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A Russian Space Station: The Mir Complex

Mission Operations Directorate
Space Flight Training Division
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A RUSSIAN SPACE STATION: THE MIR COMPLEX

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FOREWORD

The content of this document was provided by the Space Station Systems Section, Systems Training Branch, Space Flight Training Division (SFTD), Mission Operations Directorate (MOD), Lyndon B. Johnson Space Center (JSC), National Aeronautics and Space Administration (NASA).

This document was initiated from the recent decision to combine United States (U.S.) efforts with the Russians in space, not only for the proposed Space Station, but also with forthcoming astronaut and cosmonaut transfer programs involving the Shuttle and Mir Complex. The manual is intended as familiarization material for anyone who is supporting any of these missions, not as a detailed account of the design and operations all of the Russian hardware. Although designed as a training manual, it is not a part of any formal training flows at this time.

Due to the recent break–up of the Soviet Union, terminology throughout documentation lists both Russian and Soviet involvement. This manual tries to address equipment designed and built before the break–up as Soviet equipment operated by the Russians. Otherwise, it is strictly Russian.

Another confusing aspect is the use of "Mir". Mir is actually only one part of the entire station, which is made up of the Mir and several other modules. Therefore, for the purposes of this manual, "Mir" refers to the base or core module of the station. The entire station is referred to as the "Mir Complex".

The document is organized in a "top–down" approach, starting with the history, then moving through operations and the different modules, down to systems descriptions. Again, the intent is to give an overview of the Mir Complex components, systems, and operations in a Training Manual format.

Sources for the document, outlined at the end, were extremely limited and often marked as sensitive. As a result, there are a few holes in the material presented that were intended to be covered, and the level of detail varies slightly from topic to topic. Also included at the end of the document is a "library" of drawings that were used for the manual. Electronic versions of these drawings/pictures can be obtained from the publisher, Space Station Information Support Group (SSISG), for use elsewhere.

If there are changes you would like to see as a user of this document or in future revisions, please feel free to call the book manager, DT47/Mark Bockman, at (713) 244–7481, with any questions or recommendations. We would also appreciate any information on additional sources that you might know about.

Please enjoy the manual!

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SECTION 1
THE HISTORY OF THE MIR COMPLEX

1.1 PERFORMANCE OBJECTIVES

By the end of this section, the reader should be able to:

- Describe the Salyut program, as a precursor to the Mir Complex
- Describe the evolution of the Mir Complex from the core module through the current configuration
- Describe the use of transport vehicles used to support the stations

1.2 INTRODUCTION

Manned space flight has been around for more than 30 years. Beginning with only brief trips into the upper atmosphere, flights have progressed to Astronauts circling the Earth for 2 weeks and Cosmonauts spending over a year in orbit. The Russians have advanced their space program incrementally by just building a little onto the previous design to get to the stage they are at today – able to maintain a long–duration human presence in space. A series of vehicles have been designed and flown, leading up to the current Russian space station, the Mir Complex. In fact, the Mir Complex is actually a complex of different vehicles that have been pieced together to form a space station.

Sources indicate that the main purpose of the Mir Complex is to provide a testbed for space technology, aimed at the successful design and completion of a manned visit to Mars. Experiments in areas such as Earth and space observation, material research, and biomedical research are also conducted. This section outlines the historical build–up of the Mir Complex, including a small synopsis of the precursor program, Salyut.

1.3 THE SALYUT PROGRAM

Although the string of Soviet–manned space stations began with the first Salyut station, launched in 1971, the Mir follows most directly from the Salyut–6 and –7 stations, direct precursors to the current Russian space station. In retrospect, the Soviets called the first five Salyuts the "first generation" Salyuts, with the "second generation" including the last two Salyuts stations, 6 and 7. This distinction was made because of the differences in capability and robustness between the two "generations", though the stations all appeared nearly identical from an external view.

Salyut–6 was launched in September of 1977, destined to be a great advancement in Soviet space presence. This new station was to be capable of not only more complex missions, but longer ones as well.

Utilized from 1977 to 1981, Salyut–6 carried several large pieces of experimental equipment installed prior to launch. The station was also host to a greater number of experiments brought onboard by a number of Progress and Soyuz modules. While the Progress modules were unmanned supply missions, the Soyuz modules primarily carried Cosmonauts to and from the orbiting vehicle. Capabilities of the station allowed new world records to be set four different times for the longest stay in space, the longest lasting 6 months. The wonderful success of

Salyut–6 promoted great anticipation for what could be accomplished with the next vehicle, Salyut–7.

Launched in April of 1982, Salyut–7 was actually a disappointment to western observers, as no great technical advances were made over the previous version. Although the equipment was improved and the experiments were different, the newer vehicle was nearly identical to Salyut–6. The Soviets never planned to permanently man Salyut–7, but it was designed for longer duration missions than its predecessor. The failure of crew health prevented Cosmonauts from setting the desired record for manned presence in space at nine months, instead accomplishing only an 8–month record.

In 1986, continuous crew operations onboard Salyut–7 ceased and the emphasis in the Soviet space program turned to the Mir Complex. Cosmonauts returned to the Salyut in May of 1986 to salvage anything they could from the dying station for the newer Mir Complex. In October of that same year, the station was boosted to an altitude of 480 km and left unmanned, monitored only from mission control. In 1989, telemetry from the station ceased. Salyut–7 entered the atmosphere and burned up in 1991.

1.4 THE BEGINNING OF MIR

The Mir (variously translated as "peace", "commune", and "world") Complex was described by the Soviets as being their third generation space station. It was to be modular in design, allowing several different vehicles to be docked together. Modular stations appeared to be in the plans for the Soviets almost from the beginning of the Salyut program. Drawings and paintings indicate that such concepts were being pieced together very early on in the manned space program. Another important feature of the Mir Complex was that it was to be permanently manned, making a huge step towards breaking Earthly ties.

The Mir was launched in February of 1986, thus making it operational for almost 8 years at the time of publication for this manual. (Marking a new openness in the Soviet space program, the launch was shown on television. This was the first clear view in the West of the Proton launch vehicle in action.) As with all of the following modules, the Mir was launched unmanned. The Mir module design was largely based on the modules of the second generation Salyut stations, and was intended to act as the core module for the entire Mir Complex. See Figure 1–1.

The Mir Complex is made up of all the vehicles that are attached to the Mir at any time. As is explained later in the manual, various means of docking and attachments were used to connect the modules together.

On March 13, 1986 the first mission to the Mir was launched: a Soyuz module containing two veteran Salyut Cosmonauts. The mission of the crew was to dock with and activate the Mir, then undock with the Mir and dock with Salyut–7. Once inside the older station, the Cosmonauts were to continue the experiments started by a previous crew, whose visit had been cut short due to health problems. Upon completion of these experiments, the Cosmonauts returned to the Mir, taking 20 instruments from Salyut–7. Aboard the newer space station, the Cosmonauts continued checking out the station, starting experiments, and preparing for the arrival of the Kvant astrophysics module.

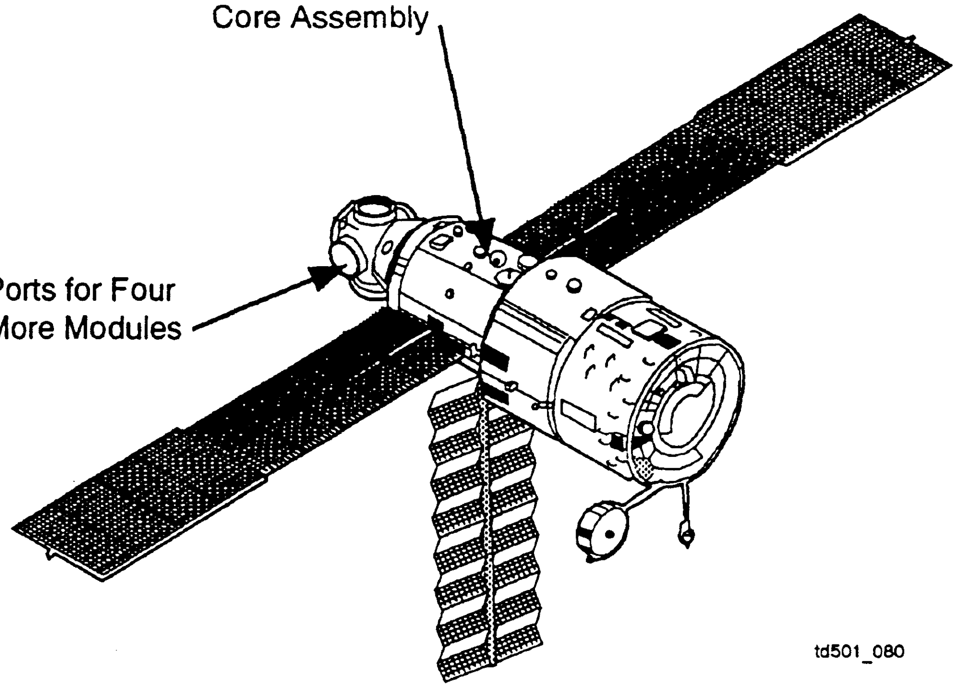

Figure 1–1. Mir module

Work on other modules for the Mir Complex was advancing slowly. This invoked the decision to use a veteran Salyut crew to finish those experiments, rather than fly a Mir–trained crew to a basic module with little equipment. Delays also forced the "permanently manned" station to remain unmanned after the Cosmonauts left until February, 1987, when another crew was launched for a 10–month mission on the Mir.

1.5 THE KVANT–1

Launched on March 31, 1987, the Kvant–1 carried a series of international astrophysics experiments. Though the Soviets had a difficult time initially trying to dock the Kvant–1 to the Mir, hard–dock was achieved on April 12, 1987. See Figure 1–2. A discussion of this difficulty appears later in the manual.

1.6 THE KVANT–2

The Kvant–2 was the first in a series of specialized scientific modules that were to make up the Mir Complex. Launched on November 26, 1989, Kvant–2 was docked to the forward axial port on December 6, and then moved to a radial port on December 8. This gave the Mir Complex an unbalanced "l–shape" (see Figure 1–3), but freed up the axial port for the docking of visiting Soyuz modules.

A very important feature that Kvant–2 added was an airlock that made Extravehicular Activity (EVA) missions easier to perform. Previously, the EVAs were done using the multiple docking node on the Mir. (See Section 3.)

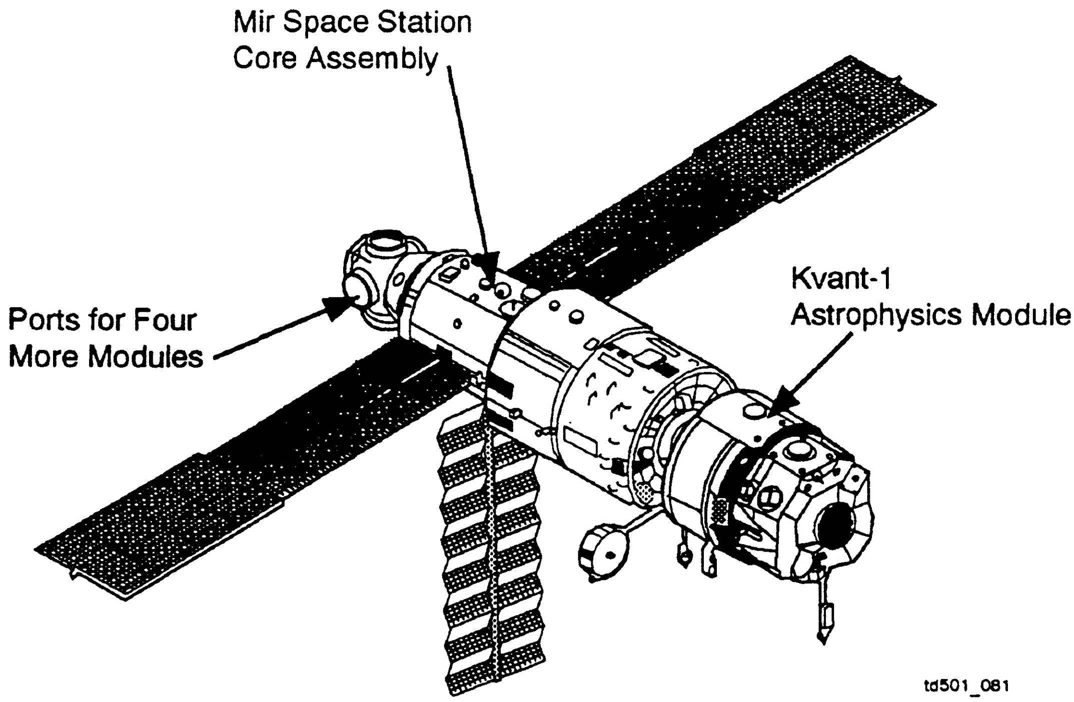

Figure 1–2. Mir module with Kvant–1

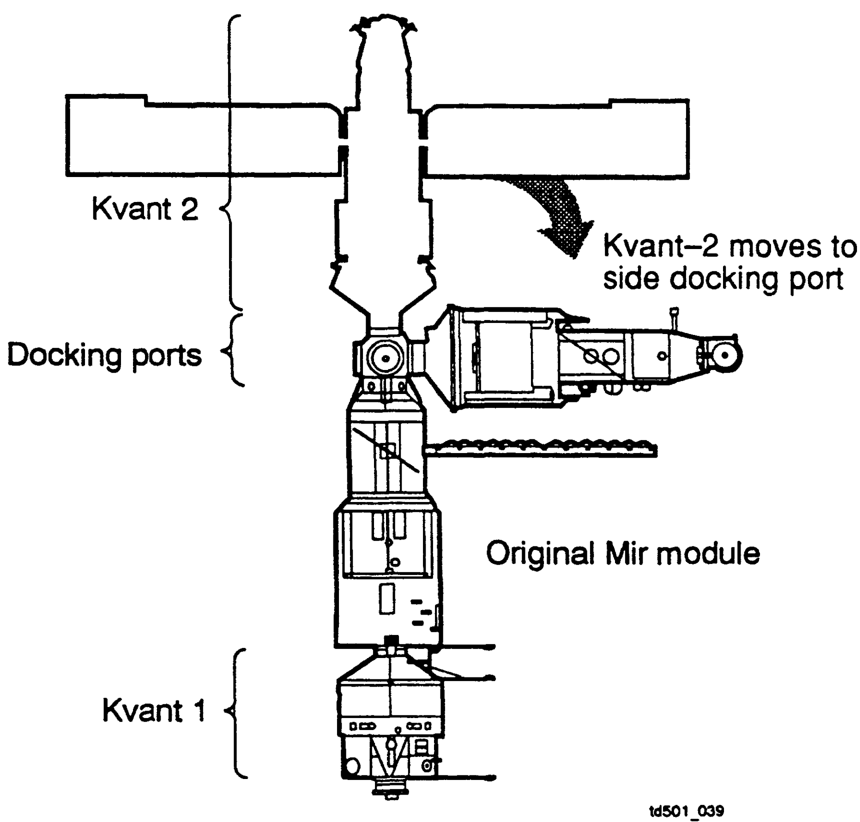

Figure 1–3. Mir Complex showing Kvant–2 relocation

1.7 THE KRISTALL

The balance of the complex was restored about 6 months later with the arrival of Kristall. The same set of maneuvers for attaching Kvant–2 were used to attach Kristall. After leaving the ground June 1, 1990, the Kristall was docked to the Mir axial port on June 10, and moved to a radial port, opposite Kvant–2, on June 11. See Figure 1–4.

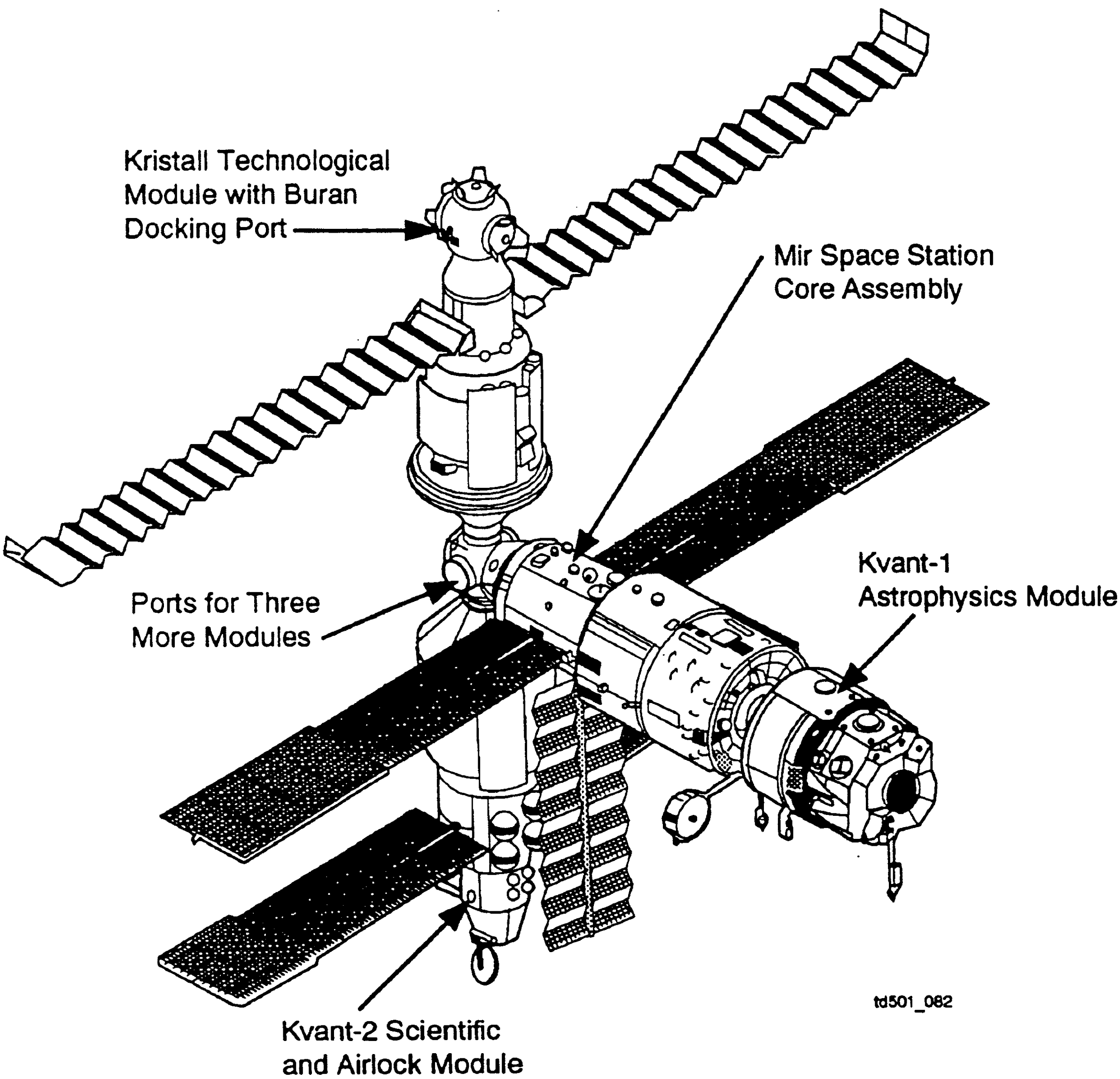

Figure 1–4. Mir, Kvant, Kvant–2, and Kristall

Also similar to the Kvant–2 was the fact that Kristall was a specialized module carrying an array of experiments and equipment.

1.8 THE SOYUZ

"Space taxi" would be an equitable name for the Soyuz crafts that have ferried the Cosmonauts back and forth to the various Russian stations over the years. Although the Cosmonauts were able to bring some small equipment with them, the Soyuz have been primarily responsible for transporting humans to and from space.

Evolution of the Soyuz craft has somewhat paralleled that of Soviet space stations, with a solid design being improved upon throughout time. Originally designed to go to the moon after docking with a booster in Earth orbit, the Soyuz was modified to fly crews to space stations. The first Soyuz flight was launched on April 23, 1967, and ended in disaster when Cosmonaut Vladimir Komarov could not properly control the descent of the spacecraft on landing, and the craft hit the ground at high velocity. Most of the design problems were worked out and the Soyuz went on to have several successful missions, including ones that were comprised of several of the crafts docking together in orbit.

On June 15, 1973, the first Soyuz Ferry launched into orbit, marking the first major modification to the tried Soviet design. One of the big visible differences was the replacement of solar arrays with batteries to reduce weight. This allowed more payloads to be carried to space stations. Another major difference was the result of another failure of the previous Soyuz design. In this previous design, three Soyuz–11 crewmembers were lost when cabin pressure was lost in the capsule. Due to the size constraints, the three crewmembers did not wear pressure suits during the flight. The Soyuz Ferry was designed for only two, suited crewmembers. July 15, 1975 marked the launch of Soyuz 19 for the Apollo–Soyuz Test Project. The Apollo and Soyuz docked with each other on July 17, marking the only international meeting in space as of the printing of this manual.

On December 16, 1979, the first Soyuz T craft was launched, marking the next major modification to the design. This design had new engine and computer systems and could carry three suited crewmembers.

One more version has been introduced: Soyuz TM–1 was launched on May 21, 1986. This new craft had a new docking system and slightly improved payload capability. Only a few months after the Mir was launched, this new transportation vehicle was ready for the Cosmonauts. See Figure 1–5.

