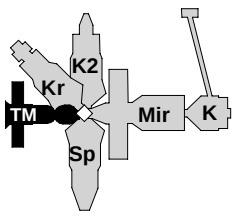
September 5-11, 1995



Kristall Kvant 2
Soyuz-TM 22 - Mir - Kvant - Soyuz-TM 21
Spektr

Soyuz-TM 22 docks. After 2 days of autonomous orbital flight toward Mir, on September 5 the Soyuz spacecraft circled the station from 90 to 120 m out, then made a successful automatic docking at the -X docking port. About an 1.5 hr later, the crew checked the hatch seals, removed their pressure suits, and entered the station to be met by Solovyev and Budarin with greetings and the traditional bread and salt.[98] Then the two crews began a week of joint work, including briefings from the Mir 19 crew to familiarize their replacements with the status of onboard systems and experiments.

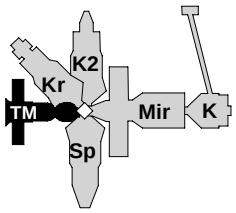
September 11 - October 10, 1995



Kristall Kvant 2
Soyuz-TM 22 - Mir - Kvant
Spektr

Mir 19 ends. Solovyev and Budarin ended their 75-day mission on September 11, departing the station in the Soyuz-TM 21 that had brought the Mir 18 crew up on March 16. Their Soyuz made a safe landing in Kazakhstan, 302 km northeast of Arkalyk,

September 11 - October 10, 1995



Concluded

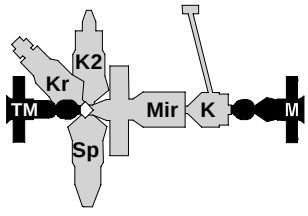
"far away from the aiming point." Rescue parties, however, found the crew in excellent condition.[99]

Euromir science activities begin. The Mir 20 crew began activating and calibrating the Euromir 95 experiments on September 13. The 41 experiments included 18 in life sciences, 5 in astrophysics, 8 in materials science, and 10 in technology.

- Life sciences experiments were mostly investigations of weightlessness effects on the human body, including
  - Cardiovascular monitoring through a network of blood pressure sensors at various points on the body
  - Bone-mass-loss studies done by simulating heel striking in weightlessness
  - Studies of the effects of weightlessness on kidney, lung, and muscle functions
- A major astrophysics study involved capturing and analyzing natural and man-made particles in low Earth orbit in the European Space Exposure Facility (ESEF) on Spektr
- Technology experiments included
  - Radiation monitoring to study the effects of the space environment on electronic components
  - Methods of measuring microbial contaminants in the station interior
  - Measurement of disturbances produced by the movements of a small robotic arm
- Many of the materials science experiments involved the processing of alloy, glass, and semiconductor samples in TITUS, a six-zone tubular furnace capable of attaining 1250°C

An average of 4.5 hr a day was allotted for experiment work, with the rest of the time devoted to exercise and station maintenance.[100] The Mir 20 crew was active in the Euromir experiments and the ESA crew member, German Thomas Reiter, in addition to his Euromir duties, participated in Russian experiments and, as flight engineer, helped maintain the station's onboard equipment.

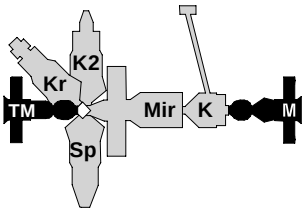
October 10 - November 15, 1995



Kristall Kvant 2
Soyuz-TM 22 - Mir - Kvant - Progress-M 29
Spektr

Progress-M 29 arrives. Another Progress-M vehicle was launched from Baikonur at 18:51 UTC on October 8 by a Soyuz-U. The cargo module docked with Mir at 20:23 UTC on October 10 with about 2.5 t of fresh supplies and equipment for the Mir 20 crew. Included was about 80 kg of additional experiment hardware for Euromir 95, such as the cassettes to be installed during an EVA in the ESEF on the exterior of Spektr. After some problems opening the hatch, the crew entered Progress-M 29 and began inspecting and unloading the cargo.[101]