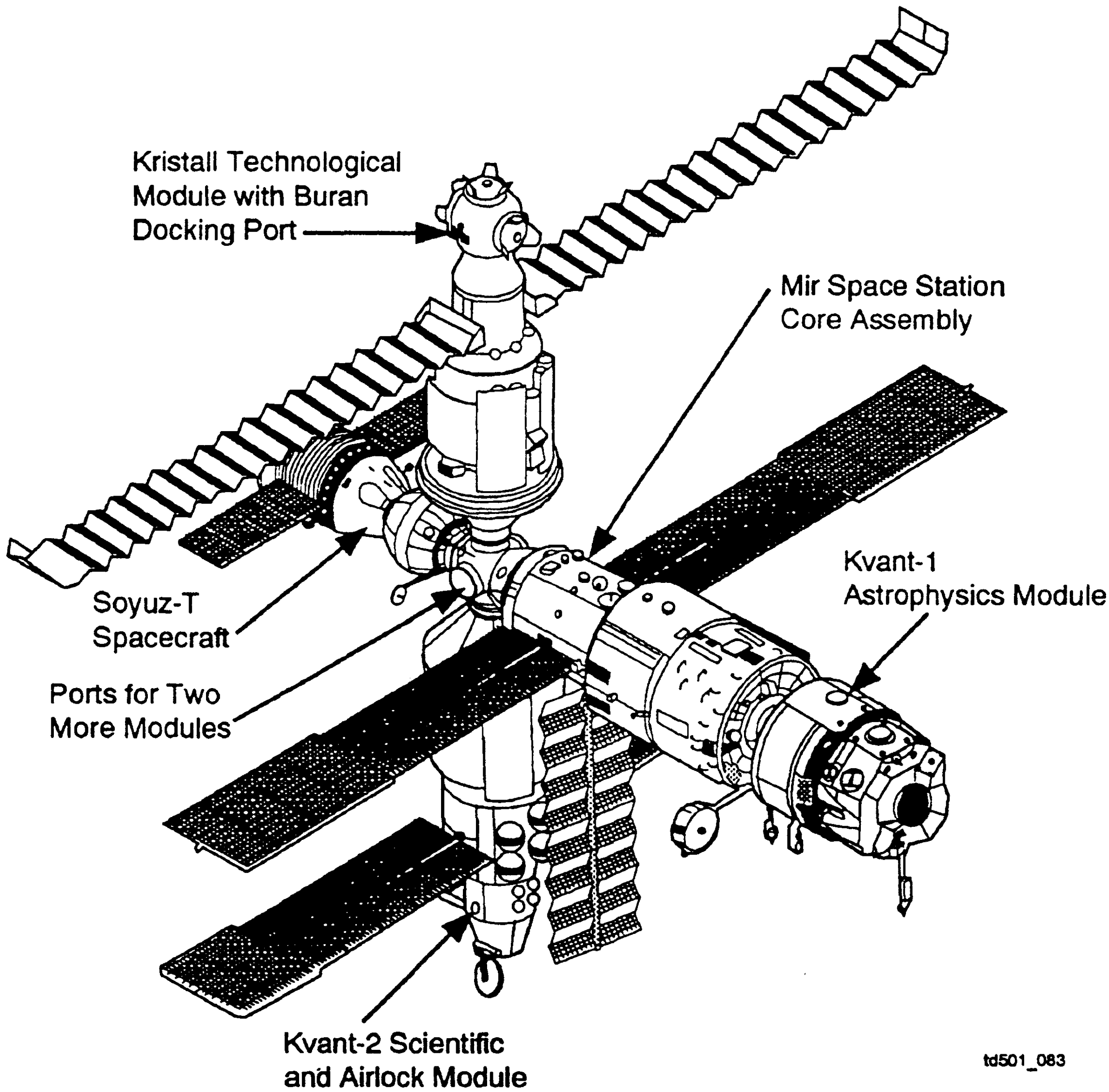

Figure 1–5. Mir, Kvant–1, Kvant–2, Kristall, and Soyuz

1.9 THE PROGRESS

Since little space was left for cargo on the Soyuz flights, some form of cargo transport needed to be developed to support the space stations. As, with most of the new designs coming from the Russian space program, an existing vehicle (a Soyuz capsule) was modified to provide the function required. On January 20, 1978, the first Progress supply ship was launched in support of Salyut 6. Progress 1 was the first in a long line of automatic transport vessels that are still supporting Russian space stations. The Progress operates automatically without any Cosmonauts onboard, and with no control from Cosmonauts on the Mir Complex. A new Progress visits the space station regularly to resupply Cosmonauts with O_2 and N_2, propulsion fuel, food, water, clothing, equipment /experiments, etc. See Figure 1–6.

Once the supplies have been moved to the station, trash, used equipment, and other "throw away" articles are placed in the Progress, and the vehicle is deorbited in a manner to cause its destruction. Judging by material available at the time of publication, well over 50 Progress resupply missions have been flown to Russian space stations.

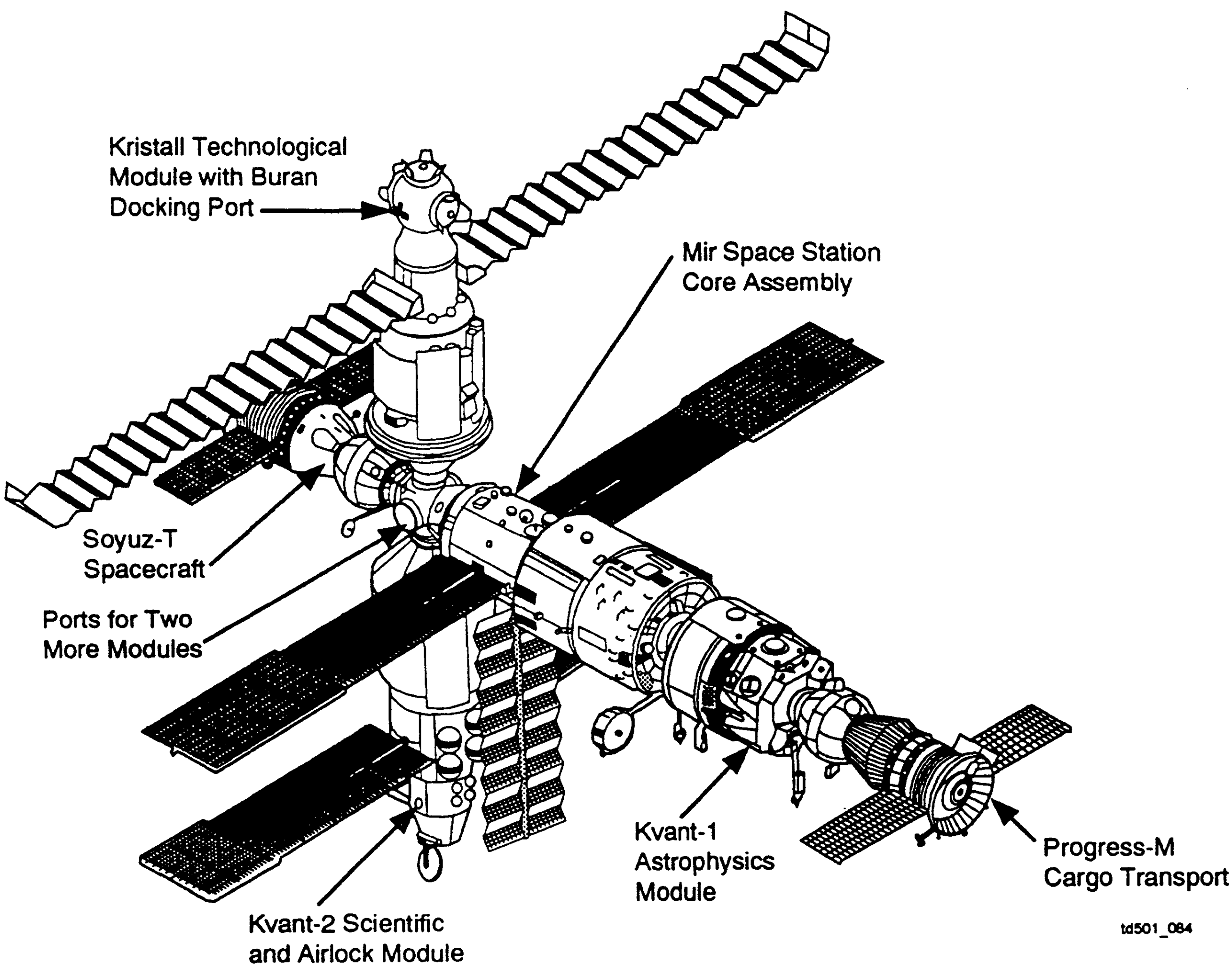

Figure 1–6. Mir Complex

1.10 SUMMARY

Through the years, the space program of the former Soviet Union has made extensive advancements, using very small steps. Almost every new vehicle they have produced is the result of slight modifications to an existing one. Transportation capsules are all very similar whether they are automatic or manually operated, and whether they carry crewmembers or simply cargo. The early Salyut space stations transformed into the Mir Complex of today. The design life of the current Mir Complex will expire in 1996. Prior to arrangements made by the United States (U.S.) and Russian governments, the Russians were planning to build a second Mir Complex. Sources indicate that the Russians intend to continue the pursuit of space technology on future stations with the main goal of travel to Mars in mind.

QUESTIONS

1. The Salyut program can best be described as

   a. The permanently manned space station prior to the Mir Complex

   b. Spacecraft used to transport cosmonauts to the various space stations

   c. A series of stations leading up to the Mir Complex

2. The Mir Complex is a "______ generation" space station.

   a. Second

   b. Third

   c. Fourth

3. The Mir Complex evolved in the following order

   a. Mir module, Kvant–1, Kvant–2, Kristall

   b. Mir module, Soyuz, Progress, Kristall, Kvant–1, Kvant–2

   c. Kvant–1, Mir module, Kvant–2, Kristall, Progress

4. Once in orbit, the Mir Complex has been resupplied primarily using

   a. Both the Progress and Soyuz crafts to transport cosmonauts

   b. Soyuz craft for cosmonauts and Progress craft for cargo

   c. Salyut craft for cargo and Soyuz craft for humans

SECTION 2
OPERATIONS PROFILE

2.1 PERFORMANCE OBJECTIVES

By the end of this section, the reader should be able to:

- Describe the operations performed by flight controllers and those performed by the crew during a Mir Complex mission
- Describe operations performed jointly by the crew and ground teams during Mir Complex missions
- Discuss the Mir Complex mission profile with respect to crew and flight control team preparation, crew change–out, unmanned operations and logistics resupply

2.2 INTRODUCTION

The Soviet design philosophy for the Mir Complex was to allow the ground perform all actions unless the crew was absolutely required to perform them. Examples of actions to be performed by the crew include things like closing hatches, performing maintenance and equipment change–outs and correcting failures that are usually several layers deep and are not covered by autonomous functions. This design philosophy has led to an interesting mix of crew and ground responsibilities. In addition to the design philosophy, the communications coverage also dictates the operational environment.

2.3 GROUND OPERATIONS

2.3.1 Control Center

The Russian manned space program has three control rooms located within a single complex in Kaliningrad. The Control Center, Mission Control Center–Moscow (MCC–M), is capable of processing data from up to 10 spacecraft; however, each of the control rooms is dedicated to a single program. One of the control rooms is dedicated to Soyuz–TM vehicles, one to Buran, and the other to the Mir. It should be noted that each module of the Mir Complex is capable of producing its own telemetry stream and hence could be regarded as a separate vehicle. Controllers can display data from up to three different vehicles simultaneously.

Unlike the Mir and Buran control rooms, which resemble closely the MCC–H, the Soyuz control rooms physically resemble an office–type room. The Soyuz control rooms have low ceilings and a flat, non–tiered floor. The room is physically long and narrow and has approximately seven rows of consoles that face a large wall display system.

Flight control personnel for the Mir are organized into teams, much like U.S. Mission Control Center (MCC) teams are, with front– and back–room operators. Little information is available at this time as to the specific split of responsibilities between front and back room controllers; even the number of back room controllers is not detailed. Figure 2–1 shows a block diagram of the functional positions in the front room (denoted by Flight Control Room (FCR)) and the back rooms (denoted by Systems Support Room (SSR)) for the Soyuz; it is assumed that the positions for the Mir are the same, although this has not been formally documented. The actual layout of

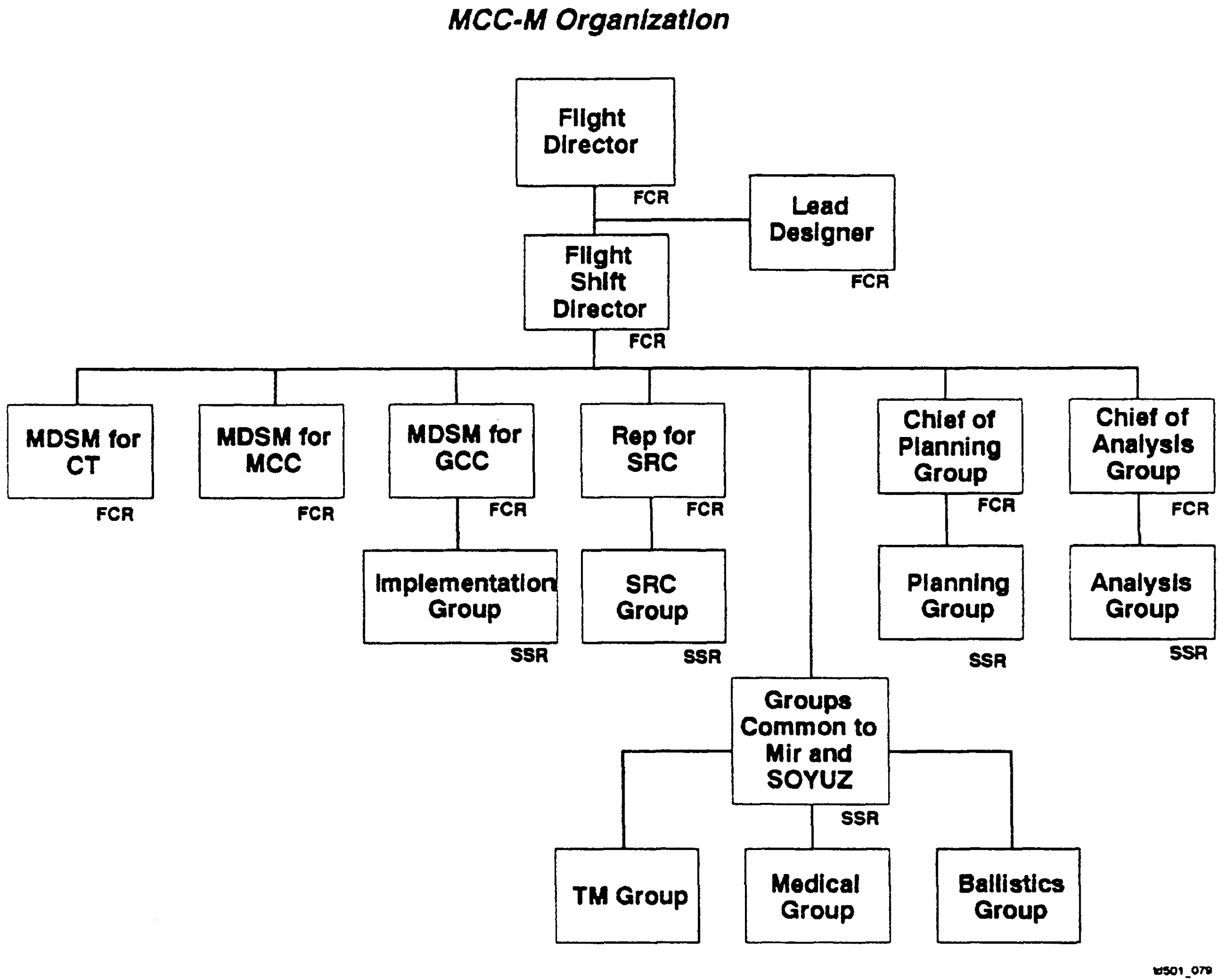

Figure 2–1. MCC–M organization

the Mir (and the Soyuz) control room is similar to the MCC, including a large world map display at the front of the room.

The responsibilities of the positions in the Soyuz control room are as follows:

Flight Director – This position, which is not manned full time, is somewhat similar to the Mission Operations Directorate (MOD) position in the MCC. The flight director provides policy guidance and serves as an interface to the State Committee, which is apparently similar to our mission management team.

Flight Shift Director – This person is analogous to our flight director and is responsible for real–time decisions within the bounds of "the documentation". This is interpreted to mean that the Flight Shift Director operates within guidelines much the same way our flight directors work within the framework of the Flight Rules.

Mission Deputy Shift Manager (MDSM) for the MCC – This person is responsible for the operations of the control center itself. It is believed that this includes the consoles and the mission operations computer equipment and peripherals.

MDSM for the Ground Control Complex (GCC) – This person is responsible for the configuration of the communications network equipment. The MDSM for the MCC is supported by a backroom known as the Implementation Group.

MDSM for Crew Training – This is the CAPCOM position. This person generally was the lead instructor for the crew prior to the flight.

Shift Chief of the Efficient Planning Group – This is analogous to our Flight Activities Officer, and is supported by the Efficient Planning group backroom.

Shift Chief of the Efficient Analysis Group – The specific role of this person is not detailed. The Efficient Analysis Group is co–located in the frontroom with the Shift Chief. This group performs the systems flight control functions.

Representative for the Search and Rescue Complex (SRC) – As the name implies, this person is the point of contact for the SRC during landing and recovery operations.

Representative of the Lead Designer – This person is similar to our Mission Evaluation Room representative.

As noted on Figure 2–1, there are several backroom groups which are common to the Soyuz and the Mir. These groups are the Telemetry group (TM), the Medical group and the Ballistics group. The Ballistics group performs functions similar to the Flight Dynamics officer in our MCC.

There are four teams of controllers for each Soyuz flight, five teams for Mir Missions. Each team works a 24–hour shift, then rotates off for 3 days, (4 days for Mir). Only a few of the console positions are actually present for much of the time, because of the brief communications coverage. Reports have indicated that there is only 12 minutes of communications per revolution using the ground sites. During Loss Of Signal (LOS), most of the controllers return to their offices until the next Acquisition Of Signal (AOS). Communications using a satellite link are also possible, in which case the controllers remain on console.

One of the activities of each team includes planning for their next shift, 5 days away. The plans are converted into a cyclogram, as shown in Figure 2–2, and uplinked to the crew. The cyclogram includes ground coverage, crew activities, ground site configurations, etc. Some documents report that the crew actively participates in preparing the crew activities part of the plan, as do medical personnel concerned with the physiological and psychological well–being of the crewmembers. However, there is no information on how this planning activity is coordinated. The plans are checked out prior to uplink using some type of simulation, although the details on this implementation are also not well understood.

Orbit (day)		11	12	13
Moscow time				
Visibilty ranges (ID) initial data				
Sun illumination				
Dynamic conditions		Joint flight with OM	THC	MCS OM:TS on braking
Programmable timer Flexible cycle Programs				
Radio equipment operation conditions		TD ORC	TD Setup recording in ODCC DCS ORC	TD Setup recording in ODCC DCS (r) ORC
Crew operations		† TS activition, autonomous power So Final loading of return cargo	Transfer hatch closing Pressure drop from DA Pressure control in DA † LC ACS SO	Spacesuits, belts, Carcass donning transfer to DV Hatch closing DV-LC † DV ACS SO Check-out of spacesuits and DV-LC hatch pressuretightness
Message from (on-) board		Check-out of communication from TS (Time initiating)	Report on autonomous power SO Radiogram on F.03 TS Report on THC	Report on pressure control results in DA
Message to (on-) board		Radiogram on autonomous power SO Data on descent Radiogram on GLOBE correction	Permission for THC Mention of belts, carcass donning and Water-salt additions taking	Data on undocking Time correction Descent cyclogram correction
Command-program data transmission				
Data transmission to MCC				
Data exchange	MCC	On 8-10 orbits F.512 is sent for descent on 1-3 orbits		
	BG	† TS wight (if needed)		

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Figure 2–2. Cyclogram

2.3.2 Mission Preparation

Flight controllers as well as crewmembers receive theoretical training, which is done primarily by using technical design documentation along with lectures by scientists and vehicle systems designers. Written and oral exams are required prior to moving on to the next phase of training. The duration for this training is unspecified.

Controllers for the Soyuz are assigned to a team for a specific mission once they have successfully passed all of the exams on the theoretical material. Teams of controllers then participate in simulations, which start about 2 weeks prior to flight. Each team will have three sims prior to flight and each controller must successfully complete the objectives of the sim. In the event a controller does not perform satisfactorily during a sim, the entire team must repeat the exercise until everyone performs correctly. There is no information available concerning the impact to flight schedules if sims must be repeated.

The first phase of training for the Mir controllers is assumed to be the same, consisting of theoretical material and exams. There is no capability for integrated sims for the Mir as such. It is assumed that On–the–Job–Training (OJT) accounts for a large portion of the controllers training. The MCC has the capability of introducing "malfunctions" into the front end during real–time to achieve proficiency training for the controllers.

Training for crewmembers is somewhat different. The crews also receive practical training as well as the theoretical training. The practical training involves examining and working with real hardware. In addition, there are several simulators and mock–ups used for crew training.

Soyuz crews can train at Kaliningrad or Star City on fixed base simulators. The simulator complex at Kaliningrad is capable of integrating with the control center; the complex at Star City is stand–alone only and has two identical simulators. Prime crews do all of their training in Star City, and therefore do not participate in the integrated simulations.

Mir crews train primarily in Star City. There is a 1–G trainer which has all of the Mir Complex modules represented, although the orientation of the modules is altered to support the 1–G operations. This trainer is used primarily for procedural training and cannot be integrated with the control center. There are also several Part Task Trainers (PTTs) that have been identified, including ones for rendezvous, docking, and neutral buoyancy training. Star City also has a planetarium with over 30,000 stars in which the crewmembers can practice using navigational devices.

Crews participate in extensive physical training in addition to their flight training. Each crewmember is expected to participate in some type of sport or physical conditioning for up to 2 hours per day. This is a scheduled activity which is continued on orbit. Crewmembers are also given extensive training in centrifuges and neuro–vestibular adaptation devices in an attempt to minimize the effects of weightlessness.

2.4 ONBOARD OPERATIONS

A flight plan is uplnked to the crew each day. This plan covers activities scheduled for a single day which is 5 days in the future. Note that the execution of this plan will coincide with the next duty shift of the MCC–M team which generated it. Most sources state that the flight plan leaves room for a high degree of autonomy, allowing the crewmembers to adjust the timing of activities to suit their needs. The crew day starts at 8 a.m. (Moscow time) and extends until 11 p.m., allowing 9 hours for personal time and sleep. Crews are not required to do any circadian shifting (the alteration of sleep cycles) for their flights, because it is believed that efficiency will be increased by leaving crewmembers on the same time–base as their home. Most sources indicate that crews work 5 days per week and are allowed 2 days off. During the off days, the crews are only required to conduct some light housekeeping activities and perform their exercises. Crewmembers are required to exercise for 2 hours each day, which is scheduled during the working hours of the day.

Since the Mir systems are intended to be autonomous, very little crew involvement is required to operate the systems. Most of the time is spent performing housekeeping and maintenance tasks, and relatively little time seems to be dedicated to conducting experiments. As little as 2 to 2.5 hours per day may be allocated to experiments. The Mir is used as a technology test–bed, testing out various systems components in parallel with operating components. It is unclear whether time spent working on such test equipment is considered a maintenance task or an experiment.

Crewmembers can interact with the onboard systems via dedicated control stations located in each module. The control systems include several Cathode–Ray Tube (CRT) display screens as well as matrices of push–buttons and status lights. More information concerning the control stations can be found in Section 4, Computational Systems.

As mentioned earlier, interaction with the ground is limited because of the use of ground–based communications rather than satellite communications most of the time. During periods of AOS, the crewmembers have voice as well as two–way video communication capability. Two–way video is used for family visits, which improves the morale of the crew. Other efforts to enhance crew morale include the use of music and video taped programs designed to be motivational or relaxing.

Since the systems on the Mir were designed to be run autonomously, the Mir can be operated unmanned. This is accomplished by using a combination of software programs which are stored on the Mir as well as monitoring and commanding the Mir Complex from the ground.

2.5 MISSION PROFILE

Typical missions begin with the launch of either two or three crewmembers aboard a Soyuz–TM spacecraft from the Baikonur complex. It typically takes 2 days for the spacecraft to reach the Mir Complex and perform the rendezvous and docking operations. Only the approaching spacecraft is required to perform any maneuvers for such operations. When the spacecraft is preparing to dock, the resident crew puts on EVA suits and retreats into the resident Soyuz–TM as a precautionary measure. Docking always occurs at one of the axial ports. Once the hatches are opened, both crews remove their suits and begin the handover activities. The duration of a handover is variable, depending on the experiments to be carried out while both crews are present.

During the handover period, the resident crew instructs the arriving crewmembers on specific operational characteristics of the station complex. This includes explaining any deviations from planned activities. At the end of the handover period, all crewmembers again put on their suits. The returning crewmembers get into the resident Soyuz–TM, i.e., the one that has been on the station the longest. The remaining crewmembers retreat to the newly arrived spacecraft until the undocking of the returning spacecraft is complete. The Soyuz–TM spacecraft has a limited on–orbit lifetime, so this rotation ensures that the crew always has a way to return to earth.

Once the Soyuz has left the Mir, the new Soyuz is moved to a radial port, thereby freeing the axial port for docking of another spacecraft. The new crewmembers settle into their routine of system operations, maintenance, and conducting experiments. Resupply of fresh foods, equipment, consumables, and mail occurs on a relatively frequent basis using either Progress or unmanned Soyuz–TM spacecraft. Therefore, crewmembers can request supplies and equipment as needed and replacements will not take too long to arrive. The frequent resupply also helps keep crew morale high.

2.6 SUMMARY

The Mir Complex was designed to be operated with minimal interaction from the crew. The systems on the Mir Complex either operate automatically or are controlled by the ground and most functions can be carried out when the Mir Complex is unmanned. The MCC–M, located in Kaliningrad, is functionally similar to the MCC in Houston. The MCC–M consists of three dedicated control rooms, each capable of displaying data from at least two spacecraft. The control teams for the Soyuz–TM are similar in composition and function to Shuttle control teams, but little information is currently available on the composition of the Mir Complex control team.

Training for both the crew and mission controllers begins with theoretical lectures by scientists and design engineers. The controllers then go through a series of simulations without the capability for integrated simulations, except for Soyuz operations. The crew gets hands–on training with actual hardware, mock–ups, and standalone trainers. Much of the controllers' training occurs via OJT.

Crew operations are carried out 5 days per week, single shift, with activities scheduled from 8 a.m. until 11 p.m. Moscow time. Much of the crew's day is consumed with performing maintenance activities, with little time dedicated to systems operations or experiments. Crewmembers are required to exercise for 2 hours each day to maintain physical fitness.

Crew rotations are implemented using the Soyuz–TM spacecraft, always leaving one Soyuz–TM docked to the complex as an escape vessel. In addition to crew rotations, unmanned Soyuz and/or Progress vehicles are used for frequent resupply flights. Resupply flights deliver fresh foods, equipment, consumables, and personal items such as mail to the crewmembers.

QUESTIONS

1. Which of the following statements most accurately describes the activities of the Mir Complex flight controllers?

   a. There are three shifts per day, and each team works one 8–hour shift then has 4 days off

   b. There is one shift per day, and each team works on 24–hour shift, then has 4 days off

   c. There is one shift per day, and each team works from 8 a.m. till 11 p.m., then has 4 days off

2. The crewmembers spend most of their work day

   a. Eating, exercising, and conducting scientific experiments

   b. Monitoring and operating the onboard systems

   c. Performing housekeeping and maintenance tasks on the onboard equipment

3. The systems on the Mir Complex are primarily operated by

   a. Autonomous software and hardware functions

   b. Commands sent from the controllers in the MCC–M

   c. The crewmembers from dedicated displays

SECTION 3
STATION COMPONENTS

3.1 PERFORMANCE OBJECTIVES

By the end of this section, the reader should be able to:

- Identify the different modules which make up the Mir Complex
- Describe the compartments and functional elements of each Mir Complex module
- Identify the support systems and capabilities of each Mir Complex module

3.2 INTRODUCTION

The purpose of the section is to introduce and discuss the component modules which make up the Mir Complex. Information will be presented on the physical layout, systems, and scientific capabilities and working compartments of each module. Finally the distributed system support available in each module will be identified.

The Mir Complex (Figure 3–1) is currently made up of four separate modules. They are, in order of launch, the Mir (core module), the Kvant–1 Astrophysics Module, the Kvant–2 Scientific and Airlock Module, and the Kristall Technological Module. The Mir Complex is serviced by the Soyuz–TM Spacecraft and the Progress–M Cargo Transport.

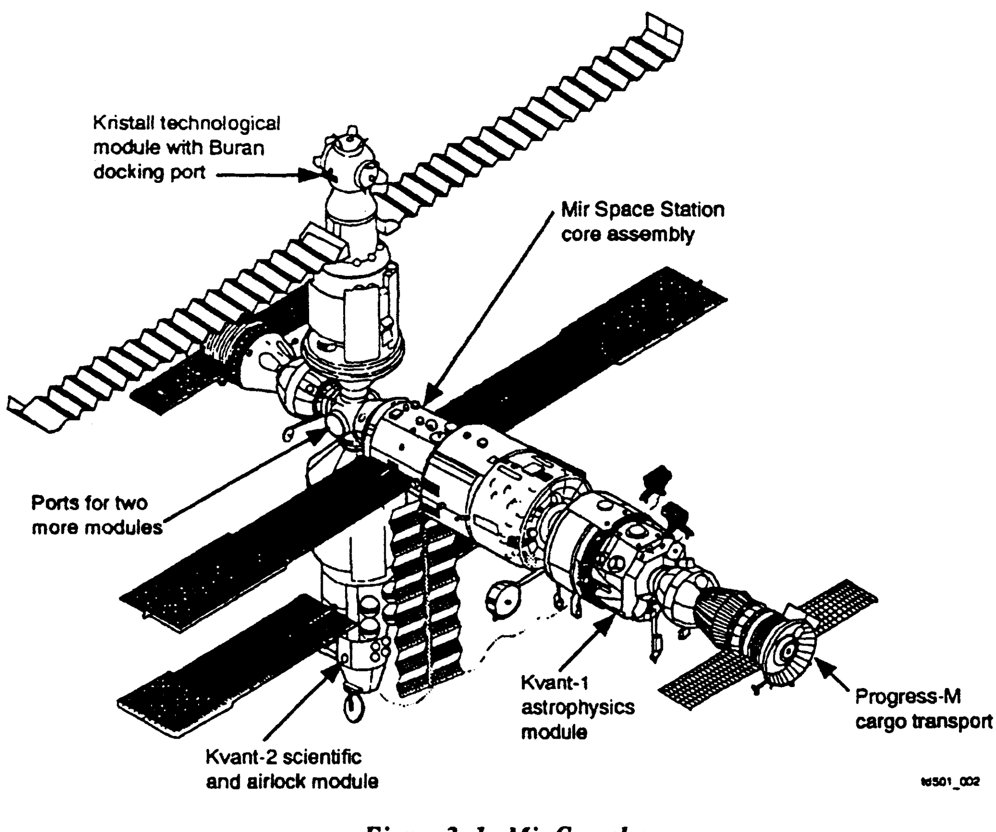

Figure 3–1. Mir Complex

3.3 MIR

The Mir is the central portion of the Mir Complex. The Mir supports the design concept of a Mir Complex as an assembly of separate pressurized modules with both core and specialty functions.

The Mir is made up of four compartments which are shown in Figure 3–2. These compartments are designated the transfer, working, intermediate, and the assembly compartment. All but the assembly compartment are pressurized.

3.3.1 Transfer Compartment

The purpose of the transfer compartment is to provide multiple docking ports for additional station modules or transport craft as well as a means of crew and equipment travel between Mir Complex modules. The transfer compartment is a sphere with five circular docking ports as shown in Figure 3–2. The main docking port is located axially along the Mir centerline and provides docking capacity for transport and cargo spacecraft. The remaining four docking ports are located radially on the sphere at 90° increments. These radial ports provide the means to expand the Mir Complex by the addition of specialized modules.

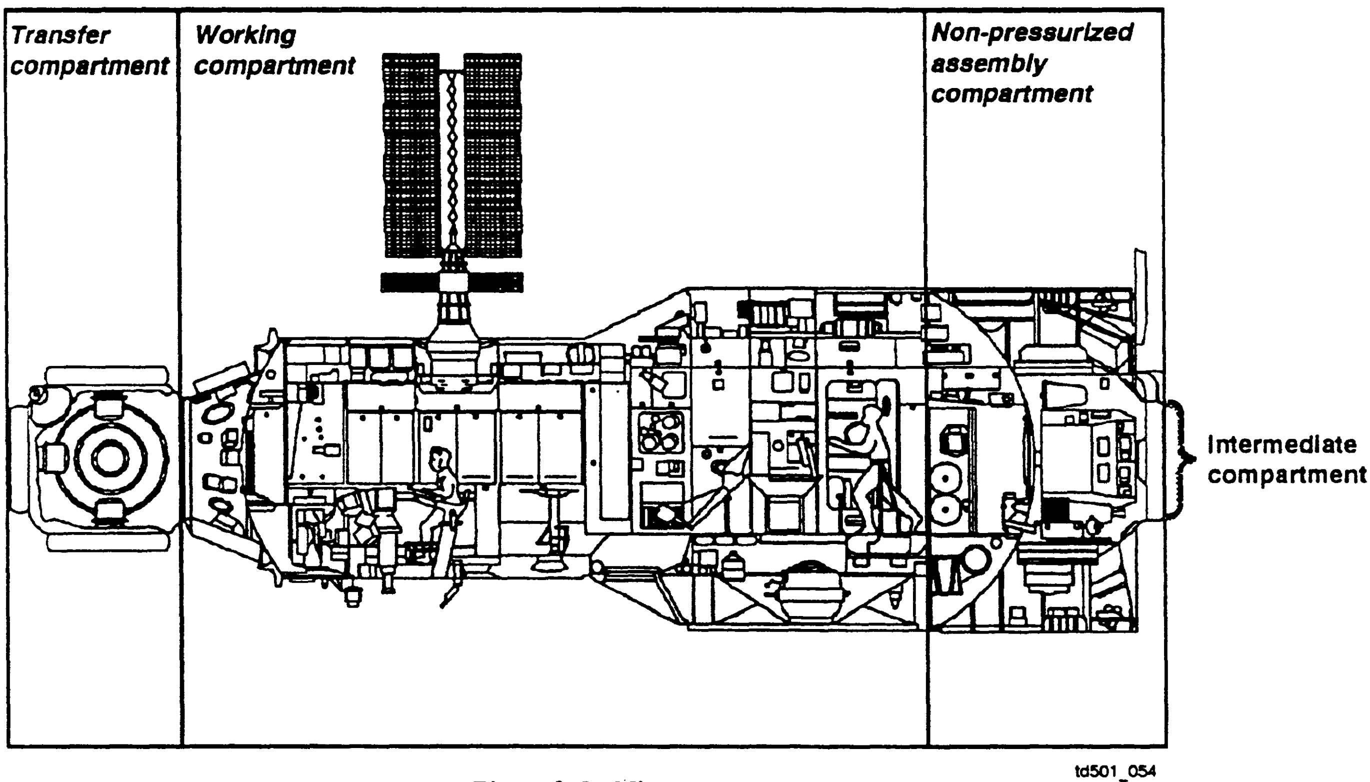

Figure 3–2. Mir compartments

3.3.2 Working Compartment

The working compartment is the main habitable volume on Mir and is made up of two concentric cylinders connected by a tapered conical section as shown in Figure 3–2. The maximum compartment diameter is 4.1 m (13.5 ft), and the length is 13.2 m (43.3 ft). The weight is 21 metric tons on Earth. The forward and aft bulkheads of the working compartment are spherically curved. The forward bulkhead connects to the transfer compartment and is smaller, 2.2 m (7.2 ft) in diameter. Three solar panels with a total area of 200 m^2 (2,150 ft^2) are attached to the outside of the smaller cylinder.

The interior of the working compartment is divided into an operations zone and a living area. The operations zone occupies the smaller diameter section. The Mir Complex crews prefer a spatial orientation of floor and ceiling with the sides arranged in a bottom–to–top orientation despite the formal irrelevance of the terms in the absence of gravity. The floor of the operations area is covered with dark green carpet, the walls are light green and the ceiling is white with florescent lamps. The arrangement of equipment and the interior finish of the working compartment are designed to reinforce this bottom–to–top orientation. The living area uses the same spatial orientation concepts, but soft pastel colors are used to imply a home–like atmosphere.

The operations area functionally acts as the "brain" of Mir Complex. Monitoring and commanding of the core systems, scientific equipment, and mechanisms are carried out in the Mir Complex central control station. The operations compartment also contains the piloting station. Medical monitoring equipment and a bicycle ergometer are located in the conical portion of the working compartment.

The living area of the working compartment provides the necessities for long–term manned missions. The living area contains a galley area with a table, cooking elements, and trash storage. Individual crew cabins, which include a porthole, hinged chairs and a sleeping bag are found next as one moves axially through the working compartment. The aft end of the working compartment which is bounded by the curved bulkhead, contains the personal hygiene area with toilet, sink, and shower.

3.3.3 Nonpressurized Assembly Compartment

Beyond the aft bulkhead is the nonpressurized assembly compartment (Figure 3–2). This annular space contains the main engine and fuel tanks. Externally, this assembly supports the satellite communication pencil–beam antenna, docking radar antennas, lights, and optical sensors.

3.3.4 Intermediate Compartment

The intermediate compartment is a pressurized tunnel that is 2 m (6 ft) in diameter that connects the working module to the aft docking port. The tunnel is located in the center of the nonpressurized assembly compartment.

3.3.5 Mir System Support

The Mir is supported by a core Electrical Power System (EPS), Thermal Control System (TCS), Computational Systems (CS), Environmental Control and Life Support System (ECLSS), Communications and Tracking System (C&T), and a propulsion system. The core is covered with screen–vacuum heat insulation to aid in temperature control.

3.4 KVANT–1 ASTROPHYSICS MODULE

The Kvant–1 Astrophysics Module (Kvant–1) is located on the aft docking port of the Mir as shown in Figure 3–1. The purpose of the Kvant–1 module is to provide data and observations for research into the physics of active galaxies, quasars, and neutron stars. This data is gathered with devices which measure electromagnetic spectra and x–ray emissions. The Kvant–1 also supports biotechnology experiments in the areas of anti–viral preparations and fractions.

The Kvant–1 module is shown in Figure 3–3. Kvant–1 is 5.8 m (19 ft) in length and has a maximum diameter of 4.35 m (14.3 ft). The Kvant–1 is docked to the aft portion of the Mir via the Active Docking Unit. The Kvant–1 is divided into a pressurized laboratory compartment and a nonpressurized equipment compartment. The laboratory compartment is further divided into an instrumentation area and a living area, which are separated by an interior partition. A pressurized transfer chamber connects the Passive Docking Unit with the laboratory chamber. The nonpressurized equipment compartment contains power stabilizers.

1. Igla docking antenna
2. Docking probe
3. Orientation device
4. Camera port
5. Launch shroud
6. Transponders
7. Docking target
8. Star tracker
9. Rear docking port
10. Kurs docking antennas
11. Igla docking antennas
12. Instrument section intermediate compartment
13. Work section

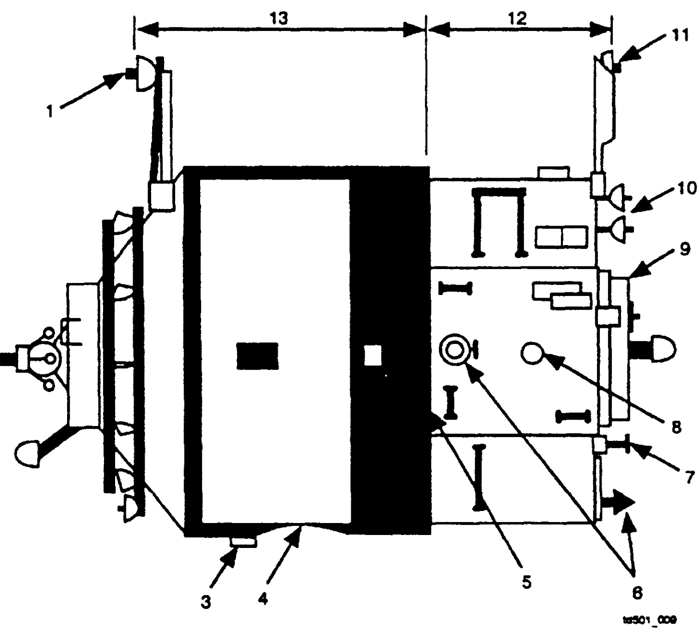

Figure 3–3. Kvant–1 module

3.4.1 Kvant–1 Systems Support

The Kvant–1 contains gyrostabilizers that can change the station attitude without using propulsive fuel. The Kvant–1 is supplied electrical power and contains some ECLSS equipment as well as thermal control equipment.

3.5 KVANT–2 SCIENTIFIC AND AIRLOCK MODULE

The Kvant–2 Scientific and Airlock Module is attached to a radial docking port of the Mir transfer compartment as shown in Figure 3–1. The purpose of the Kvant–2 is to provide biological research data, earth observation data, and EVA capability.

The Kvant–2 is shown in Figure 3–4. Kvant–2 is 12.4 m (40.7 ft) long with a maximum diameter of 4.35 m. The module has two solar panels. Kvant–2 is divided into three pressurized compartments; instrumentation/cargo, science instrument, and airlock.

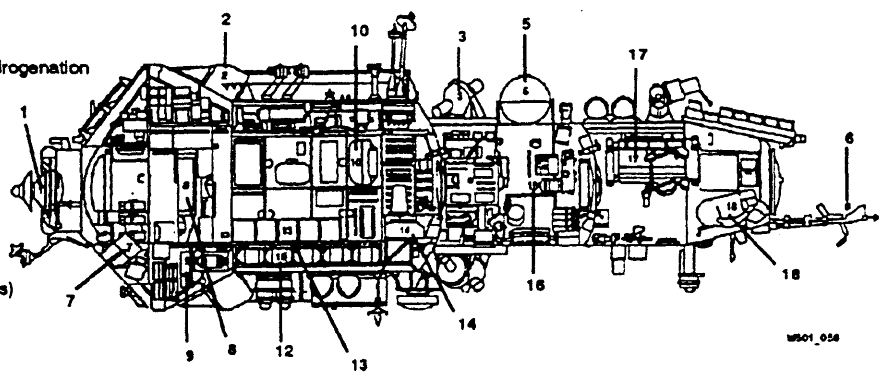

Figure 3–4. Kvant–2 module

3.5.1 Airlock Capability

The Airlock not only provides EVA capability, but also contains a self–sustained cosmonaut maneuvering unit that increases the range and complexity of tasks that can be attempted via EVA. For instance, various construction materials and electronic components can be placed on the outside of the Mir Complex modules via EVA. The effects of the space environmental exposure on these construction materials can later be investigated.

3.5.2 System Support

The Kvant–2 also adds additional system capability to the Mir Complex. The Kvant–2 includes additional life support system, potable water, and oxygen provisions, motion control systems, and power distribution, as well as shower and washing facilities.

3.6 KRISTALL TECHNOLOGICAL MODULE WITH BURAN DOCKING PORT

The Kristall Technological Module (Kristall) is located on the radial docking port of the transfer compartment opposite the one that is used for the Kvant–2 as shown in Figure 3–1. The purpose of the Kristall module is to develop biological and materials production technologies in the space environment, as well as provide a potential means of docking for the Buran reusable shuttle orbiter.

Kristall is shown in Figure 3–5. Kristall is 12 m (39 ft) long with a maximum diameter of 4.35 m (14.3 ft). Kristall has two solar panels. Unlike the other solar panels on the Mir Complex, these can be folded or unfolded as a function of electrical power requirements. Kristall is divided into instrument/cargo and instrument/docking compartments.

1 Active docking unit
2 Engine installation
3 Telescope GLAZAR 2
4 Tank system RODNIK
5 Instrumentation MIRINA
6 Androgenous-peripheral docking assembly
7 Control post
8 ONIKS panel for the KRATER V installation
9 Running track
10 Motion control system
11 Energy supply system
12 SVET arrangement
13 RODNIK system panel armature
14 Freezer
15 KSENIA device
16 Reusable solar battery drive
17 Kristallizer ChSK-1
18 PRIRODA-5 equipment

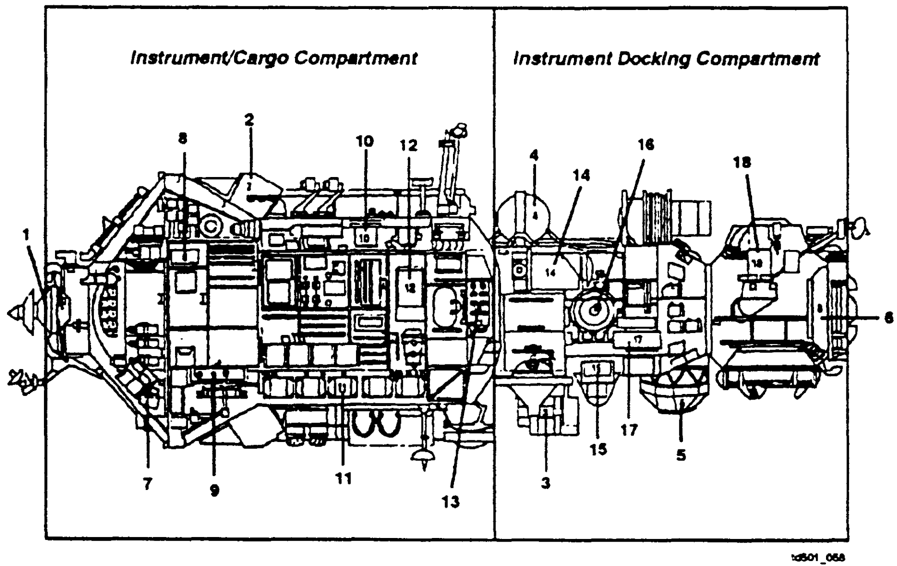

Figure 3–5. Kristall module

3.6.1 Instrument/Cargo Compartment

The instrument/cargo compartment includes instrumentation for materials production technology and biological experimentation.

3.6.2 Instrument/Docking Compartment

The instrument/docking compartment serves as a berth for the Buran orbiter which is the Russian Space Shuttle equivalent. The Buran docking assembly is of the androgynous periphery type. A radial docking port exists also to allow linking with the scientific laboratory which can by ferried in the Buran cargo bay.

3.6.3 System Support

Kristall includes a motion control system, energy supply (electrical) system, environmental control system equipment, and a TCS.