October 10 - November 15, 1995



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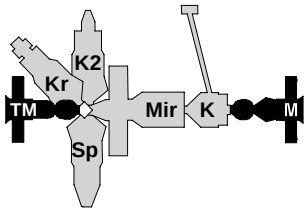
Mir 20/Euromir 95 extended. ESA and Russian organizations officially announced on October 17 the decision to add 44 days to the joint mission, originally scheduled to be 135 days long. The possibility of extending the mission had been discussed even before launch. The final decision was made on October 6 at a meeting of the RSA, ESA, RSC Energia, the Russian Central Specialized Design Bureau (Soyuz rocket designer), and representatives of the Progress Plant where the Soyuz-U booster for launch of the next crew (Mir 21) was under construction. Postponing the Soyuz-TM 23 launch from January 15, 1996, to February 21, 1996, would shift much of the expenditure for launch vehicle processing to the next fiscal year, thus relieving a strain on the RSA budget. It would also optimize resource use by keeping the Soyuz-TM 22 module attached to the station for its full 180-day lifetime. The extension to February 27, 1996, would allow time for additional Euromir scientific research and an extra EVA. In December a new Progress-M would provide extra consumables for the crew and equipment for additional Euromir experiments.[102,103,104,105]

EVA Preparations. The Mir 20 crew spent about 5 days preparing for their first EVA-assembling and checking the hardware they were to deploy, then placing it in an EVA bag that would keep items from floating away during the work on the ESEF.[106]

First Mir 20/Euromir 95 EVA. In the first space walk by an ESA astronaut, Reiter climbed through the Kvant 2 hatch on October 20, with Avdeyev close behind. Reiter tethered himself and the bag of experiment hardware to the Strela boom. Avdeyev turned the crank at the base of the boom to move Reiter to the forward section of the Spektr module, then climbed the length of the boom himself. In a successful 5-hr, 11-min EVA, they installed four elements on the ESEF—two exposure cassettes, a spacecraft environment-monitoring package, and a control electronics box. The two clam-like cassettes could be controlled remotely from within the station. (One would be opened to sample space debris except during dockings, when it would be closed to avoid contamination; the other would be opened to sample the Draconids meteor stream when Earth passed through the tail of comet Giacobini Zinner.) Gidzenko powered up the experiments and tested their operability from inside Mir. The two spacewalkers then changed the cartridges in the nearby Russian-Swiss Komza exposure experiment, also on Spektr.[107,108,109]

Coolant loop leak discovered and repaired. A leak in a coolant line to the Kvant/core module air regeneration system was found on November 1. Approximately 1.8 L of a solution containing 37° ethylene glycol had leaked inside the Mir module. The coolant loop had to be shut down; thus the primary carbon dioxide removal system in Kvant and the oxygen replenishing system were disabled. The leak was found a few days later and repaired with a “putty-like substance.” Meantime, a backup air scrubber using lithium hydroxide canisters similar to those used on the U.S.

October 10 - November 15, 1995



Concluded

Space Shuttle was substituted to remove the carbon dioxide. The solid oxygen generators and the Kvant 2 alternate oxygen system could be used for oxygen production until the mid-December Progress-M launch. U.S. and Russian ground support teams began immediately planning solutions. They decided that Atlantis would bring extra Space Shuttle lithium hydroxide regeneration canisters and a fixture developed at NASA's Johnson Space Center to connect the canisters to Mir's air supply system.[110,111]

Dutch Biokin Air Scrubber Tested. The Biokin experiment, an innovative air filtration system that uses microbes to convert airborne contaminants to harmless compounds, was activated by the crew on November 9. After a week of operation, the air scrubber was deactivated and put in a small freezer for return to Earth on STS-74. The 500-gm system was designed by two Dutch companies and jointly sponsored by ESA and the Dutch National Institute for Aerospace Programs (NIVR).[112]

STS-74 launch. After a one-day launch delay caused by poor weather at the transatlantic abort site, Atlantis was launched from Kennedy Space Center at 7:30 a.m. EST on November 12, 1995. On the first two days of the flight, Cameron and Halsell executed a series of reaction control jet firings to gradually bring Atlantis closer to Mir.

Docking Module placement preparations. The crew prepared for on-orbit assembly of the Docking Module atop the ODS mechanism inside the payload bay. The module had been launched in the aft portion of the payload bay to provide center-of-gravity control and to allow the bay doors to close. On mission day 1, Hadfield activated the module for a system check. On day 2, Hadfield powered up and checked out the RMS mechanical arm. Mission specialists Ross and McArthur checked out their space suits in case they had to go outside the pressurized area of Atlantis for contingency operations during either the mating of the Docking Module to the ODS or the subsequent docking of Atlantis with Kristall. Other crew tasks included checkout of the ODS and the OSVS, as well as installation and alignment of the ODS centerline camera.