3.7 SOYUZ–TM SPACECRAFT

The purpose of the Soyuz–TM Spacecraft is to transport crews and cargo to and from the Mir Complex. The Soyuz–TM can dock to the axial docking port on the transfer compartment as shown in Figure 3–1.

The Soyuz–TM module is made up of three compartments as shown in Figure 3–6; the orbital module, the descent module, and the instrumentation module.

3.7.1 Descent Module

The descent module contains accommodations for three suited crewmembers. The crew stays in the descent module during launch, attitude orientation, orbital corrections, rendezvous, docking, and descent. The descent module contains the main spacecraft systems control station. Soyuz systems include flight controls, descent soft landing systems, manual control equipment, life support and cabin pressure recovery systems, television/radio communication, direction finding, electrical power supply, command, and telemetry systems.

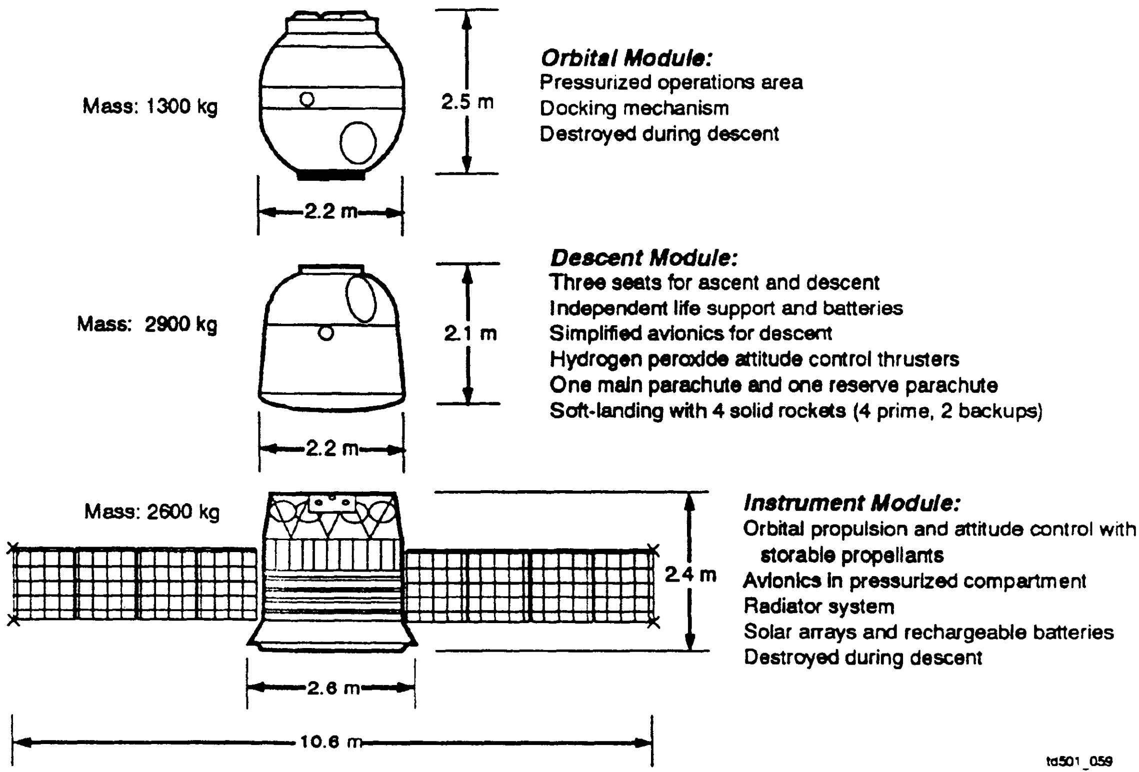

Figure 3–6. Soyuz–TM spacecraft modules

3.7.2 Orbital Module

The orbital module (Figure 3–6) is attached to the descent vehicle by explosive locks. The orbital module provides life support, rendezvous and docking systems, and onboard equipment controls. The docking unit mechanism is attached to the front of the orbital module. Some payloads that are carried to and from the Mir Complex are stored in the orbital module. The crew can remain in the orbital module during nondynamic flight phases.

3.7.3 Instrumentation Assembly Module

The instrumentation assembly module is a cylindrical shell with hemispherical ends which contains the orbital flight systems. The pressurized bay space is filled with a neutral gas. The instrument assembly contains the motion control system, command and flight path computer, radio links, telemetry, power supply, and temperature control systems. A set of solar arrays are attached externally to this module.

3.8 PROGRESS–M CARGO TRANSPORT

The purpose of the unmanned Progress–M is to transport cargo and resupply materials to the Mir Complex, to remove waste materials, and to return scientific data to earth when outfitted to do so. The Progress–M also can conduct experiments while attached to Mir Complex or in free flight. The Progress–M has a cargo capacity of 2400 kg. The Progress–M shown in Figure 3–7 has three compartments: orbital, tanker, and service/instrument.

Progress

This cutaway of the Progress resupply craft clearly shows its Soyuz derivation.

1. Short range radar transponder
2. Modified Soyuz orbital module with cargo for the Salyut crew
3. Long range radar transponder
4. Antenna
5. Soyuz instrument module
6. Soyuz KTDU-35 propulsion system
7. Equipment for the automatic control of Progress
8. Tanks for the propellant to be transferred to Salyut and nitrogen pressurant gas
9. Docking probe

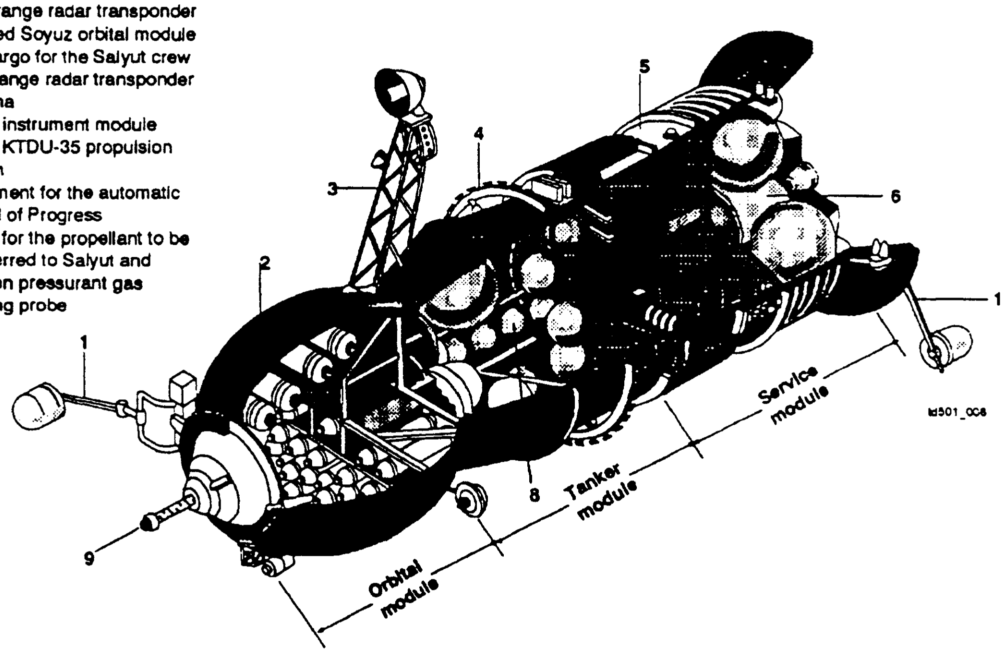

Figure 3–7. Progress–M

3.8.1 Orbital Compartment

The orbital compartment is a spherical, pressurized vessel with a volume of 6.6 m^3. The orbital compartment supports the docking system and supplies scientific equipment, exchange equipment for repairs, air regenerators, carbon gas absorbers, air filters, water, supplies, and sanitary goods.

3.8.2 Tanker Compartment

The tanker compartment is a nonpressurized volume that contains two tanks of propellant, as well as compressed air for tank pressurization and fresh air supply. The propellant fuel can be transferred by the crew or by remote command from a ground control center.

3.8.3 Service Compartment

The service compartment is a pressurized compartment that contains control equipment and a rocket motor section.

3.9 SUMMARY

The Mir Complex is a modular space station made up of four separate modules that were flown into orbit at different times. These modules include the Mir, Kvant–1 Astrophysics Module, Kvant–2 Scientific and Airlock Module, and the Kristall Technological Module with Buran docking Port. The Mir is the control portion of the Mir Complex and was launched first. Kvant–1 is an astrophysics laboratory, Kvant–2 supports biotechnology research and provides an airlock for EVA. Kristall supports crystal growth experiments and production technology research. Kristall also provides a docking port for the Buran orbiter. Crews and scientific cargo are transported via the Soyuz–TM Spacecraft. Cargo, returned scientific materials, and waste products are transported by the Progress–M Cargo Transport.

QUESTIONS

1. The Mir Complex currently consists of how many modules?

   a. Three

   b. Four

   c. Two

   d. Five

2. The Kvant–1 module is located on the axial port of the Mir?

   a. True

   b. False

3. The Mir is made up of four compartments.

   a. True

   b. False

4. The purpose of the Mir transfer compartment is to provide multiple docking ports for station modules or transport craft.

   a. True

   b. False

5. The purpose of the Kvant–2 module is to provide data and observations for research into astrophysics.

   a. True

   b. False

6. The purpose of the Kvant–1 module is to provide biological research data.

   a. True

   b. False

SECTION 4
COMPUTATIONAL SYSTEMS

4.1 PERFORMANCE OBJECTIVES

By the end of this section, the reader should be able to:

- Identify the functions of the onboard computational systems
- Describe the capabilities onboard computational systems
- Describe the interfaces between the onboard computational systems and other Mir Complex systems
- Briefly describe any similarities/differences between the onboard computational systems and the equivalent U.S. Space Shuttle systems

4.2 INTRODUCTION

The onboard computational systems used for Mir Complex operations are required to support the computational requirements for an orbiting platform. These requirements, such as state vector calculation, system management, communication, telemetry, etc., are similar to the requirements for the currently planned International Space Station. Included in this section are descriptions of the Soyuz–TM and Progress computational systems, which share components with Mir.

4.3 FUNCTIONS OF THE ONBOARD COMPUTATIONAL SYSTEMS

The topics covered by this section are the computational hardware, software, and support devices of the Mir Complex, the Progress resupply vehicle and the Soyuz–TM.

These functions are required due to the need to control dynamic operations of the vehicles, manage the onboard systems, and properly manage the various resources used to support the crew during missions. These functions are also required for Shuttle operations, and much of the computer system architecture is similar at a high level.

However, due to constraints on manufacturing capabilities, Soviet computational systems (hardware) were generally significantly less powerful than U.S. computational systems. Much of this was overcome by developing stronger programming techniques than those required by U.S. programmers. Even today, Russian programmers write software that is much more efficient in the use of Central Processing Unit (CPU) power. Additionally, the Soviet space program had less faith in automation than the U.S. program, a trend that continues under Russian leadership. Logic in many instances is accomplished by hardwiring the system, as in analog computers.

With this in mind, a direct one–to–one comparison of hardware and software does not provide an accurate picture. Functional comparisons will be used (where sufficient data exists), which should provide a better comparison.

4.4 DESCRIPTION AND LOCATION OF THE ONBOARD COMPUTATIONAL SYSTEMS

For clarity, the computer systems of each vehicle are covered individually. While much of the same computer architecture is applied to the different Russian vehicles, the purposes they are used for are substantially different.

4.4.1 Soyuz–TM

Unlike the Mir modules, the Soyuz–TM computer systems must be capable of supporting systems operations during ascent, orbit and re–entry. Dynamic vehicle control during ascent must also be supported by the Soyuz–TM computer systems, which is not required of the Mir modules (except for processing telemetry).

The computational functions for the Soyuz–TM are shared among three systems: Onboard Computer System (OCS), Onboard Digital Computer Complex (ODCC), and Onboard Complex Control System (OCCS). The OCS handles the majority of "number crunching" requirements for motion control. The ODCC includes the software for motion control, acts as a mass storage device for algorithms, commands, etc., and includes some small computers. The OCCS processes commands, performs data and command routing, power switching and includes the network hardware. This architecture and terminology is also used on the Mir Complex. See Figure 4–1.

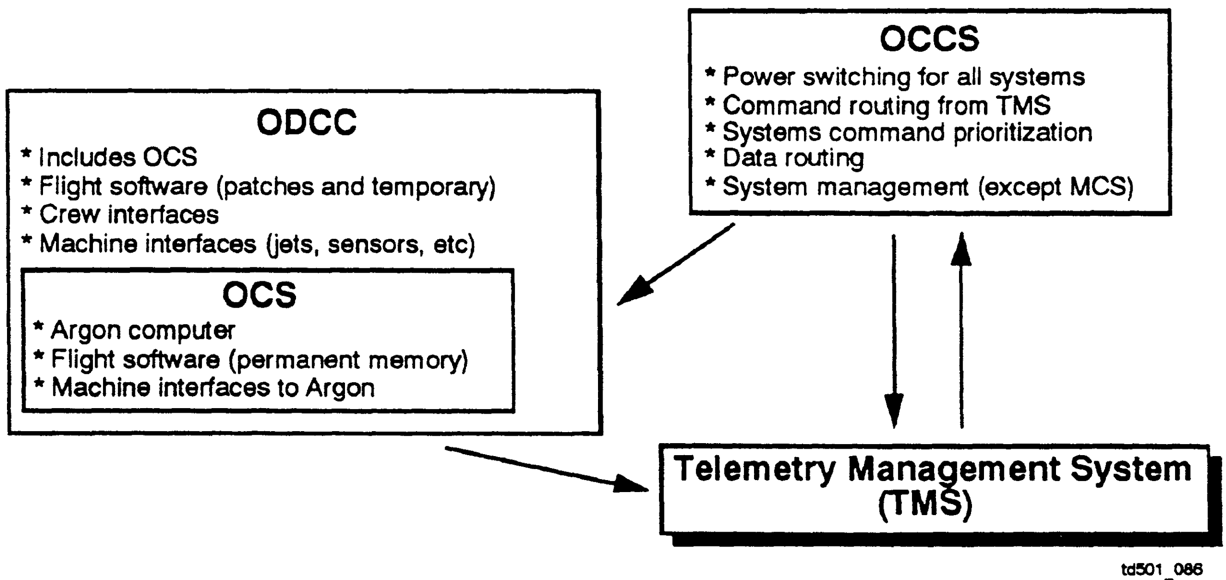

Figure 4–1. Computational system overview

a. Onboard Computer System

The main computer system currently used on the Soyuz–TM, modified from previous spacecraft applications and used on the Soyuz–T, is the Argon–16. Argon is a class of computers, with the Argon–16 being analogous to a particular model in that class. The Argon–16, located within the Instrument Module, reportedly contains 16 KB of Random Access Memory (RAM), and an unspecified amount of permanent Read–Only Memory (ROM). Some data sources state the total memory as 16 KB, which is split into ROM and RAM. The software used to conduct flight operations, or flight software, is contained within the permanent memory. Most dynamic flight operations that require computational support are conducted by the Argon–16.

Although reported as highly reliable, the Argon class of computers has experienced failures. One reported failure of an Argon class computer occurred during docking while the Soyuz was approximately 900 m from the Salyut. After rotating the Soyuz to perform a breaking maneuver, the Argon fired the engine and then failed the program. The software had erroneously detected a gimbal lock failure, shutting down the sequence of events. As with the previous failures, the crew established manual control and successfully docked. The manual docking required the crew to rotate the vehicle through all three axis, since they could not make a visual reference to the Salyut from the failed orientation, a worst case scenario situation.

As with the orbiter General Purpose Computers (GPCs), the Argon–16 interfaces with a number of the onboard systems, including communication and tracking, rendezvous systems, telemetry and the TV system. The Argon–16 is alternatively (erroneously) referred to as the OCS, but is actually part of the OCS. The function (and hardware) of the Argon–16 is analogous to the orbiter GPC set (five GPCs). Functionally, the OCS is somewhat analogous to the orbiter Data Processing System (DPS), which includes hardware, software, peripherals, and machine interface devices . However, some significant functions, such as systems management and crew interfaces, contained within DPS are not considered part of the OCS. See Table 4–1.

Table 4–1. Comparison of Soyuz-TM computer to Shuttle GPCs

	Argon–16 Soyuz	Orbiter AP101B	Orbiter AP101S	SSF EDP-16
Instructions				
Number	32	154	158	Intel 80386 ISA
Word Length	16/32	16/32	16/32	32
Logic Type		TTL	TTL Fast	CMOS
Performance 4 add/1 Mpy (MIPS)	.015	0.420	1.27	3.4
Main Storage				
Technology	Core	Core	CMOS	CMOS DRAM EDAC
Size	64 KB R/W 2 KB ROM	106496 Words	262144 Words	16 MB
Input/Output		24 1 MHz Serial	24 1 MHz Serial	
Power (W)	300	650	560	256
Weight (kg)	83	54.5	29.1	25.9
Size (cm)	30.5 x 30.5 x 30.5 estimated	2 boxes each 49.6 x 25.9 x 19.4	1 box 49.6 x 25.9 x 19.4	1 box 36.5 x 22.9 x 33.6
MTBF (hours)	19950	5000	18500	54,710 (est)
Probability of no failure over 100 hours	.995	.98	.995	.998
Probability of no failure over 5000 hours	.778	.368	.763	.913

The Argon system has been described as "triply redundant". This implies that all functions performed by the Argon are triplicated, as well as the inputs. This is not accurate, since a number of single sensor inputs are electronically reproduced (triplicated) and then placed on the three separate data buses. Many single point failures can occur from using this strategy.

The Argon system includes three CPUs, three Input/Output Processors (IOPs), three memory sets, and three sets of support buses. Power to the computers is shown as redundant, but probably does not get power from three redundant sources. See Figure 4–2.

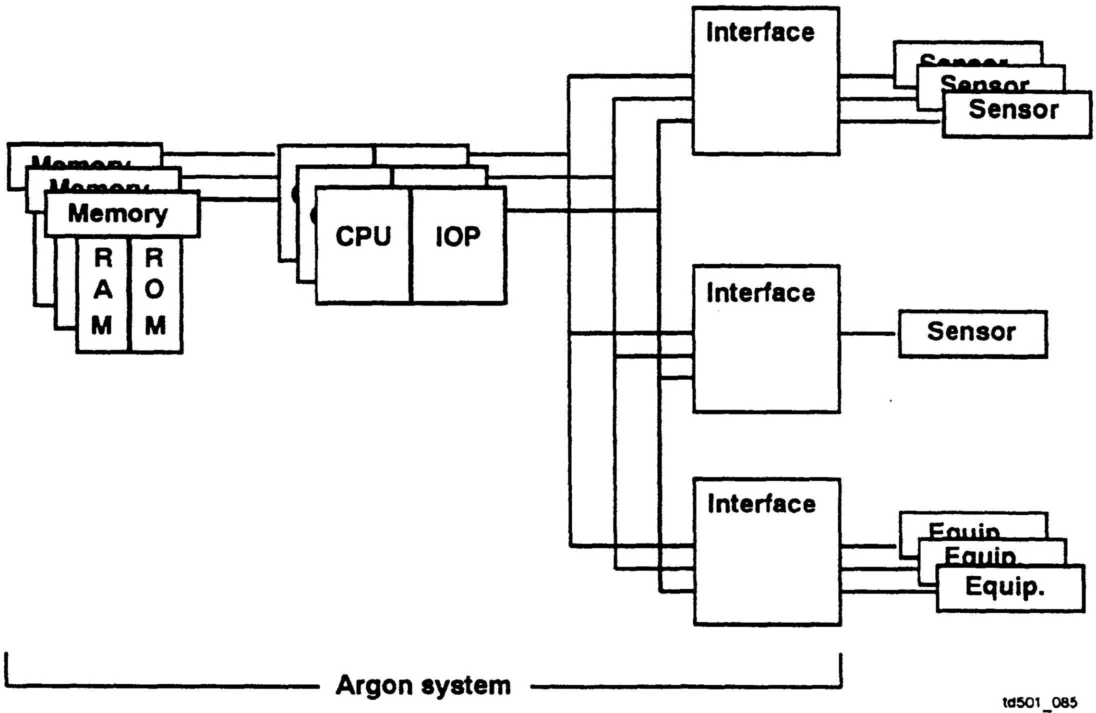

Figure 4–2. Argon system overview

The Argon operations are also similar to the GPCs. The three CPU/IOPs operate in parallel, with timing closely controlled. Software is processed independently in parallel, with the resulting solutions compared. This triple string voting arrangement is called Mode 1. As with the GPCs, a voting system is used for comparing solutions. If two Argons agree, the third is voted out of the set. Voting out is automatic and, unlike the oribter, only the ground is notified if a CPU/IOP is voted out of the set. Mode 1 is the normal mode of operation.

If a failure occurs, something which is deemed highly unlikely by the designers, then either the crew or the ground can downmode to Mode 2, priority voting. In this mode, two of the three sets are determined to be failed, and the remaining set has complete control. Operationally, the Russian space program feels operating in Mode 2 is acceptable up to the Mean Time Between Failure (MTBF) of the CPU/IOP. Information on whether this mode has been used, and the resulting consequences is currently unavailable.

In the final mode, Mode 3, each CPU/IOP operates separately. This is loosely similar to OPS 9 in Shuttle flight software, used for ground processing and testing. The purpose of Mode 3 for the Argon is probably much more focused on testing the computer system and used minimally for supporting systems ground processing.

b. Onboard Digital Computer Complex

The ODCC is a collection of application specific computers, mostly analog (contrary to its name). (Note: The closest U.S. analogy is the use of firmware.) Some references list the OCS as a subsystem of the ODCC, while other references list them as separate, distinct systems. In actuality, the systems are probably integrated systems, with the ODCC architecturally being a layer above the OCS. See Figure 4–3.

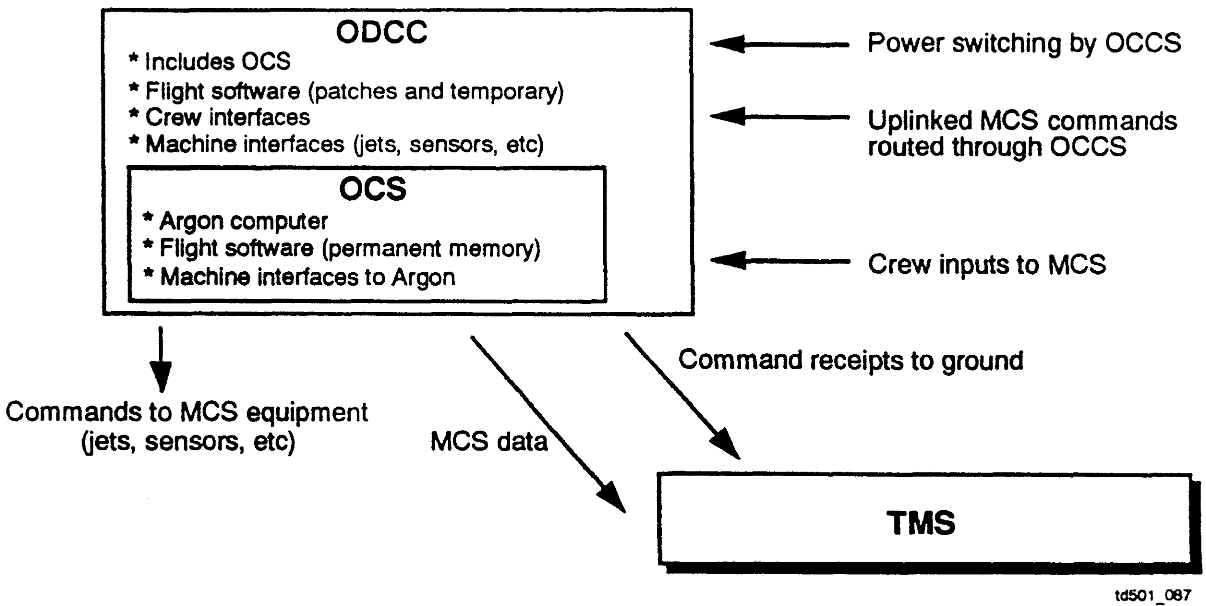

Figure 4–3. ODCC overview

The bias in the U.S. against using analog computers is not warranted. For a number of applications, analog computers are faster and more reliable than a digital application. Reliability reports on the failure rates for Russian analog space hardware are not unrealistic. Very little information exists on the number and design of components within the ODCC, other than the Argon.

The ODCC contains many of the algorithms needed for rendezvous and docking, as well as other GNC functions. The ODCC is the interface with the Motion Control System (MCS) jets and activates them upon receipt of a command from the OCS. Most of the MCS support equipment, such as sensors, is interfaced with and controlled by the ODCC.

Temporary software for motion control, as well as software patches, are contained within the ODCC. When needed, they are rolled into the OCS, in the RAM. Since the priority for software execution of the Argon is to first look in RAM for instructions, patches to the flight software are loaded into RAM. The erroneous flight software code in ROM is ignored. The software language used in the ODCC is C, used commonly in the U.S. for scientific applications.

The crew interfaces with the ODCC through the control panel, called the Neptune panel. See Figure 4–4. The crew uses the panel to enter commands, for system monitoring via the TV screen, and monitoring caution and warning. See Figure 4–5. An orbiter Rotational Hand Controller (RHC) equivalent, called an Attitude Control Handle (ACH) and a Translation Hand Controller (THC) equivalent, called a Transitional Motion Control Handle (TMCH) are also provided as interfaces to the ODCC. A Globus apparatus, part of the GNC function, is also on the control panel and is a representation of the Earth with the Soyuz ground track superimposed. The Globus is loosely analogous to the Shuttle "eight–ball", or Attitude–Direction Indicator (ADI).

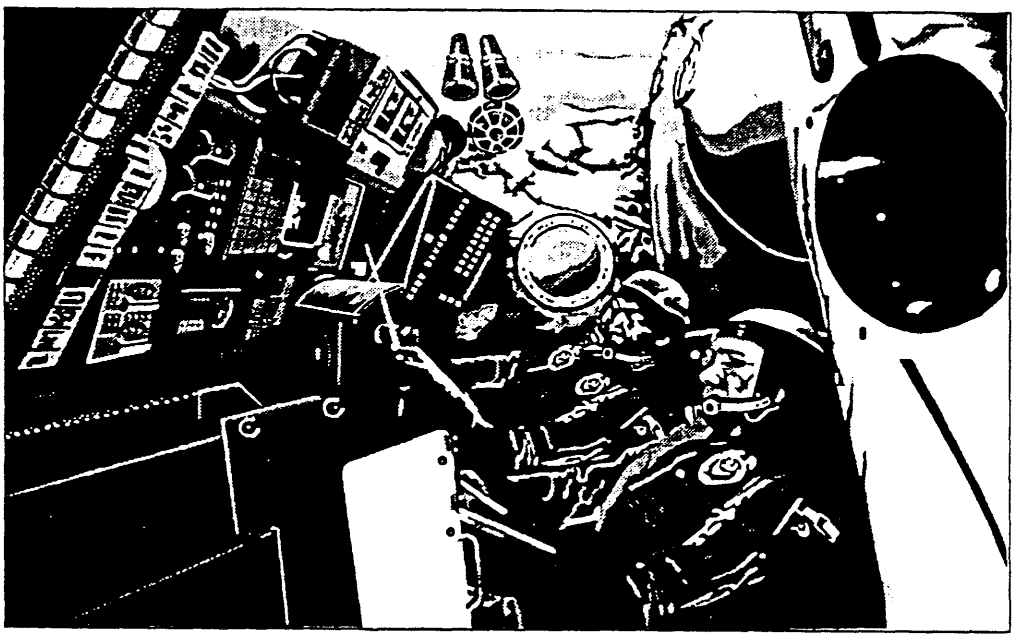

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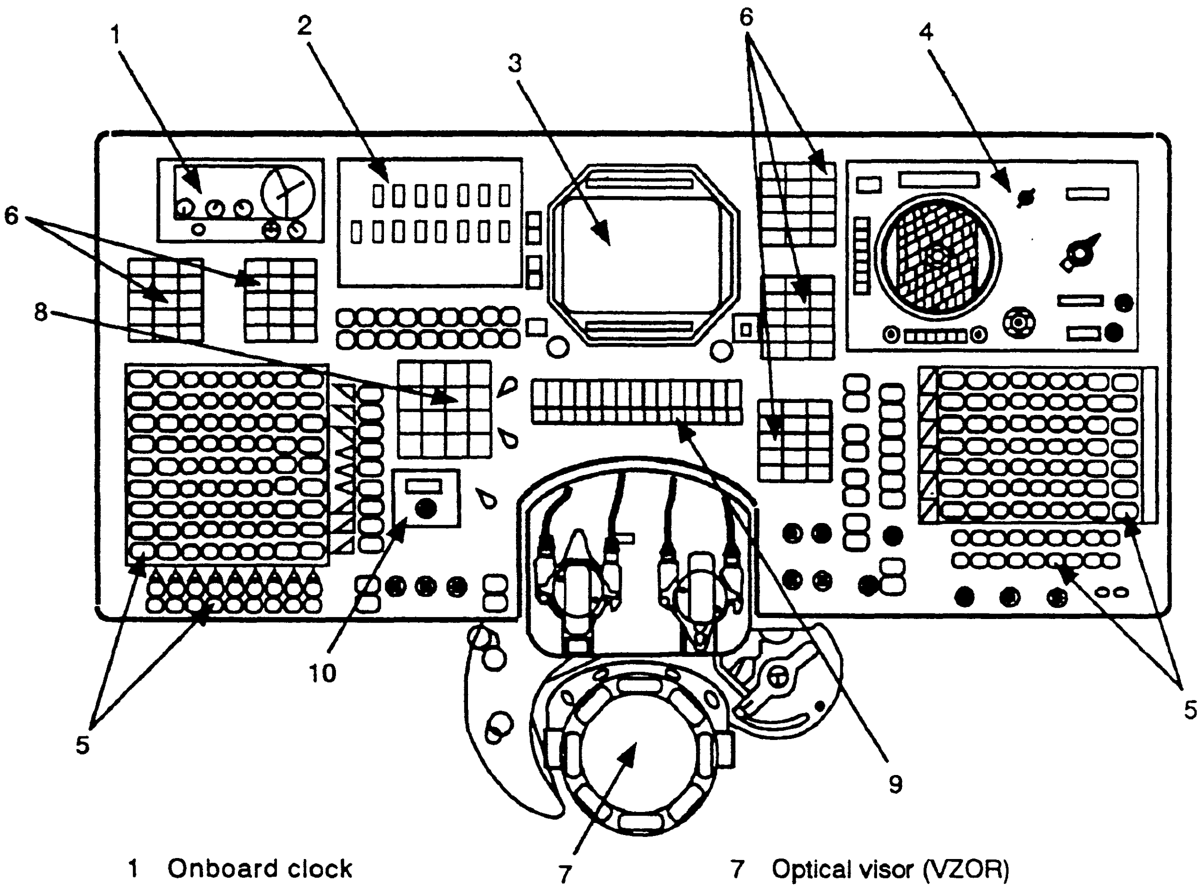
Figure 4–4. Crew interface

Additional equipment is also located on this panel, and is not part of the ODCC. The Neptune includes a communications panel for crew headsets, a command matrix used for entering and monitoring commands, a caution and warning panel, a voltage display, a current display, and a pressure display. There is also an electronic clock and a g–load meter.

The ODCC processes and displays rate/range data, angular attitude values, and unspecified (but known to be limited) Guidance, Navigation, and Control (GN&C) data. MCS command status is also processed and displayed to the crew on the command signaling device (command matrix).



1 Onboard clock
2 Keyboard for the computer
3 Computer display
4 "Globus" apparatus
5 Control panel and signal lighting
   81 lights on the left
   62 lights on the right
6 Onboard systems status lights/panels
7 Optical visor (VZOR)
8 Covered keyboard for main start-up commands
9 Keyboard for information selection
10 Ergol reserves indicator
11 Oxygen supply valves

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Figure 4–5. Soyuz–TM Control (Neptune) Panel

c. Onboard Complex Control System

The OCCS is also referred to as the Onboard Complex Control and Management System (OCCMS). The primary functions of the system are to provide power switching, command processing and prioritizing, data and command routing, and some crew interfacing. See Figure 4–6.

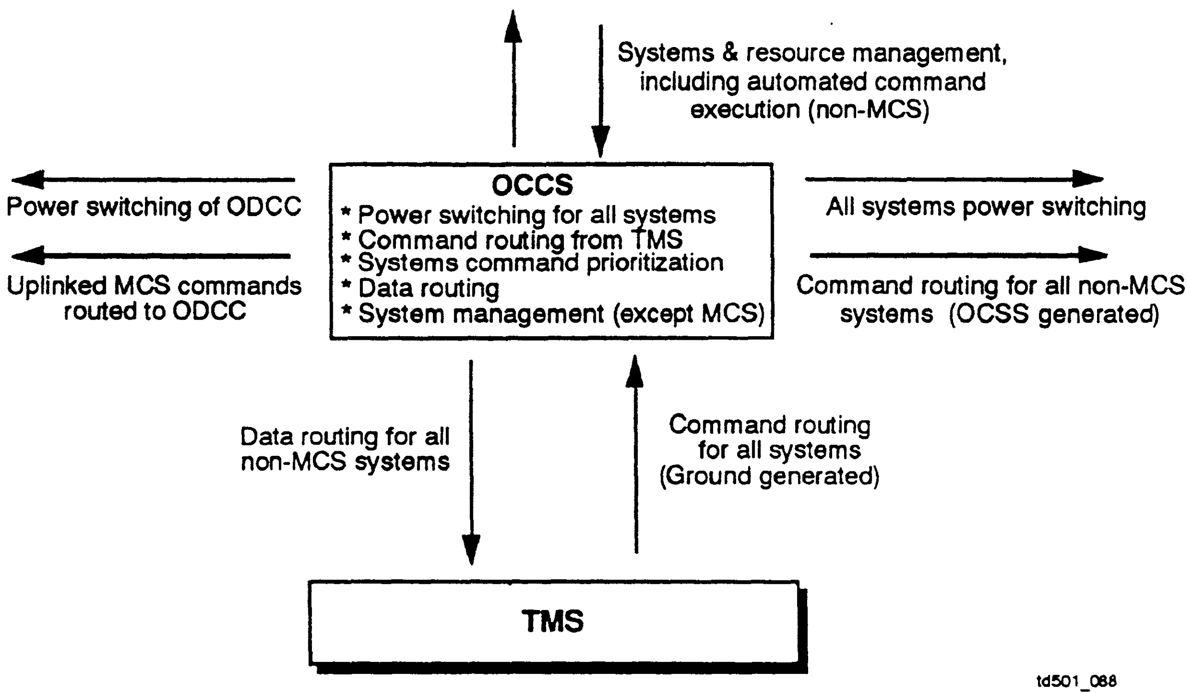


Figure 4–6. OCCS overview

System management is primarily done by the application and termination of power to a given piece of equipment. Automated, time–tagged commands are processed by the equipment from a buffer. Because the OCCS controls the power switching, it interfaces with every onboard system.

Figure 4–7 shows some of the systems the OCCS manages. As with all onboard computational systems, it is difficult to separate the subsystems into distinct, independent entities.

The command processing unit is the main operating unit that performs the program logic processing of command signal information with assistance of automatic control and check algorithms. This unit performs command prioritizing among the three sources of vehicle commands. For each command received, the unit initiates the required response returned to the command initiator.

The automatic power unit provides electrical feed to all vehicle modules and onboard systems. The device receives inputs from either the command processing unit or the crew panel. Switching devices protect the power generation system against current overloads.

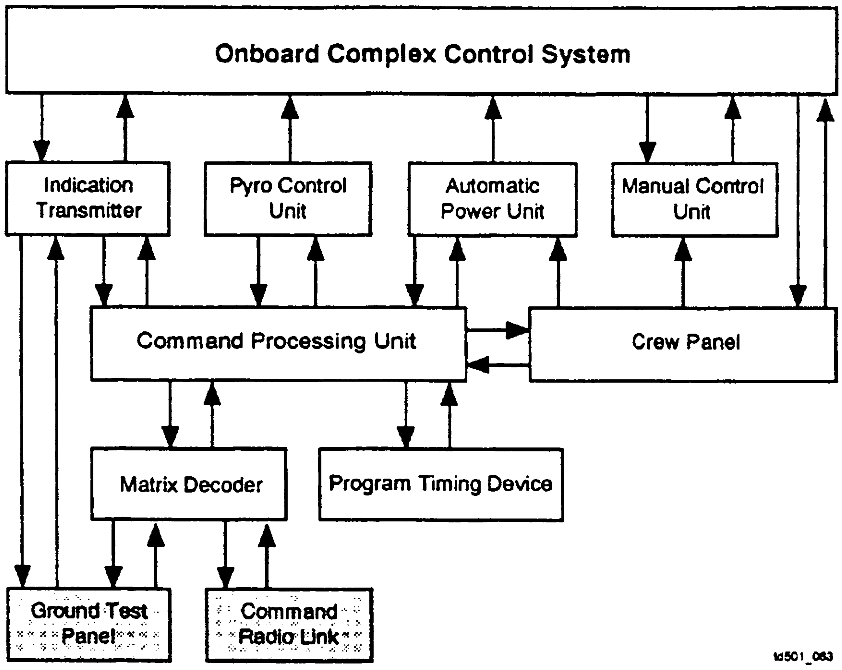


Figure 4–7. OCCS interfaces

The matrix decoder translates coded commands relayed from crew panels and the Command Radio Link (CRL) and routes to them the appropriate command processing unit. The unit receives the 12–bit single commands transmitted from the ground and sends to the CRL the appropriate coded response for downlink.

The manual control unit is the interface device between the crew panel and onboard systems. It provides the crew direct access to control the onboard systems in a manual mode. The unit incorporates fuses and logic to protect electric mains and power sources against current overloads.

The pyro control unit contains squib switches, provides interlock of the pyro facilities, and supplies voltage to the pyro facility elements.

The crew panel (manual control panel) creates and transmits single commands to the manual control unit and the command processing unit.

The program timing device supplies timing information to the command processing unit. Functions include maintaining a vehicle time reference and the generation, storage, and transmission of timing signals.

The indication transmitter selects, compresses, and transmits status and signal information to the command processing unit. During vehicle ground testing, information is transmitted to the ground test panel.

Data routing to the TMS is also performed by the OCCS. Most supporting data sources indicate that no telemetry processing (cal curves, display processing, etc.) is done within the OCCS, as the TMS is designed for this function. However, the raw data is used within the

OCCS to manage the various onboard systems. Analog (hardwired) computers are probably the main method used for system management.

A major function performed by the OCCS is to interface with the TMS for command routing and prioritizing. Commands for the MCS are passed to the ODCC for execution. System commands other than MCS are prioritized and executed by the OCCS.

Commands generated by the ground that are uplinked have the highest priority for execution. Due to limited communication coverage (see C&T section), most commands from the ground are not executed real time, but are planned out in advance, time–tagged for execution, uplinked during the limited communication AOS windows, and stored onboard for future execution.

OCCS generated commands have the second priority for execution. This assures that overriding ground commands will be executed instead of the lower priority OCCS command. This priority hierarchy also provides a means of work–around for the limited ground coverage.

Crew inputs have the lowest priority. This is warranted, since the crew has very limited insight into vehicle status and reduced systems training compared to U.S. space program standards. The Russian analog to Flight Data File (FDF) is also limited compared to Shuttle.

4.4.2 Mir Complex

The onboard computer system architecture found on the Soyuz–TM is essentially replicated on the Mir Complex, with some minor differences. These differences are driven by the need for a more open system that allows additional elements and allows system upgrades.

a. Onboard Complex Control System

Although described in public literature as being replicated on the Mir Complex, the OCCS functions actually appear to be handled mostly by the ODCC. This may be a reflection of the limited data available on the Mir Complex, or it could reflect a system design simplification.

Control of some systems appears to be more automated on the Mir Complex than on the Soyuz–TM. Communications activation is handled by the OCCS, which interfaces with the ODCC for data on ground station locations. This data is compared to an electronic template of crew sleep/wake times, and automatically turns the communications system on and off if the crew is awake. If the crew is scheduled to be sleeping, the system keeps the communications (audio) system off, and records the missed windows of communication.

Other systems management, such as turning payload power on and off, is also believed to be done by the Mir OCCS. Some references suggest that the systems power switching on the Mir Complex is handled by the ODCC. If the OCCS system from the Soyuz–TM is replicated on the Mir Complex, the most probable situation is that the systems management function is shared between the upgraded Central Computer (CC) and the OCCS, due to the limited capability of the OCCS.

b. Onboard Computer System

The Mir Complex OCS computer building block has been called the Strela in much of the public literature. The system is in actuality an Argon based system. Strela may just be a designation used to discern it from the Argon on the Soyuz–TM.

Instead of just one Argon system, the Mir Complex has two called "Central Computers" within the OCS. Reportedly, one has performance characteristics identical to the Argon used on the Soyuz–TM, the Argon–16, and the second is an upgraded Argon–16 with additional memory and faster performance.

The lower capacity Soyuz–TM system (200 thousand short operations per second) used on the Mir Complex has been used in spacecraft operations for over 13 years. This CC is used as a backup for critical MCS functions (low thrusters only) in the event the larger, primary CC fails. When the Mir was originally placed in orbit, the backup CC was capable of complete control, but as the station grew, the backup CC could only backup the most critical functions.

The higher capacity, primary CC (500 thousand short operations per second) originally was an upgraded Argon system, with more memory. The primary CC has been upgraded at least once inflight and may actually be significantly different than the baseline Argon. The inflight upgrade may have included the addition of some support equipment to allow better monitoring by the crew of onboard systems health. The primary CC is used for the Mir Complex MCS functions, as well as possibly supporting other computational tasks. See Table 4–2.

Table 4–2. Comparison of Mir Complex computer to Shuttle GPCs

	Argon–16 (Back–up)	Argon–16 Mir (Prime)	Orbiter AP101B	Orbiter AP101S	SSF EDP–16
Instructions					
Number	32	32	154	158	Intel 80386 ISA
Word Length	16/32	16/32	16/32	16/32	32
Logic Type			TTL	TTL Fast	CMOS
Performance 4 add/1 Mpy (MIPS)	.015	.015	0.420	1.27	3.4
Main Storage					
Technology	Core	Core	Core	CMOS	CMOS DRAM EDAC
Size	64 KB R/W 2 KB ROM	96 KB 16 KB	106496 Words	262144 Words	16 MB
Input/Output			24 1 MHz Serial	24 1 MHz Serial	
Power (W)	300	300	650	560	256
Weight (kg)	83		54.5	29.1	25.9
Size (cm)	30.5 x 30.5 x 30.5 estimated		2 boxes each 49.6 x 25.9 x 19.4	1 box 49.6 x 25.9 x 19.4	1 box 36.5 x 22.9 x 33.6
MTBF (hours)	19950	19950	5000	18500	54,710 (est)
Probability of no failure over 100 hours	.995	.995	.98	.995	.998
Probability of no failure over 5000 hours	.778	.778	.368	.763	.913

Interfaces between the two CCs, if any, occurs at the ODCC level.

c. Onboard Digital Computer Complex

As with the Soyuz–TM, the ODCC is believed to include the OCS system, with both CCs included. Temporary software, flight software patches, and roll in, time–tagged commands for MCS (sometimes referred to as the Motion Control and Navigation System (MCNS)) are considered part of the ODCC.

An added computer on the Mir Complex within the ODCC, possibly installed inflight, is the EVM (unknown acronym). The EVM was added as an improvement over the older Delta navigation computer used on Salyut. The older Delta required periodic updates (state vectors, etc.) from either the ground or the crew. The EVM was designed to maintain the orientation of the Mir Complex, indefinitely, without any human intervention. This requirement arose from the failure of the Delta on the Salyut, requiring close monitoring by the ground and crew, and finally resulted in the abandonment of the Salyut.

When a module is added to the Mir, connections are made to the ODCC to allow communication between the new module and the existing station. The physical interfaces required to connect the new expansion module into the network are listed as "existing", which implies the network was launched in place on the Mir. Each module has a digital

Peripheral Computer (PC), which probably acts more like a terminal then a computer. The physical configuration, connectivity, and panel layouts for the expansion modules are unavailable.

The central Mir control station is known to have two CRTs for display of digital data and TV. This SECAM (European standard – 625 lines) TV system can be used to display ODCC generated data or an uplinked black and white TV signal or both simultaneously (data overlaid on TV). The crew can also download whatever is displayed on the screen for ground use. Each of the expansion modules has only one CRT. See Figures 4–8 through 4–10.