Docking Module on-orbit assembly. On mission day 3, Hadfield powered up the OSVS. Then with McArthur's assistance, he grappled the Docking Module with the 50-ft RMS and removed it from its moorings in the payload bay, lifting it horizontally out of the bay. When it was clear of all structures, he pivoted the module 90° to a vertical position, spun it almost 180°, and brought it over the ODS. After Hadfield placed the arm in a "limp" position (with no power on, no mechanical parts working), Cameron fired Atlantis's steering thrusters to gently bring the two docking systems together, thus engaging the hooks and latches which locked the Docking Module to the ODS. After tests to confirm a secure engagement and removal of the mechanical arm, the crew mounted a centerline camera on the Docking Module's top hatch to be used in the next day's docking with Mir.[113, 114]

STS-74 Mission Highlights

November 12-13, 1995
Kenneth D. Cameron, Commander (3rd flight)
James D. Halsell, Pilot (2nd)
Jerry L. Ross, Mission Specialist (5th)
William S. McArthur, Jr, Mission Specialist (2nd)
Chris A. Hadfield, Mission Specialist (1st)

Highlights. STS-74 was the second in the series of joint Shuttle-Mir missions planned before assembly of the International Space Station. This flight was the last of U.S. Space Shuttle's seven missions in 1995, three of which had Mir rendezvous or docking among their major objectives. It was the 15th flight for Atlantis, the 73rd U.S. Space Shuttle flight. When its five-member crew, including Canadian Chris Hadfield, joined the Mir 20/ Euromir crew, four different nations-Canada, Germany, Russia, and the U.S.-were represented on one mission in the same orbiting complex. In addition to the docking itself, a major objective of the mission was to deliver a new Russian-built Docking Module (DM) and new solar arrays to Mir. Hadfield, using the Canadian-built Remote Manipulator System (RMS), attached the Docking Module to the Mir Kristall module. The solar arrays, stowed in containers on the shell of the docking module, would be deployed in later missions.

Docking Module

Specifications
launch weight-approx. 4090 kg
length-4.7 m
diameter-2.2 m

Description
Concept discussions for the module began in November 1993 and were finalized in June 1994. It was designed and built during 1994 and 1995 in Russia by RSC Energia for the RSA. NASA and American space contractor Rockwell Aerospace provided technical oversight. After final assembly and functional tests in Russia, the module was delivered to Kennedy Space Center on June 7, 1995. There it had the distinction of being the first article made flight-ready in the new Space Station Processing Facility, which had opened in March. By September 11, it was ready for installation in the aft payload bay of Atlantis.[115, 116]

The new module (figure 9) simplified U.S. Space Shuttle Orbiter dockings with Mir by eliminating the need to move Kristall to the -X port at Mir's longitudinal axis each time an Orbiter visits. That port is free for the Progress and Soyuz dockings, and Kristall can remain docked at the radial port. Another consideration in the addition of the Docking Module was that Kristall's Lyappa arm, used in its moves from port to port, would reach its design lifetime before all the planned Orbiter dockings were accomplished. Also, the Docking Module's 4.7-m length provides extra clearance between the Orbiter and the Mir solar arrays as the Orbiter approaches Kristall. [117, 118]

The identical androgynous peripheral assembly systems (APASs) at each end of the new module are compatible with existing systems on Kristall and Atlantis. APAS-1 is attached to Kristall; APAS-2 will receive the Shuttle ODS in future dockings of Atlantis.[119] Visiting crews enter the pressurized interior through the APAS-2 hatch. From there they access Kristall (and thus Mir) through the APAS-1 hatch.