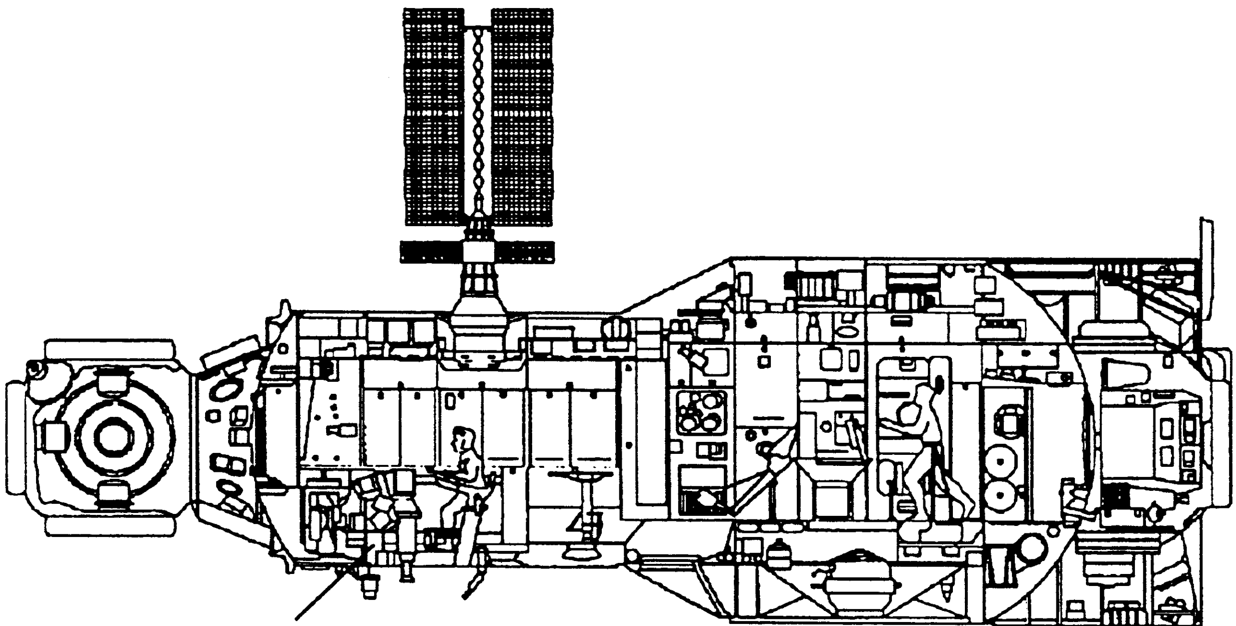


Figure 4–8. Mir central control station location

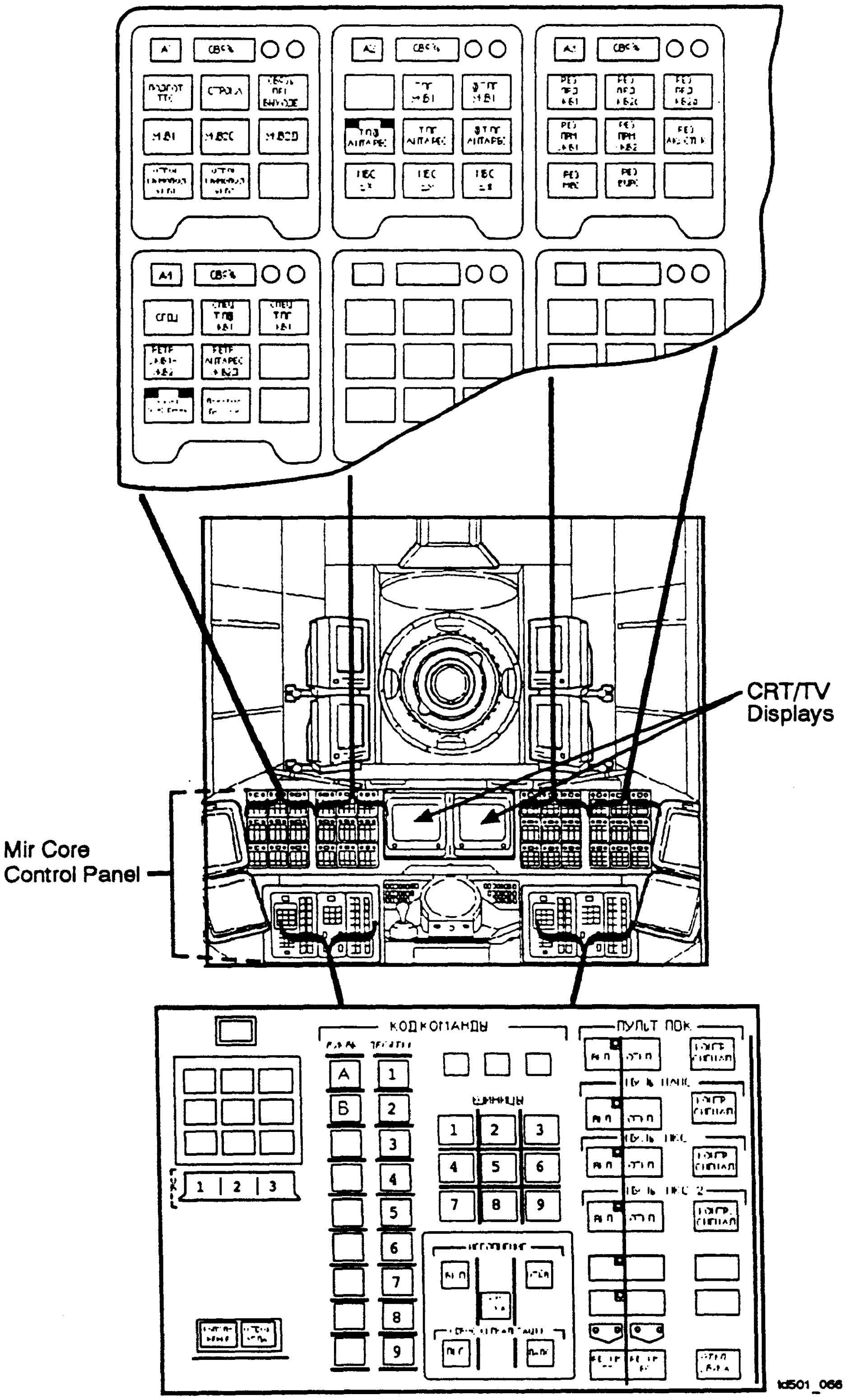


Figure 4–9. Mir core control panel and CRT/TV displays

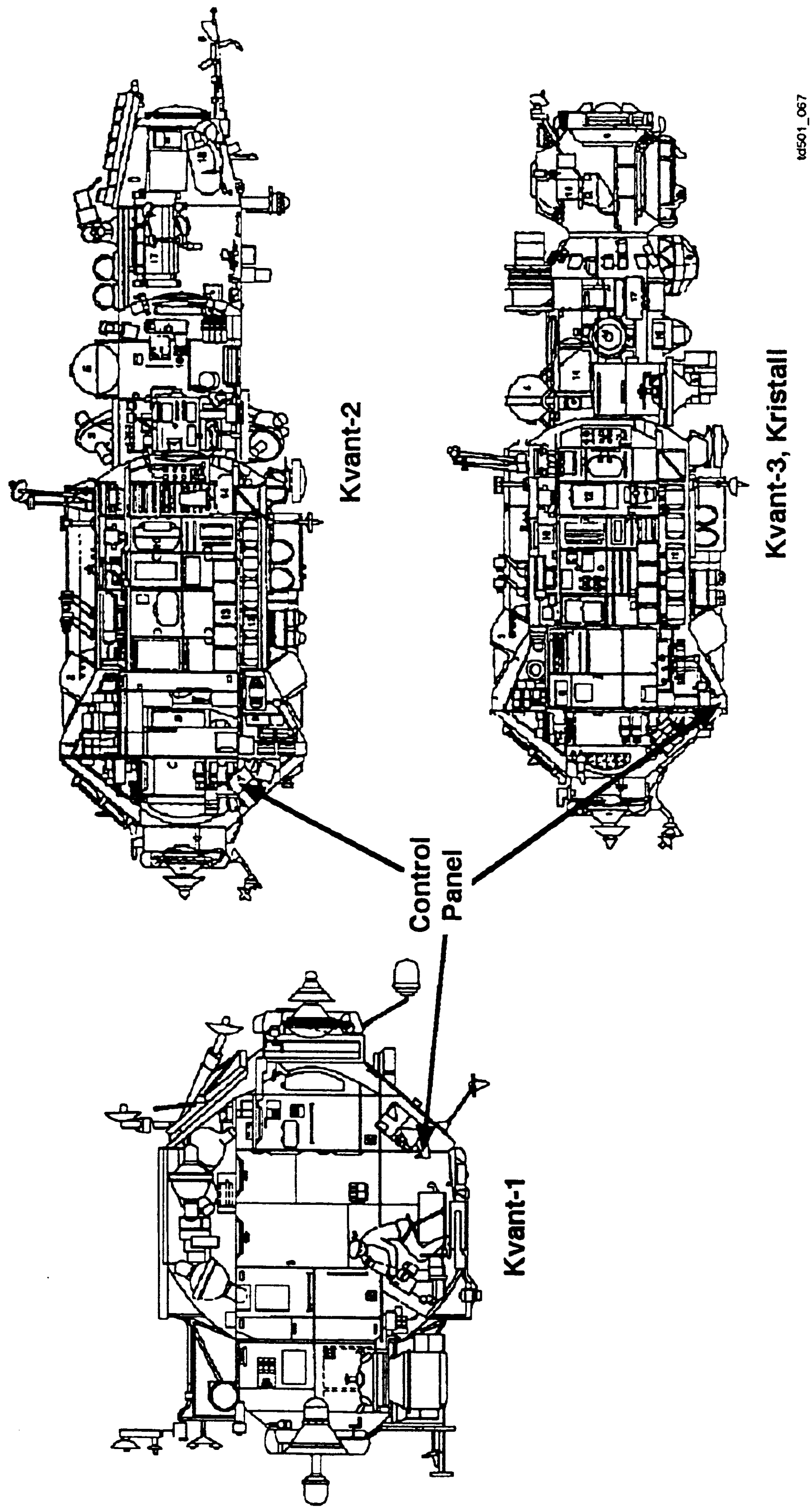


Figure 4–10. Kvant–1, Kvant–2, and Kvant–3 control panel locations

4.5 PROGRESS

Very little is known about the Progress computational systems. However, since the Progress is a derivative of the Soyuz–TM, the computer system is most probably the same. Some equipment is probably deleted, since systems management needs are not as rigorous (non–manned vehicle), and no control panel nor crew interfaces are required. The processor has a reported capability of 0.5 MIPS, indicating that it is probably the upgraded Argon–16.

Some computational hardware is also known to be added to support the complete automation of docking.

4.6 COMPUTATIONAL SYSTEMS SUMMARY

The Soviet–designed computational systems used by the Russian space program to support the Mir Complex operations have similarity to Shuttle systems from a functional perspective. Some strategies used in the architectural design are also very similar, such as operating computers in parallel.

The details of the computer systems used on Mir Complex and transport vehicles in most instances are very dissimilar to the orbiter Data Processing System (DPS) and GN&C systems. Use of analog and digital computers and the lack of automation require the operational strategies used in the Russian space program to be radically different than in STS operations.

QUESTIONS

1. The onboard computational systems on the Soyuz–TM are responsible for controlling GN&C operations.

   a. True

   b. False

2. The Mir onboard computational system is comprised of OCS, ODCC, and TMS.

   a. True

   b. False

3. For the Soyuz–TM, the OCCS

   a. Includes the ODCC

   b. Commands the MCS

   c. Controls all power switching to all systems

   d. a. and c.

   e. None of above

4. The reliability of the Argon class computers is

   a. Much better than current Orbiter GPCs

   b. Similar to current Orbiter GPCs

   c. Much worse than current Orbiter GPCs

   d. Unknown

5. The Mir interfaces with the computers in expansion modules

   a. Through an RF link

   b. Through existing hardwired connections at the ports

   c. And operates as one integrated system

   d. b. and c.

   e. No links exist: each module operates separately

6. Each Mir expansion module has a control panel that replicates all functions as the main control panel in the Mir.

   a. True

   b. False

SECTION 5
ELECTRICAL SYSTEMS

5.1 PERFORMANCE OBJECTIVES

By the end of this section, the reader should be able to:

- Identify the function of the Mir Complex EPS
- Describe the capabilities and constraints of the Mir Complex EPS
- Describe the EPS interfaces to other Mir Complex systems
- Briefly describe any similarities/differences between this system and the equivalent U.S. Space Shuttle/Station systems

5.2 INTRODUCTION

The function of the Mir Complex EPS is to provide continuous on–orbit power. The Mir Complex must continuously generate power and distribute it to the users during all phases of flight, both insolation (sunlight) and eclipse (in the Earth's shadow). Additionally, part of the EPS keeps the arrays pointed toward the Sun during insolation. The following information provides some insight into how the power is generated, regulated, distributed, and how the Mir Complex keeps the arrays pointed at the Sun. The interfaces of the Mir Complex EPS and comparisons to U.S. space vehicles are also briefly discussed.

5.3 FUNCTIONALITY OF THE EPS

The primary function of any EPS is to generate power. The Mir Complex uses two methods to ensure that the appropriate level of power is supplied during insolation and eclipse. During insolation, the arrays convert sunlight to energy to provide power and during eclipse the batteries provide power. The Mir Complex EPS provides 28.6 V dc power.

5.3.1 Insolation

During insolation, the Mir Complex uses solar arrays, pointed at the Sun by the Attitude Control System for Solar Array (ACSSA), for power. The solar arrays collect the energy from the Sun and convert it to electrical energy. The amount of energy obtained from the solar arrays is dependent on two things: the efficiency of the solar array material and the position of the array relative to the Sun. The arrays are most effective when pointed directly at the Sun and the energy collected decreases sinusoidally with the offset angles from the Sun. The ACSSA keeps the arrays pointed at the Sun to maximize the array output during insolation.

The power output of the arrays is regulated and distributed to the Mir Complex. Since the power for on–orbit operations must be continuous, the solar array power is also used to recharge the batteries during insolation. Power distributed to the batteries is also be regulated to ensure proper charging.

5.3.2 During Eclipse

During eclipse, the Mir Complex uses batteries to provide power. The batteries are made from Nickel Cadmium (NiCd). The batteries must be recharged during insolation to prevent them from becoming completely discharged after a few orbits. The power output of the batteries is regulated to produce power for the Mir Complex and the power from the arrays is regulated to make sure that the batteries are properly charged.

5.3.3 During the transition between eclipse and insolation

During the transition between insolation and eclipse, the solar arrays and batteries work in tandem to provide power. As the Mir Complex moves from the eclipse into the sunlight, the arrays progress from a very small output to full output. As the transition occurs, the batteries change from discharging (providing full power) to charging (from power supplied from the arrays). The batteries continue to augment power to maintain the nominal level for any situation where the arrays are unable to provide full power.

Figure 5–1 is a block diagram of the power system for the Mir Complex. Each of the Russian modules has a self–contained power system. The functional block diagram found in Figure 5–1 is representative of the design of the power systems contained in the other modules of the Mir Complex.

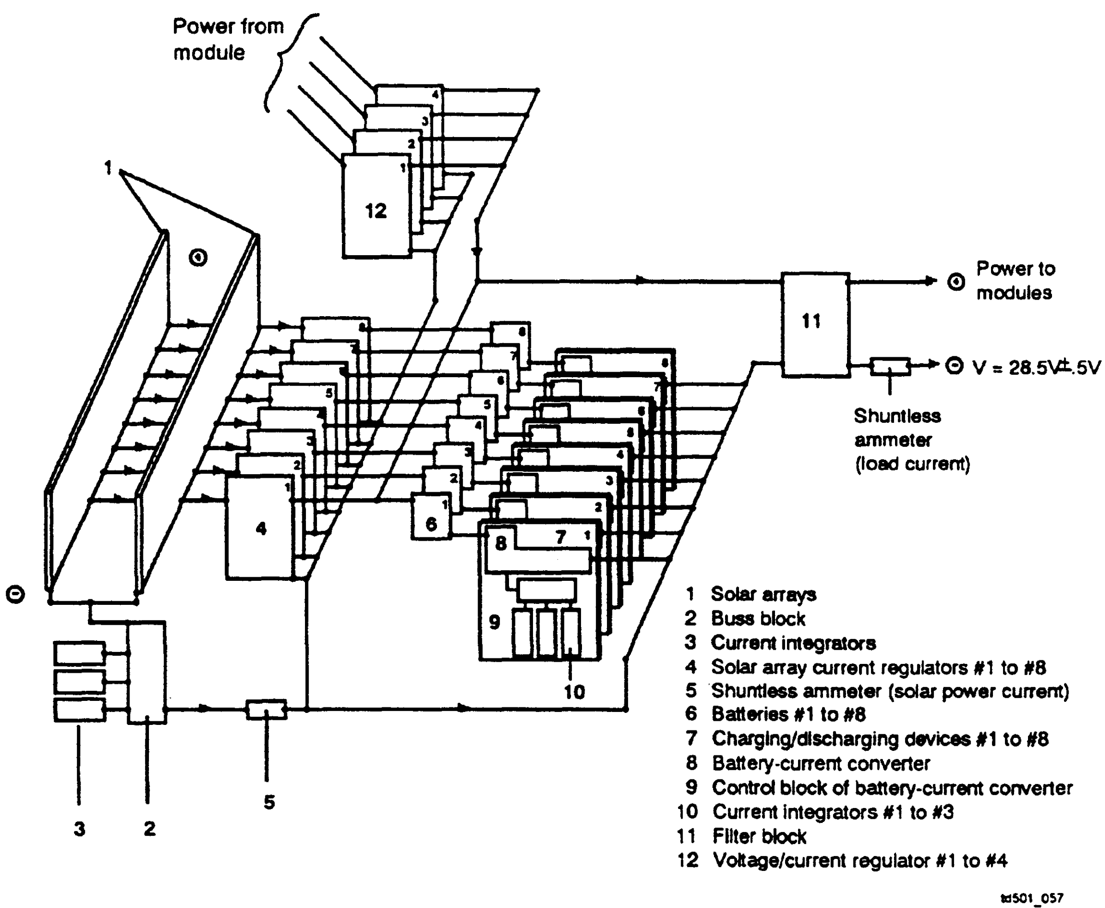


Figure 5–1. Russian power system block diagram

Following is a brief description of the function of the blocks within Figure 5–1. The blocks are presented in the order that power flows in the system when the Mir Complex is in insolation. The functional blocks are numbered. The arrays are in the first block considered and the final block is the interfaces to other systems. This will show the architecture and function of a Russian EPS. Similarities to U.S. systems are mentioned briefly where applicable.

a. Functional Blocks

1. Solar–arrays – Same function as the solar arrays on the Space Station. The basic function is to convert sunlight into electrical power.
2. Buss Block – This is a switch or set of switches. This is used to connect power from the arrays to the bus. This is similar to the Direct Current Switching Unit (DCSU) on the Space Station.
3. Current integrators – There is some uncertainty on exactly what this device does, but it appears to be a capacitor bank to ensure that no large inrush currents or spikes are generated when the buss block is switched on. Several similar devices are found on the Space Station.
4. Solar–Panel current regulator – This device regulates the output of the solar arrays so that the energy needed is provided. This is similar to the Sequential Shunt Unit (SSU) found on the Space Station.
5. Shunt–less Ammeter – In–line amperage meter to monitor the current level from the solar array. This is a common device on both Space Shuttle and Space Station.
6. Batteries – NiCd batteries. The Space Station uses batteries (NiH) and the Space Shuttle does not use batteries for power generation.
7. Charging/Discharging Devices – Controls the charging and discharging of the batteries. This is similar to the Battery Charge/Discharge Unit (BCDU) on the Space Station.
8. Battery–Current Converter – Regulates battery energy for the system. This function is performed by the BCDU on the Space Station.
9. Control Block of Battery–Current Converter – Controls the level of output of the Battery–Current converter. This function is performed by the BCDU on the Space Station.
10. Current integrator – Same as described in no. 3.

b. Interfaces

1. Filter Block – This block filters the output power so the power can be sent to the other users.
2. Voltage/Current Regulators – This device controls the power level coming into the module from other sources.

5.3.4 Distribution of Power

As mentioned previously, various modules of the Mir Complex have independent EPSs. These systems are connected together using the interfaces described in the overview of Figure 5–1. In general, power produced from each module is used within the same module. Power is sent out to other modules if needed, or power is supplied from other modules if needed. All of the EPS of the Mir Complex can be controlled from the ground or the Mir.

The functionality of the Mir Complex EPS has been described along with some of the devices used to provide those functions. Those functions are further defined by describing the components and the method of operation used to provide these functions in the Mir.

5.4 DESCRIPTION OF EPS SYSTEM

5.4.1 Power Generation

The power generation function is the most critical function of the Mir Complex EPS. This function is provided by the solar arrays, along with the ACSSA, and batteries.

The material used for most solar arrays on the Mir Complex is GaAs. The arrays are a large group of GaAs photodiodes. GaAs has a theoretical limit for turning solar energy or flux into electrical energy of about 12 percent. One of the arrays on the Mir Complex is reported to be silicon which is similar but has an efficiency of up to 14 percent. Both materials are commonly used for solar energy collection diodes. The locations and areas of arrays on the Mir Complex are shown in Figure 5–2.

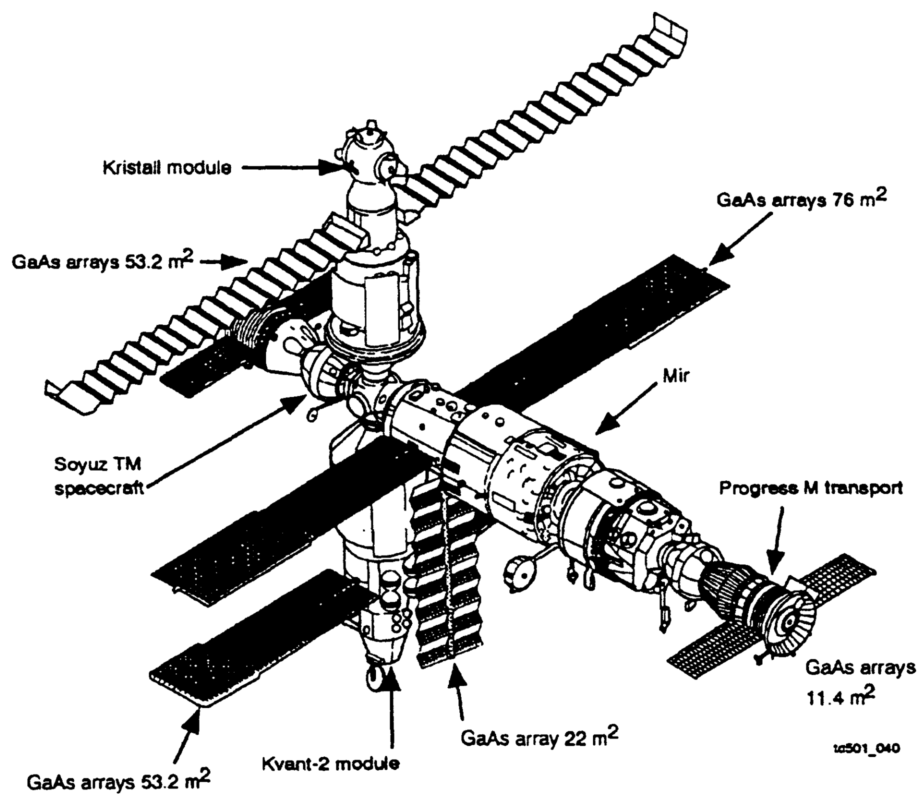


Figure 5–2. Solar arrays on Mir Complex

The operational values for the Mir Complex are outlined in Table 5–1. The values represent the best information available at this time. Table 5–1 gives the power from the arrays, area of the arrays, mass of the arrays, number of batteries, power of the batteries, average power and peak power for the Mir Complex modules. The last two columns give the totals for the Mir Complex and the totals for a single Space Station channel (there are a total of six) for comparison.

Table 5–1. Operational values

	Mir	Kvant–2	Kristall	Mir Complex total	Space Station
Power from the solar arrays (kW)	12.0	5.8	9.0	26.8	31.4
Solar array area (m^2)	98	53.2	72	223.2	311
Solar array mass (kg)	N/A	N/A	> 1,000	N/A	1,500
Array power (W/m^2)	122	109	125		97
Number of arrays	3	2	2	7	6
Number of batteries	12	6	6	24	2
Battery capacitance (Amp–hours)	720	360	360	1,440	243
Average power (kW)	6.0	4.0	5.0	15.0	13
Peak Power (kW)	18.0	8.5	8.5	N/A	31.4

Note: N/A – non–applicable

The batteries on the Mir Complex are made of NiCd and are rechargeable. All of the batteries on the Mir Complex are of the same type and are of the same output power. Very little information is available on the dimensions and capabilities of the batteries. The number of batteries on each module are shown in row five of Table 5–1.

By dividing the amp–hour total by the number of batteries in Table 5–1, it can be assumed that the batteries are each capable of 60A/hr performance. It is believed that after the batteries are discharged to 50 percent of total charge, they are recharged under normal conditions.

The "actual" performance of the solar arrays is described in Table 5–2. This Table shows the degradation and shadowing problems associated with the Mir Complex.

Table 5–2. Performance degradation

As of February 1992 the electrical power system capacity is as follows:	
Total effective surface of the solar batteries	= 223.2 m^2
Initial photocell efficiency	= 10–12%
Theoretical maximum power	= 28 kW
Losses due to mutual overshadowing of panels	= –40%
Losses in photocell efficiency with time	= –40%
Net remaining power capacity (approximately)	= 10 kW

5.4.2 Distribution

The systems and payload power are controlled primarily from the ground. The crew normally controls the power system only under conditions where the ground is unable to. For example, the crew might control the EPS when the station is not in communication with the ground.

The payloads can be connected to a 5A, 10A, 20A or 50A bus. The architecture of this bus is unknown. The payloads are designed to meet power consumption constraints imposed by the Mir Complex EPS. The specifics of payload power consumption requirements are not available.

The crew are able to power some appliances, such as lights, inside the modules via plugs in the capsule. The majority of the crew interface with the power system is for maintenance purposes only.

5.4.3 ACSSA

The ACSSA provides pointing for the solar arrays in order to maximize the energy output during insolation. The ACSSA provides one degree of freedom and can only rotate ±90°. After each orbit, the arrays must be reset to some initial position for the next orbit.

The ACSSA consists of a Sun sensor, a control unit, and a drive unit or actuator for the array. The system can be used in either autonomous or nonautonomous mode. The autonomous mode of tracking uses the Sun sensor to determine the Sun's position relative to the array. The control system is used to determine where the array should be pointing and to send commands to the actuator device. The actuator system is used to physically point the array at the Sun and feedback the current position of the array. The autonomous system can be used open–loop or closed–loop. The difference between an open–loop control method and closed–loop control method is that the open loop does not compare the position of the array (via the actuator) against the position that the array should be in (generated by the control system).

The ACSSA also transfers power from the arrays to the rest of the Mir Complex, using a slip ring–type device that can transfer power while providing 180° of rotation around a shaft. This device is very similar to the beta gimbal roll ring mechanism found on the Space Station.

For non–autonomous tracking, a state vector or predetermined position is used for the control of the pointing of the array instead of a Sun sensor.

5.4.4 Russian/U.S. Comparison

a. Shuttle/Mir Comparison

The Shuttle uses no solar arrays and has battery power only as a backup for critical systems. The voltage level used on Mir Complex (28.6 Volts Direct Current (V dc)) is similar to the level provided by a Shuttle fuel cell (30 V dc). The Shuttle uses Alternating Current (ac) power to drive rotary equipment. The ac power on the Shuttle is 120 V at 400 Hz, which is military specification for aircraft.

b. Station/Mir Comparison

The Station system is very similar to the Russian system. Both employ solar arrays and batteries to provide continuous power. Both use pointing systems to maintain maximum output from the solar arrays. There are several technical differences between the Russian Mir Complex and the U.S. Space Station power systems:

1. Space Station uses silicon as an array material and NiH batteries. NiH and NiCd are similar, but NiH has slightly better thermal properties and cycle life. The Russians use GaAs (with a single Silicon array) and NiCd respectively.
2. The Station uses a higher voltage level (123V dc) due to having to transport the power along the truss from the solar arrays to the modules. The need for the higher voltage is driven by the loss characteristics of transmission lines. The losses are a function of current. In the Space Station, the power is sent from the arrays to the modules at a high voltage and low current and is then converted (by the Direct Current–to–Direct Current Converter Unit (DDCU)) to a lower voltage and higher current. This technique is also used for commercial power transmission lines.
3. The switches on the American power systems are connected to the positive side of the system, while the Russian power systems connect switches to the negative side of the system.

5.5 EPS SYSTEM INTERFACES WITH OTHER SYSTEMS

The Russian EPS provides power for all of the other systems, including power for the payloads and crew as described above. The EPS has an interface with the Russian DMS for command and control purposes and with guidance and navigation for state vector information for pointing when necessary.

5.6 ELECTRICAL SYSTEMS SUMMARY

Both the Mir Complex and Space Station EPS provide continuous power on an autonomous vehicle in both insolation and eclipse. Both systems depend on arrays, array pointing systems, and batteries to provide the continuous power. The Mir Complex is similar to Space Shuttle in that the voltage level is similar. Overall, the EPS of the Mir Complex is most similar to the Space Station EPS.

QUESTIONS

1. The Mir Complex uses which means to generate power during insolation?

   a. Nuclear fuel

   b. Solar dynamics

   c. Solar arrays

   d. Batteries

2. The Mir Complex uses what to generate power during eclipse?

   a. Nuclear fuel

   b. Solar dynamics

   c. Solar arrays

   d. Batteries

3. The Mir Complex EPS uses what material for the batteries?

   a. NiH

   b. NiCd

   c. Foam

   d. Alkalide

4. The Mir Complex does pointing using what subsystems?

   a. GN&C or ACSSA

   b. GN&C or C&T

   c. TCS and C&T

   d. C&T and TCS

5. The Mir Complex EPS is most similar to which U.S. space vehicle?

   a. Space Station Baseline

   b. Space Shuttle

   c. Apollo

   d. Voyager

SECTION 6
ENVIRONMENTAL AND THERMAL CONTROL SYSTEMS

6.1 PERFORMANCE OBJECTIVES

By the end of this section, the reader should be able to:

- Identify the purpose and functionality of the Mir Complex ECLSS/TCS
- Describe the Mir Complex ECLSS/TCS capabilities and constraints by module
- Describe the interfaces between the Mir Complex ECLSS/TCS systems and other Mir Complex systems
- Identify the differences in capabilities between the Mir Complex and Space Station Baseline ECLSS/TCS systems

6.2 INTRODUCTION

The Mir Complex and the Soyuz vehicle which services the Mir Complex both have a self contained TCS and an ECLSS. These systems basically serve the same functions as the analogous systems which were designed for Space Station. The TCS removes waste heat from avionics, systems equipment, and payloads and rejects it to space. The ECLSS system provides and maintains a proper atmosphere, water supply, and fire detection and suppression capability.

6.3 MIR COMPLEX ECLSS FUNCTIONALITY

The Mir Complex ECLSS can be broken down along six functional lines that are analogous to the Space Station Baseline. These six functions include Atmospheric Revitalization (AR), Water Recovery and Management (WRM), Atmosphere Control and Supply (ACS), Waste Management (WM), Fire Detection and Suppression (FDS), and Temperature and Humidity Control (THC).

6.3.1 Atmospheric Revitalization

The purpose of the Mir Complex AR equipment is to provide Carbon Dioxide (CO_2) removal, gas recovery and regeneration, trace contaminant monitoring, and trace contaminant control.

a. CO_2 Removal

CO_2 removal is accomplished via a four–bed molecular sieve. This device employs two desiccant beds and two regenerative molecular sieve beds that contain an adsorbent similar to Zeolite. The absorption is performed by solid, porous, regenerating absorbers. The operation is based upon gas–capillary action. The quantity of gas that can be absorbed is directly proportional to gas/absorbent surface area, and pressure until the absorbent surface is saturated by gas. The absorbing capacity is inversely proportional to temperature. The saturated absorbers are regenerated by the pressure differential resulting from opening valves that expose the desorbers to vacuum. See Figure 6–1.

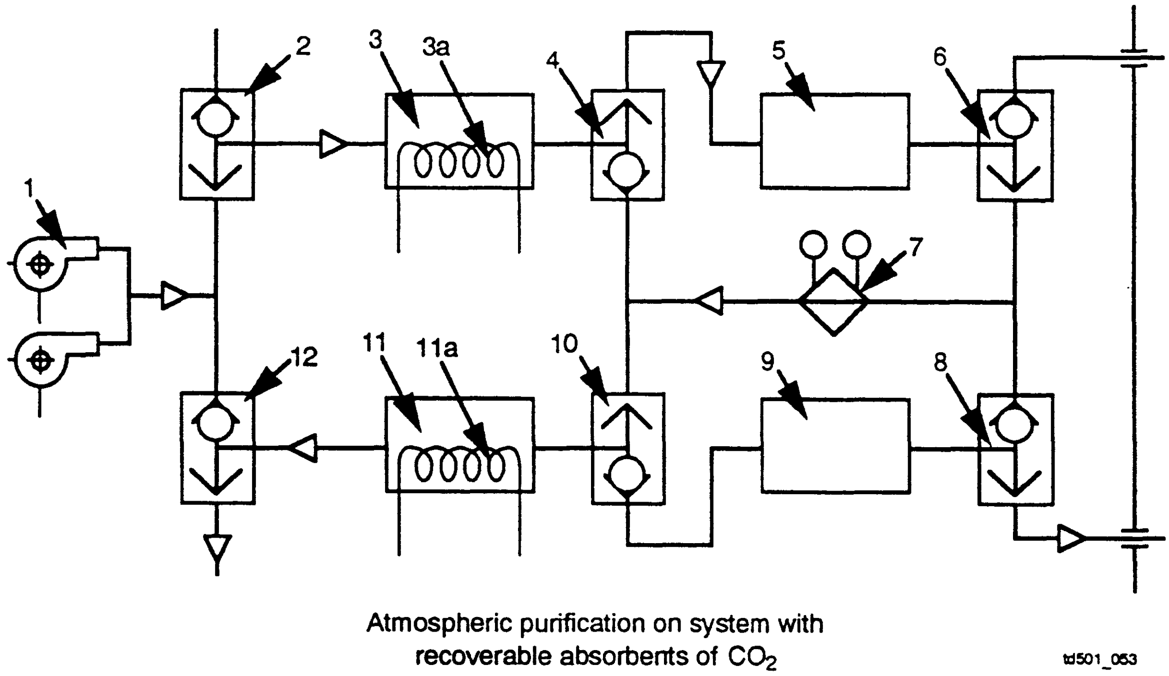


Figure 6–1. Atmospheric purification on system with recoverable absorbents of CO_2

The system used on the Mir Complex is shown schematically in Figure 6–1. A fan (1) draws cabin air through a valve (2) to a silica–gel dryer (3). The purpose of the silica–gel dryer is to remove any water from the air in order that dry air only is sent to the zeolite container. Up to 3000 kJ/kg of heat may be released by the silica–gel water absorption process. This heat is removed by cooling coils (3a). Dry air continues through another valve (4) at a temperature between 220 to 230 K to the zeolite container (5) where the CO_2 is removed. The dry air is then routed through a valve (6) past a heater (7) which increases the air temperature to a point between 350 to 370 K. This heated dry air passes through valve (10) where it enters the silica–gel container (11). Regeneration of the silica–gel occurs when the hot dry air vaporizes the water stored in the silica–gel. This process rehumidifies and cools the air to a point where it can be returned to the cabin via valve (12). The saturated zeolite container (9) is regenerated by exposing it to vacuum by the configuration of valves (10) and (8). This pressure gradient serves as the driver which removes the CO_2 from the zeolite absorber.

When zeolite bed (9) is regenerated and bed (5) is saturated, the system is reconfigured to run in a parallel operation to the process described above. Valves (2) and (12) are reconfigured to force cabin air from the fans into silica–gel container (11). Valves (10) and (4) are reconfigured to channel the dry air into zeolite absorber bed 9. The dry air sans the CO_2 and is rerouted by reconfiguring valves (8) and (6) to channel the air through heater (7) via valve (4) to regenerate silica–bed (3). Finally the purified air enters the cabin at valve (2). Meanwhile valve (4) isolates zeolite bed (5) and valve (6) is open to vacuum to allow regeneration.

This system is practically self contained. The only expendable is air which is lost during evacuation of the zeolite chambers to space. Some air (up to 0.8 percent) is also absorbed by the zeolite along with the CO_2. The maximum air loss rate is 0.23 kg/day.

The above system contains an interface to the Mir Complex TCS and EPS.

The backup system consists of 15 cartridges that can remove 3.3 man/days worth of CO_2.

The CO_2 removal function that was planned for Space Station used a system of similar design known as the Carbon Dioxide Removal Assembly (CDRA). Air is dehumidified by two desiccant beds and CO_2 is removed by Zeolite desorbing beds. The CDRA runs in 4–hour cycles and consumes 500 W of power.

b. Gas Recovery/Regeneration

The Mir Complex generates Oxygen (O_2) by Potassium Hydroxide (KOH) driven water electrolysis. By mass, water is 89 percent O_2. The electrolysis of 1 kg (2.2 lbs) of water/crewmember/day is sufficient to meet basic O_2 requirements of 25 liters/hour at 101 kPa. On average, the Mir Complex requires 3 to 4 kg/day of water for O_2 requirements.

The water electrolysis process is shown schematically in Figure 6–2. Water with a 30 percent concentration of KOH acts as the electrolyte. During the reaction, O_2 is released, H_2O is formed, and Hydrogen (H_2) is released and is vented to vacuum. The power consumption necessary to drive the process is 177 W at 1.48 V/crewmember/hour. The current necessary is 119 amps.

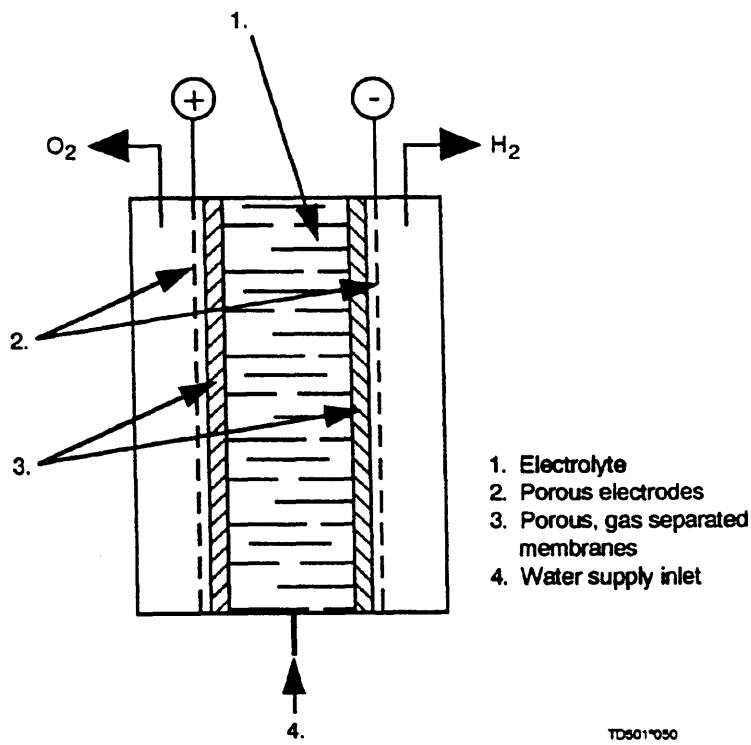


Figure 6–2. Water electrolysis process

The Mir Complex system contains 12 electrolysis cells in explosion proof containers. The cell sizes are 0.8 m X 0.12 m. These 12 cells are cooled by the Mir Complex TCS. Electricity for the process is provided by the Mir Complex EPS.

The Mir Complex has a second O_2 production system that employs Sodium Chlorate ($NaClO_3$). When $NaClO_3$ is thermally decomposed at temperatures ranging from 1000 to 1100 K, O_2 is released. The Mir Complex has 40 cartridges of $NaClO_3$. A high temperature charge ignites the reaction and produces the O_2. This system is used as a backup for the H_2O hydrolysis system, or when there are more than three crewmembers aboard the Mir Complex. A typical application of this system is O_2 repressurization after airlock operations.

The Space Station Baseline did not provide for an O_2 regeneration system. Instead O_2 and Nitrogen (N_2) were stored cryogenically and mixed in appropriate ratios to maintain the proper O_2 partial pressure.

c. Trace Contaminant Control

The Mir Complex provides trace contaminant control by the use of regenerated charcoal beds and catalytic oxidizers. The Charcoal beds are regenerated by vacuum for 6 hours once every 10 days. The trace contaminants removed from the Mir Complex are Carbon Monoxide (CO), ammonia, and methane.

The Trace Contaminant Control function planned for Space Station used a charcoal bed technology to remove high molecular weight contaminants while a sorbent bed was used for high molecular weight gases.

d. Trace Contaminant Monitoring

The Mir Complex employs a gas analyzer that determines the percent composition of O_2 and CO_2 in the atmosphere. Sensors also monitor H_2, O_2, and CO. The sensors have a 1–year life.

The Trace Contaminant Monitoring function planned for Space Station used a major constituent analyzer and a separate CO analyzer. The major constituent analyzer used a magnetic sector mass spectrometer to monitor partial pressures of O_2, N_2, H_2, CO_2, H_2O, and methane (CH_4).

6.3.2 Water Recovery and Management

The purpose of the Mir Complex WRM equipment is to provide water processing, monitoring, storage and distribution as well as microbial control.

a. Water Processing

The Mir Complex provides three types of water: potable, hygiene, and electrolysis grade. The Mir Complex has three water purification systems: condensate recovery, hygiene/kitchen water recovery, and electrolysis water recovery.

The condensate recovery system generates potable grade water from recovered condensate. The process is the same one used on Salyut 6 and Salyut 7.

Used hygiene and kitchen water is recycled for hygiene use only. The process begins by pumping the used fluid into storage columns that contain various ion exchange resins and activated charcoal. The water is then sent through filters containing fragmented dolomite, artificial silicates and salt. Finally, minerals are added which include calcium, magnesium bicarbonate, chloride, and sulfate. This process can recover 21 liters of water at one time. This process requires power to drive the pumps that is derived from the Mir Complex EPS.

Water is also recovered from urine and used in the O_2 production electrolysis. A vapor–diffusion distillation method is used that has the capability of generating 5.4 liters/day. A schematic of this process is shown in Figure 6–3. Urine is pumped from the air/liquid separator (15) by a pump (19).

The urine enters the urine concentration and water extraction system. The urine exits pump (19) and enters a junction where it either goes to a buffer tank (20) or into the vapor–diffusion distillation apparatus. Urine enters the device at (21) and is heated by hot fluid form the TCS (26). The heat causes water molecules to diffuse through a membrane (22) into a cavity filled with either air or an inert gas (23). The vapor is drawn through a porous membrane (24) by the force of capillary action . The vapor condenses in cavity (25) which is cooled by cold fluid (27) from the TCS.

Concentrated urine is stored in tank (28). The recovered water is pumped (29) through an absorber (30) and a mineralization unit (31) into a storage tank (32) where the water is available for the O_2 generation electrolysis process.

The above process requires cooling from the Mir Complex TCS as well as electrical power.

The water processing function planned for Space Station includes potable water processing and urine water processing. There was no provision for water electrolysis for O_2 generation.

Unlike the Mir Complex, the U.S. Space Station Baseline planned to process potable water from hygiene, waste, air condensate, and fuel cell water. The Mir Complex only processes potable water from condensate water. A Multifiltration Assembly was designed for potable water processing. This device used heating and filters to upgrade water to potable status. The device used 650 W of power every day. Filters were due to be changed out every 15 days.

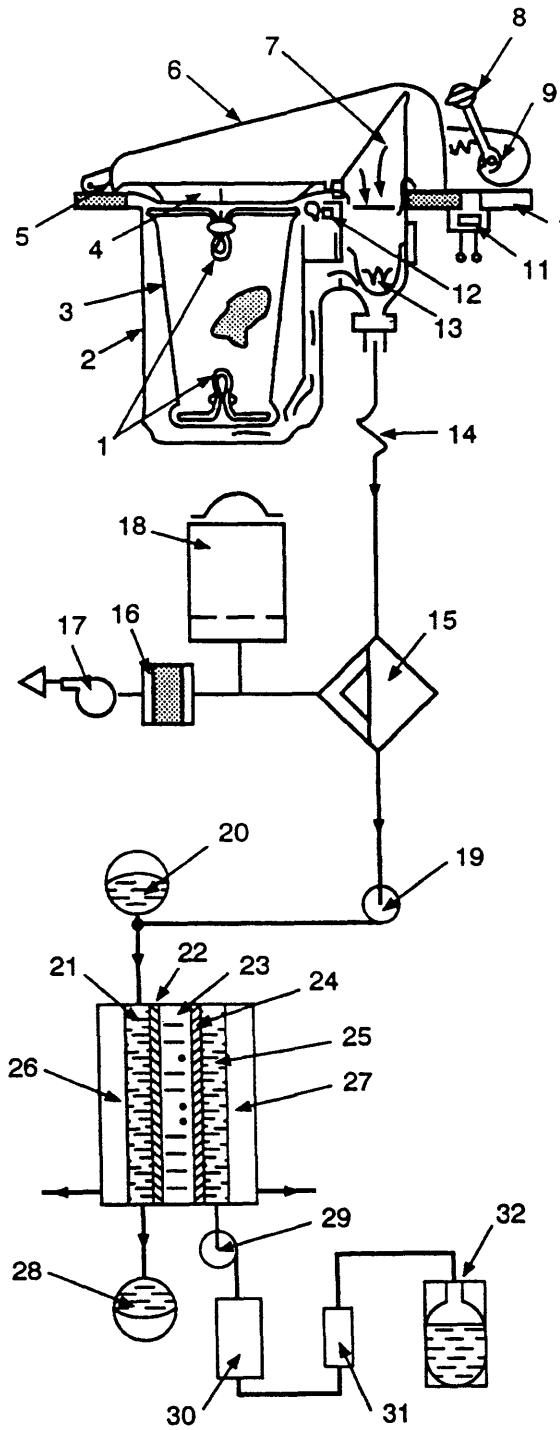
The U.S. Space Station Baseline also planned to use a vacuum filtration process to recover water from urine.

b. Water Monitoring

The purpose of the Mir Complex water monitoring equipment is to insure a safe potable water supply for the crew. The Mir Complex provides a water monitoring function that uses water analyzers. This is the extent of the information currently available.

c. Water Storage and Distribution

The purpose of the Mir water storage and distribution system is to provide the crew access to potable water when necessary. Water is stored in containers located in the Kvant–2,



Urine/Water Regeneration

19 - Pump
20 - Intermediate storage tank
21 - Cavity
22 - Membrane
23 - Cavity
24 - Porous membrane
25 - Cavity
26 - Hot liquid
27 - Cold liquid
28 - Tank
29 - Pump water
30 - Absorber
31 - Mineralization unit
32 - Storage tank

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Figure 6–3. Body waste management system

Kristall, and Mir modules. These containers use pressurized bladders to deliver water for crew use. This is the extent of the information currently available.