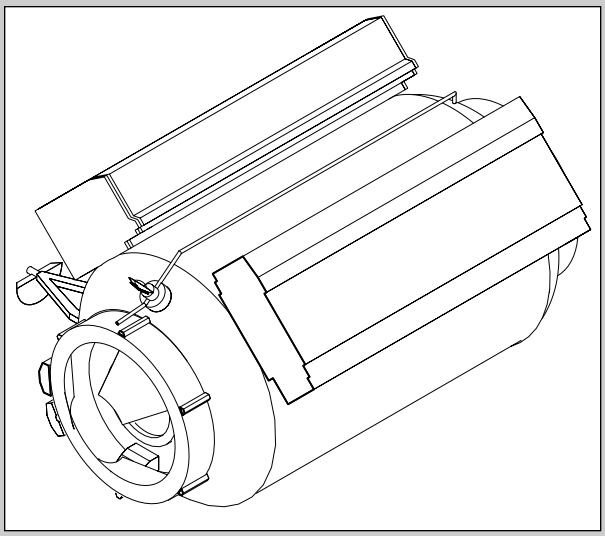


Figure 9a. The Russian-designed Docking Module which was added to Kristall in November 1995 to accommodate future Space Shuttle dockings with the Mir complex. An APAS mechanism shows at the end of the module (left side of drawing). The module was transported to Mir by Atlantis on STS-74.

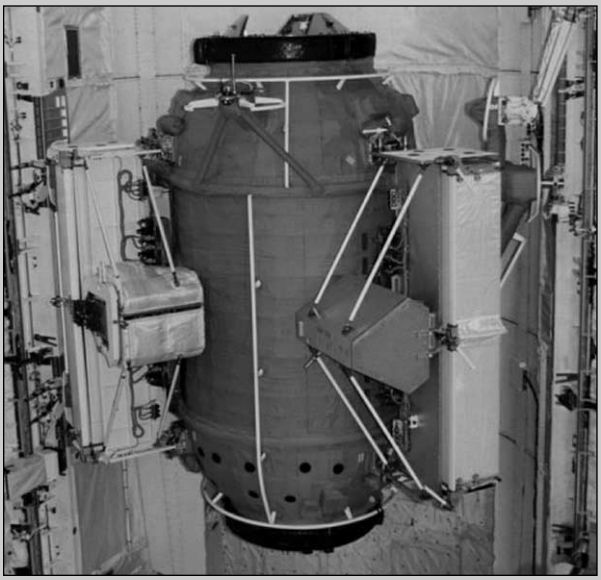


Figure 9b. The Docking Module in Atlantis' payload bay before launch of the STS-74 mission.

The cylindrical aluminum alloy module is protected in the orbital environment by a micro-meteoroid shield and a passive layer of screen vacuum thermal insulation. Further thermal control for the pressurized interior is provided by a coolant loop; there are also fans for the avionics and the APAS window.

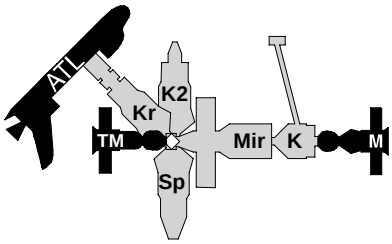
Because the docked module obscured the Orbiter commander's line of sight to his Kristall docking port target, a new Orbiter space vision system (OSVS) was tested on STS-74. It consisted of a series of large dots on both the Docking Module and the ODS.[120]

STS-74 Solar Array Package

Two solar array containers are attached to the exterior of the Docking Module for later deployment. In one is stowed the Mir Cooperative Solar Array (MCSA), in the other an all-Russian solar array. The MCSA, designed as part of the International Space Station Phase 1 program, uses a Russian structural frame and 80 NASA silicon photovoltaic cells. It will provide 6 kW of power through 42 segments that will measure 9 by 60 ft when deployed. Solar arrays on the International Space Station will use the same type of U.S.-made silicon cells.[121, 122]

November 15-18, 1995

Atlantis
Kristall Kvant 2
Soyuz-TM 22 - Mir - Kvant - Progress-M 29
Spektr



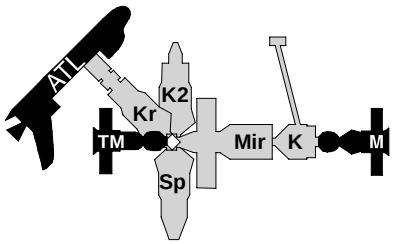
Second Shuttle-Mir docking. As Atlantis approached Mir on the fourth day of the STS-74 mission, the crew augmented Atlantis's navigation computer and trajectory control system laser with a handheld laser to provide precise targeting information. With Atlantis lined up with Mir along the R-bar, approaching the station from beneath, Cameron began manual control of the Orbiter. The newly installed centerline camera helped him obtain alignment coordinates with Kristall's docking port, now obscured by the protruding Docking Module. After a "go" from Russian and U.S. ground controllers, Cameron slowed the Orbiter's approach to less than one in/sec and successfully docked with the station at 1:28 a.m. EST on November 15 in an orbit 216 nmi above western Mongolia.[123] About 2.5 hr later, after docking verification and seal checkouts, Cameron opened the Docking Module hatch and met Mir Commander Gidzenko inside the new module. A handshake between the two commanders signaled the formation of a multinational crew.[124]

Multinational crew activities. After traditional greetings, the crews got to work transferring cargo items between the visiting Orbiter and Mir. Supplies carried into the station during the 3 days the two vehicles were docked included over 300 lb of food, over 700 lb of experiment equipment, about 900 lb of by-product water from fuel cells in Atlantis,[125] and 20 lithium hydroxide canisters to serve as backups to Mir's recently repaired primary carbon dioxide removal system. From Mir, the crews removed about 800 lb of research samples collected during Euromir 95 and experiment equipment no longer needed on the station. In addition to talking to the press on the ground, the crews received congratulations from Russian Prime Minister Viktor Chernomyrdin, Canadian Industry Minister John Manley, NASA Administrator Daniel Goldin, and U.N. Secretary General Boutrous Boutrous-Ghali.[126, 127]

Joint spacecraft experiments. While the space vehicles were docked, the crews cooperated in medical experiments and environmental investigations designed as part of International Space Station Phase I research. Examples of the studies conducted by the Shuttle and Mir crews were

- The Photogrammetric Appendage Structural Dynamics Experiment (PASDE), a set of three photogrammetric instruments located throughout the Orbiter payload bay, recorded Mir solar array structural dynamics during docking and the docked phase of the mission, gathering data for future missions.

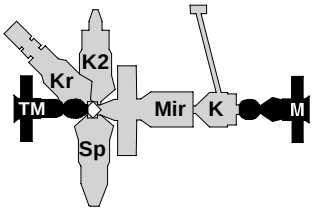
November 15-18, 1995



Concluded

- International Space Station Risk Mitigation Experiments evaluated the acoustic environment aboard Mir, remote communications systems, and the alignment stability of the Atlantis-Mir docked configuration.
- Inflight radiation measurements, for which both crews wore passive dosimeters. They gathered data about the orbital radiation environment and compared the techniques and equipment used by NASA with those used by the Russian Institute for Biomedical Problems.
- A series of jet firings by both Mir and Atlantis evaluated the dynamics of the complicated structure of the docked spacecraft, which, at more than 500,000 lb, set a new record for conjoined orbital mass.[128, 129]

November 18 - December 19, 1995



Kristall Kvant 2
Soyuz-TM 22 - Mir - Kvant - Progress-M 29
Spektr

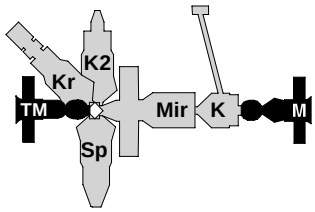
Docking phase ends. Early on the morning of November 18, Cameron activated the springs to push the ODS free of the Docking Module and slowly undocked Atlantis. At two ft out, he activated the reaction control system to move the Orbiter away from the Mir complex. At about 525 ft out, he began a fly-around. Atlantis circled Mir twice, taking a photographic survey of the station (fig. 10). Four and a half hr after undocking, Cameron fired the orbital maneuvering system to lower Atlantis to another orbit.

STS-74 mission ends. After their successful Mir mission, the crew of Atlantis, on their own once again, began closing down their experiments and stowing equipment that had been used in flight. On November 20, at 12:02 p.m. EST, they landed at Kennedy Space Center, Florida, ending their 129-orbit mission after 8 d, 4 hr, and 31 min.

Euromir experiments resume. After the departure of Atlantis, the Mir 20 crew continued with Euromir 95 activities, including medical tests and materials processing experiments. In addition to the equipment brought to Mir expressly for Euromir, Reiter used the Austrian Optovert equipment that had been on Mir since the Austro-Mir mission in October 1991. With it he investigated the effects of weightlessness on human motor system performance and the interactions of the vestibular system and visual organs.[130]

Gyrodyne maintenance. The cosmonauts did preventive maintenance on the Kvant 2 gyrodynes in late November, using the attitude control jets to maintain station orientation while the gyrodynes were inactive.[131]

November 18 - December 19, 1995



Concluded

Space art contest. On November 30, the crew announced the three winners of an art contest sponsored by the Swiss-based OURS foundation. Twenty of 171 entries on the theme of "Space and Humanity" had been selected by a panel for the journey to orbit with the Mir 20/Euromir crew. From these 20, the crew chose the three finalists.[132]

Second Mir 20 EVA. On December 8, the crew reconfigured the docking unit at the front of the Mir base block to prepare it to receive the 1996 Priroda module. From inside the depressurized docking unit, the Orlan DMA-suited crew moved the Konus docking unit from the +Z to the -Z docking port, where Priroda would dock in the spring.[133]

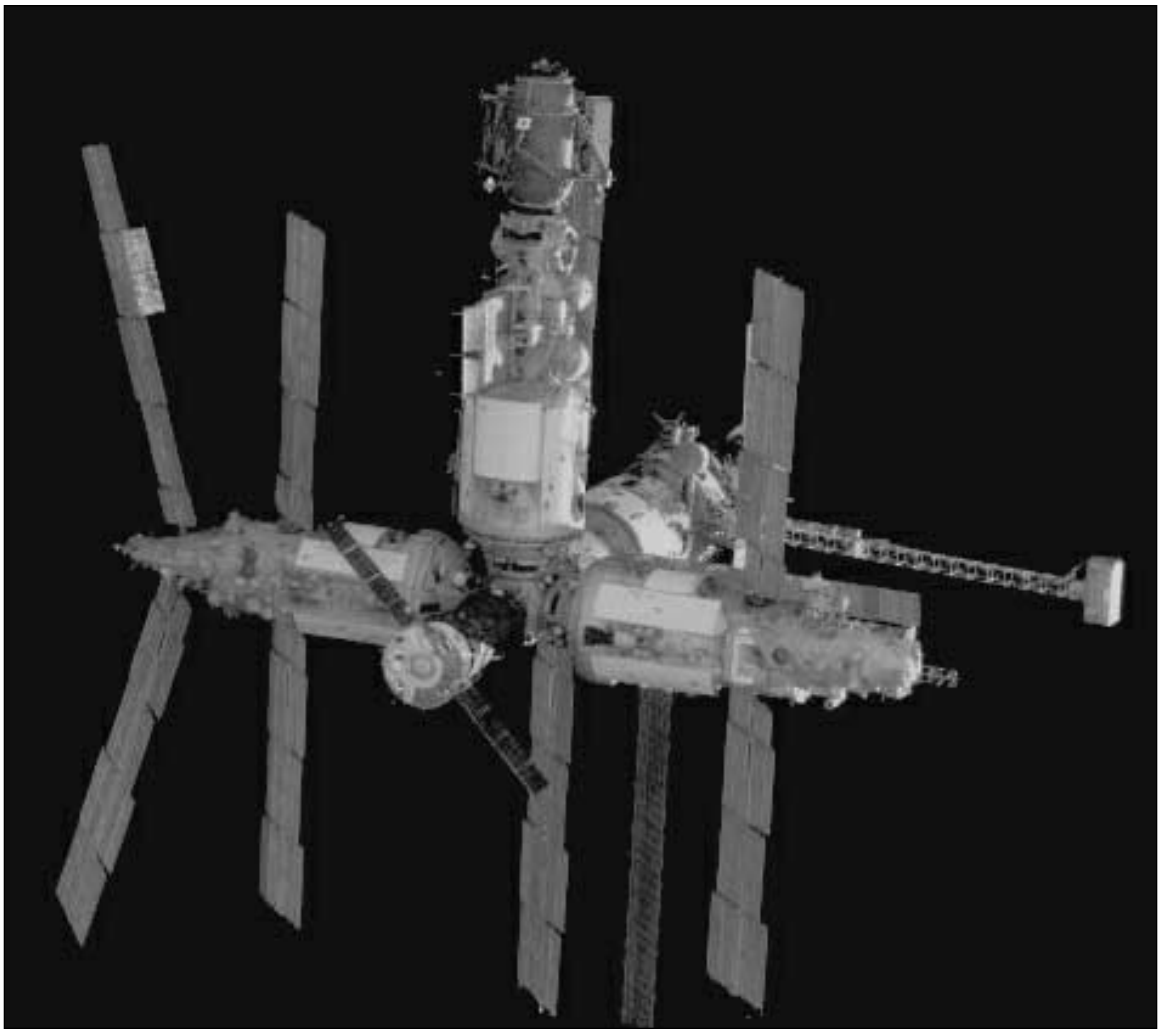
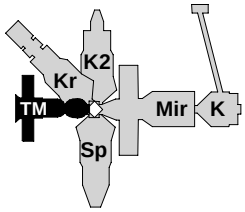


Figure 10. Mir with new docking module (top, center of photo) installed on the Kristall module. The photo was taken by the departing Atlantis on STS-74. Spektr is shown at the left, Kvant 2 at the right.

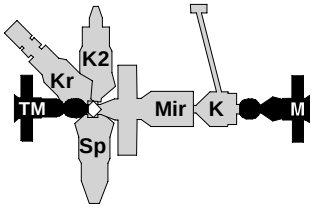
December 19-20, 1995



Kristall Kvant 2
Soyuz-TM 22 - Mir - Kvant
Spektr

Progress-M 29 departs. On December 19, Progress-M 29 undocked from the rear Kvant port and deorbited over the Pacific.

December 20, 1995 - February 22, 1996



Kristall Kvant 2
Soyuz-TM 22 - Mir - Kvant - Progress-M 30
Spektr

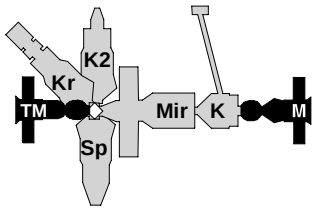
Progress-M 30 resupplies Euromir 95. Progress-M 30 was launched on December 18 from Baikonur on a Soyuz-U rocket. It docked at the vacated Kvant port on December 20 with 2300 kg of fuel, crew supplies, and research and medical equipment for use on the extended Euromir 95 mission.[134] This was the last of five Progress-M dockings at Mir in 1995.

Experimentation continues into new year. As 1996 began, the crew continued their experiments. Reiter took biomedical samples and measurements and tested the capacity of uncooled melts in the TITUS materials processing furnace. The Russian cosmonauts studied microgravity effects on hydrodynamics with the Volna-2 device, using models of spacecraft fuel system elements. With the Maria magnetic spectrometer, they investigated possible links between terrestrial seismic activity and high-energy charged cosmic particle fluxes.[135]

Reactivation of Kvant coolant loop. Between January 12 and 16, 1996, the cosmonauts resumed work on the cooling system leak that had begun in November. They hermetically sealed a manifold on the coolant line, then refilled the loop with ethylene glycol that had been sent up on Progress-M 30 to replace that lost at the onset of the leak. Following the repair, they continued their Euromir 95 materials processing experiments with melting and recrystallization of metals.[136]

Third Mir 20 (second Euromir 95) EVA. At the beginning of their EVA on February 8, Reiter and Gidzenko moved a maneuvering unit, referred to as the SPK or YMK, stored inside the Kvant 2 airlock and attached it to the exterior of the module. (The large unit, which had not been used since it was tested in 1990, was in the way of spacewalkers preparing to exit the airlock.)[137, 138] The cosmonauts then climbed out the Kvant 2 hatch and again used the Strela boom to maneuver to the forward end of Spektr, where they retrieved the two cassettes they had

December 20, 1995 - February 22, 1996



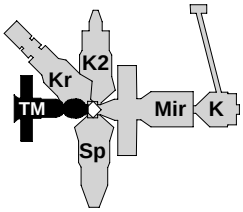
Concluded

deployed in October on the ESEF. They installed a new cassette in the facility and, with Adeyev's assistance from inside the station, verified that it would operate. Their work took only 3 hr and 6 min. Originally scheduled to last about 5.5 hr, the EVA was shortened by an aborted task on a Kristall antenna. The TsUP canceled the antenna work when the cosmonauts were unable to loosen the bolts on a joint of the antenna.[139, 140]

Tenth anniversary of base block launch. As the Mir base block marked the 10th anniversary of its launch to orbit on February 19 (February 20 in Moscow), ITAR-TASS reported a "holiday atmosphere" aboard the complex. Having already remained in orbit four years longer than was originally intended, the base block, with its complement of docked modules, held the promise of at least three more orbiting anniversaries.[141]

February 22 -23, 1996

Kristall Kvant 2
Soyuz-TM 22 - Mir - Kvant
Spektr



Progress-M 30 undocked and Soyuz-TM 23 launched. On February 21, Soyuz-TM 23 was launched from Baikonur with the Russian crew members for Mir Principal Expedition 21. Progress-M 30 was undocked on February 22 and commanded to a destructive reentry over the Pacific.[142]