The water storage and distribution function planned for Space Station provided 600 lb of potable water in both the U.S. Hab and Lab modules. Water is supplied to user endpoints which include hygiene, experiment support, and crew.

d. Water Supply Microbial Control

To protect the water supply from being contaminated by microbes, the water is heated and ionic silver is introduced electrolytically. This is the extent of the information currently available.

6.3.3 Atmospheric Control and Supply

The purpose of the Mir Complex ACS equipment is to supply a sea–level atmosphere in the Mir Complex pressurized modules. The ACS provides an atmospheric composition and gas storage function.

a. Atmospheric Composition

The purpose of the Mir Complex atmospheric composition equipment is to maintain the proper percentage and partial pressures of N_2 and O_2 in the Mir Complex pressurized module atmosphere. The Mir Complex atmosphere is up to 78 percent N_2 and 21 to 40 percent O_2. The maximum allowable partial pressure of O_2 is 6.8 psi (46.9 kPa).

The atmospheric composition function planned for Space Station uses 250 psi N_2 and 100 psi O_2, which are mixed on an element basis by the Pressure Control Assembly (PCA). This device regulates gas flow rate and gas partial pressure as well as allowing manual release of O_2.

b. Gas Storage

The purpose of the gas storage equipment is to maintain an adequate supply of atmospheric gases to maintain proper composition within the pressurized modules. N_2 is stored as a high pressure gas. Twenty liters of air is stored in pressure vessels for atmospheric makeup. The production of the stored O_2 was discussed in the gas recovery/regeneration section.

The gas storage function planned for Space Station stored N_2 and O_2 supercritically in cryogenic tanks. The pressure regulation and thermal conditioning function for these gases are performed by the Gas Conditioning Assembly.

6.3.4 Temperature and Humidity Control

The purpose of the Mir Complex temperature and humidity control equipment is to provide control of the pressurized volume atmospheric temperature and humidity, as well as performing cabin ventilation and equipment cooling.

a. Atmosphere Temperature and Humidity Control

This function is provided by the use of liquid air condensing heat exchangers. Two internal thermal control loops provide both cooling and heating of the air. Each loop has a backup piping system for redundancy. The temperature of these loops is controlled automatically. The temperature of the Mir Complex is maintained at 28° C so that air can be circulated in the weightless environment without crew discomfort. Proper air humidity is maintained by the addition of 1.2 liters of water/crewmember/day to the atmosphere. The Mir Complex TCS interfaces with the condensing heat exchangers mentioned above. The fans, used to move the air through the system, require electrical power.

The Atmosphere Temperature and Humidity Control Function planned for Space Station also used fans and condensing heat exchangers.

b. Cabin Ventilation

The cabin ventilation equipment provides air circulation to provide a continuous mixing of the Mir Complex atmosphere. In a weightless environment there is no natural convection. Cabin ventilation also prevents the build up of CO_2 pockets. Fans are used to pass air through ducts in order to exchange gas between modules. These fans require electrical power.

The cabin ventilation function planned for Space Station uses fans, filters, supply diffusers, and return ducting. This system provides 140 ft^3/min of air flow and provides circulation between all pressurized elements.

c. Equipment Cooling

Avionics equipment on Mir Complex is cooled both by heat exchangers and air pulled from the cabin. The ratio of cooling provided by both of these methods is 50/50.

The heat exchangers interface with the Mir Complex TCS. The fans that pull the air require electrical power.

An equipment cooling function was also planned for the Space Station ECLSS. This task was carried out by the Avionics Air Cooling Assembly which consisted of a filter, fan, sensible heat exchanger, and a check valve.

6.3.5 Waste Management

The purpose of the Mir Complex waste management equipment is the collection and disposal of human biological waste. The waste management includes fecal/urine handling equipment.

A commode for urine and excrement collection is provided. Urine is sent to the recovery processor and converted to hydrolysis grade water via the process described in the water recovery and management section.

Equipment of a similar design is planned for Station.

6.3.6 Fire Detection and Suppression

The purpose of the Mir Complex FDS equipment is to provide the capability to safely react to the possibility of onboard fires. Fire detection is provided by optical sensors. Fires may be suppressed by portable fire extinguishers. The crew can open valves to release suppressant in areas that cannot be reached by the portable fire extinguishers. This is the extent of the information currently available.

The FDS system planned for Space Station utilized CO_2 as the main suppressant. Flame detectors are employed to detect fires in open areas. Smoke detectors are used within closed or confined areas. The avionics air cooling equipment described in the equipment cooling section maintains a constant air flow at all times required by the smoke detectors. Fires can be isolated to the rack level and suppressed automatically by CO_2.

6.4 MIR COMPLEX GENERAL ECLSS CYCLE

The Mir Complex ECLSS has been discussed functionally. Figure 6–4 expresses all of the above ECLSS functions in the form of a cycle. The center of the cycle is the crew, which is the main customer of the ECLSS.

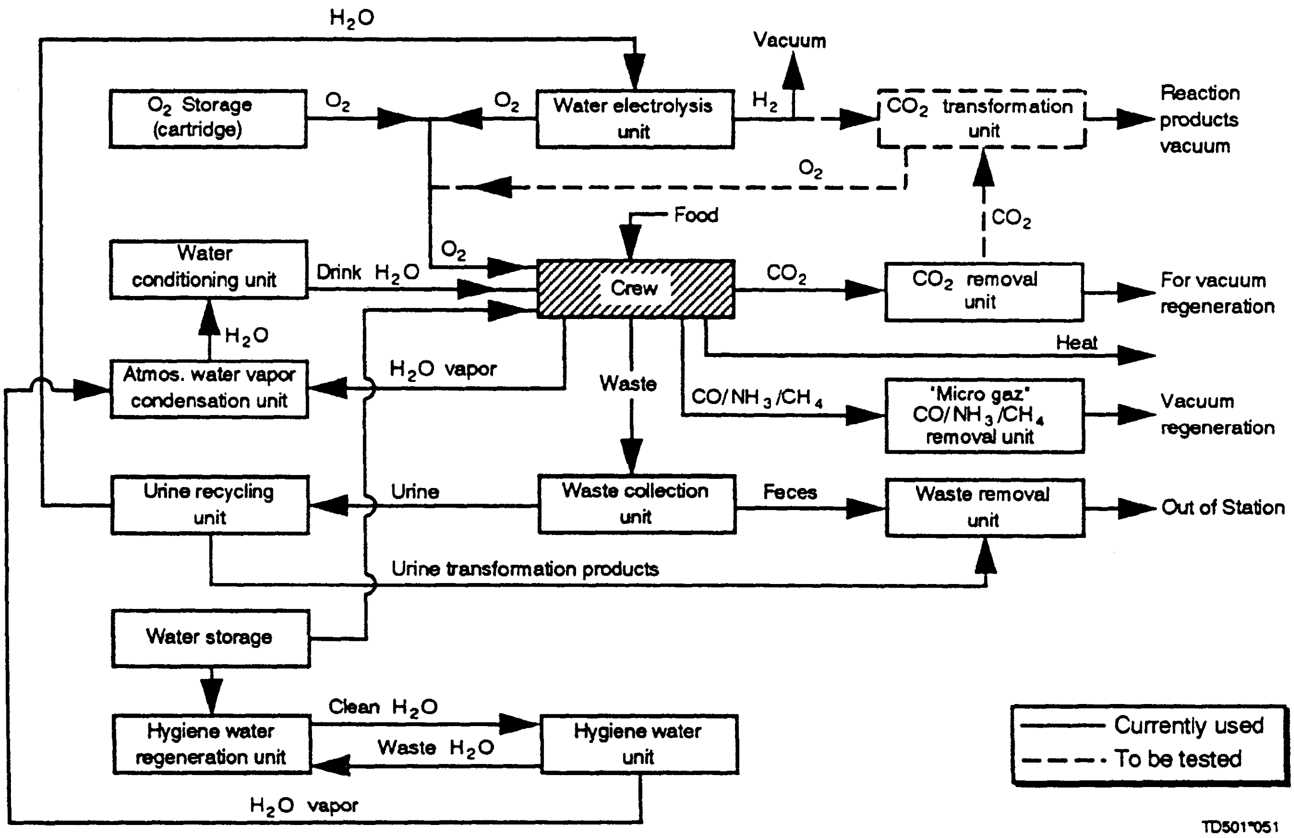


Figure 6–4. ECLSS cycle

The crew requires inputs of O_2. These inputs come from either the water electrolysis unit or the backup chemical reaction storage cartridges. The water electrolysis unit produces H_2 which is vented overboard and requires water that is obtained from the urine recycling unit. The crew metabolizes the O_2 into CO_2 which is exhaled into the cabin . The CO_2 is removed by the CO_2 removal unit and is rejected to vacuum.

The crew also requires potable water intake. Some of the drinking water is obtained from the water conditioning unit that purifies the water. The water input into the conditioning unit is the output of the water vapor condensation unit. The water vapor inputs into the condensation unit result from the relative humidity in the cabin atmosphere. This humidity is a function of crew size and the amount of evaporation from hygiene water. Drinking water is also taken from potable water that is stored on Mir Complex. This storage water is also a source of hygiene water. Purified hygiene grade water is continuously recycled between the hygiene water units and the hygiene water regeneration unit.

The crew also requires food. The waste products from food and water are dealt with by the waste collection unit. The urine goes to the urine recycling unit where the water is distilled out and sent as input to the water electrolysis unit. The remaining elements of the urine are sent to the waste removal unit as are feces from the waste collection unit. This solid waste is eventually removed from the Mir Complex.

The crew produces various "micro gases" (trace gases) that are removed by the "micro gas" removal unit. The crew also produces heat that is removed by the Temperature and Humidity Control Subsystem (THCS) condensing heat exchangers.

6.5 MIR COMPLEX ECLSS MODULE LOCATIONS

ECLSS equipment is located throughout the Mir Complex. Figure 6–5 shows the location of ECLSS equipment schematically in each module.

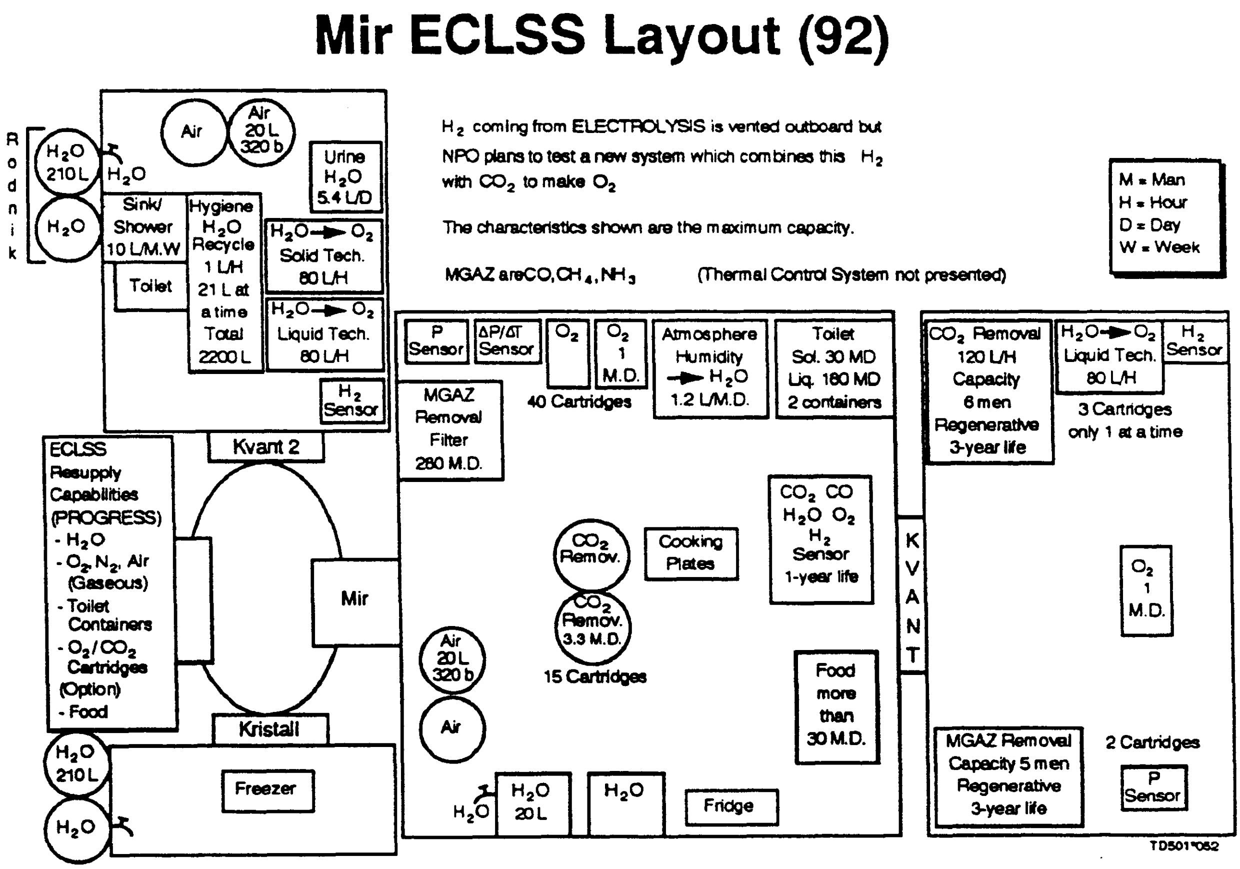


Figure 6–5. ECLSS equipment layout

The Mir contains air and water storage containers, micro gas removal filter, 40 O_2 regeneration cartridges, 15 CO_2 removal cartridges, and a Waste Management System (WMS).

The Kvant–1 module contains an absorbent CO_2 removal system, a water hydrolysis O_2 generation system, O_2 storage, and micro gas removal equipment.

The Kvant–2 module contains air and water storage, urine water removal equipment, water hydrolysis O_2 generation equipment, solid technology water–to–oxygen equipment, a WMS, sink, shower, and hygiene water recycling capability.

The Kristall module contains water storage capability. All modules contain module ventilation equipment.

6.6 MIR COMPLEX TCS FUNCTIONALITY

The purpose of the Mir TCS is to provide active cooling to Mir Complex electronics and equipment which cannot be cooled via passive means.

The Mir Complex TCS is module based and consists of two internal loops and one external loop. The internal loops are at a low and moderate temperature. The two internal loops actually pass outside of the pressurized modules to interface with the external loop. The internal fluid is a chemical compound with a low freezing point. Heat is rejected to space via radiation. There are no large surface area thermal radiators with a fluid interface analogous to those on Station. This is the extent of the information currently available.

6.7 MIR COMPLEX ECLSS/TCS SUMMARY

The Mir Complex ECLSS provides AR, WRM, ACS, WM, FDS, and THC functions for the station. The crew is the main customer. The Mir Complex ECLSS is similar in function to the Space Station Baseline.

The Mir Complex TCS provides Active Thermal Control to the Mir Complex systems that require active cooling. The Mir Complex TCS provides cooling for the Mir Complex ECLSS, EPS, and payloads when necessary.

QUESTIONS

1. The main customer for the Mir Complex ECLSS/TCS is the crew.

   a. True

   b. False

2. The purposes of the Mir Complex ECLSS include which of the following?

   a. Supply proper atmosphere

   b. Supply water

   c. Rejection of waste heat

   d. a. and c.

   e. a. and b.

3. The Mir Complex ECLSS provides CO_2 removal via a four–bed molecular sieve?

   a. True

   b. False

4. Which is not one of the Mir Complex ECLSS functional groupings?

   a. Atmospheric revitalization

   b. Water recovery and management

   c. Electrical power system cooling

   d. Temperature and humidity control

5. Which Mir Complex systems interface with the Gas Recovery/Regeneration water electrolysis system?

   a. EPS

   b. TCS

   c. Guidance and navigation system

   d. a. and b.

   e. a. and c.

6. Which Mir Complex system interfaces with atmospheric temperature and humidity control system liquid air condensing heat exchangers?

   a. EPS

   b. TCS

   c. Propulsion system

7. The Space Station Baseline for temperature and humidity control used condensing heat exchangers.

   a. True

   b. False

8. The Space Station Baseline included water electrolysis for O_2 generation?

   a. True

   b. False

SECTION 7
CREW HEALTH CARE AND MAN SYSTEMS

7.1 PERFORMANCE OBJECTIVES

By the end of this section, the reader should be able to:

- Identify the function of the Mir Complex Man Systems and Crew Health Care Systems (CHeCSs)
- Describe the capabilities and constraints of the Mir Complex Man Systems and CHeCSs
- Describe the Mir Complex Man Systems and CHeCSs interfaces to other Mir Complex systems
- Briefly describe any similarities/differences between these systems and the equivalent U.S. Space Shuttle/Station systems

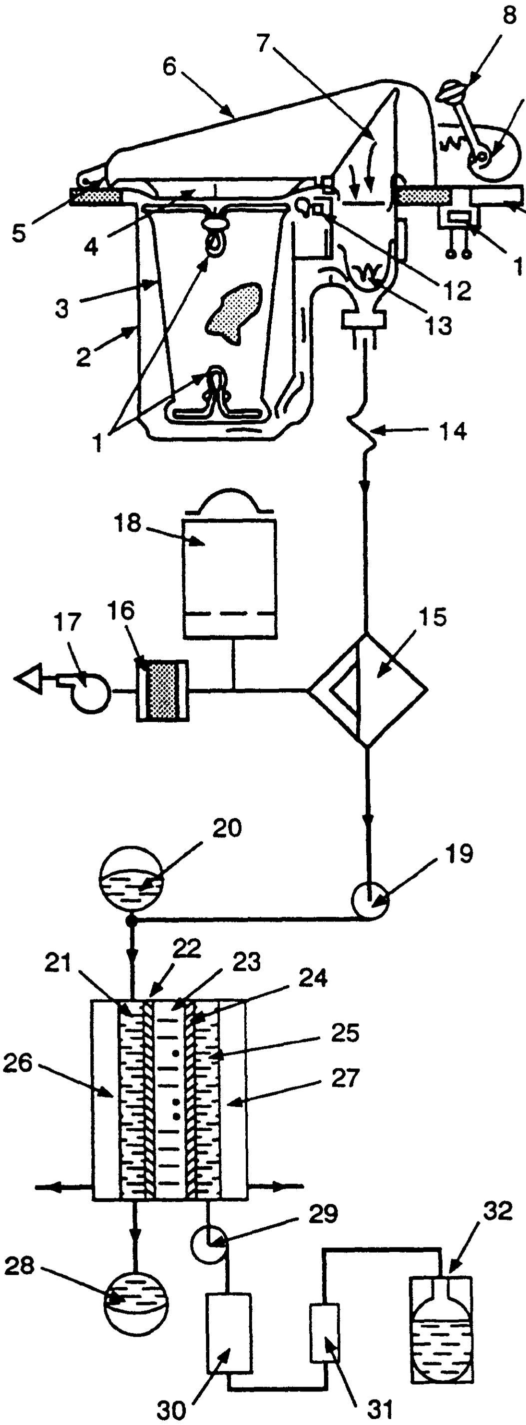
7.2 INTRODUCTION

The Mir Complex Man Systems and CHeCS are addressed in the same section because they are so closely related. Man Systems deal with items necessary for people to live in space and is divided into Body Waste Management System (WMS), Personal Hygienic System (PHS), and Habitability. The CHeCS provides services required for crewmembers to remain healthy and treat ailments in space. Countermeasure devices, radiation monitoring equipment, and emergency medical treatment equipment are the three types of components that provide substantial custom health care and health maintenance capabilities. Because the Russian Space Program supports a carefully structured health and bioscientific research and development program, its programmatic goals consistently lead towards preparation for a future manned Mars mission.

7.3 MAN SYSTEMS

7.3.1 Body Waste Management System

The Body WMS is the toilet onboard the Mir Complex. While the functions are similar to the U.S. Shuttle Waste Containment System (WCS) and the Space Station WMS, its design is slightly different. Figure 7–1 is a diagram of the Mir Complex WMS and the following numbers in parenthesis reference specific components shown on it.



Urine/Water Regeneration

19 - Pump
20 - Intermediate storage tank
21 - Cavity
22 - Membrane
23 - Cavity
24 - Porous membrane
25 - Cavity
26 - Hot liquid
27 - Cold liquid
28 - Tank
29 - Pump water
30 - Absorber
31 - Mineralization unit
32 - Storage tank

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Figure 7–1. Body WMS

Opening the sanitary lid (6) automatically starts air circulation in the unit similar to Shuttle and Space Station design. A single sanitary receiving unit provides separate collection and removal of urine and feces. Urine is collected in a fixed funnel (7) on the device or filtered through the feces collector (2) into the urine hose (14). (Shuttle and Space Station systems do not have a separate urine funnel, but utilize either a male or female urine collection device.) After being collected, the urine is sucked through a filter (13) to a gas separator (15) and sanitation unit by a pump (19). A fan (17) draws the air through an absorber (16) to remove odors and circulate air back to the cabin. The water in the urine is regenerated by vapor diffusion distillation (21–27), passed through an absorber (30) and mineralization unit (31) into a storage tank (32), and later used for electrolysis. On Mir Complex, the feces collector unit consists of a replaceable net insert (3) which is manually tied using draw strings (1) and stored in a waste collector device (18). For comparison, waste water is not reclaimed on the Shuttle and Station waste water is recycled to potable water using vapor compression distillation and multifiltration processes. All waste is disposed of using atmospheric incineration (burn up on entry) of the Progress spacecraft. Both Shuttle and Space Station waste are returned to Earth.

7.3.2 Personal Hygienic Systems

The PHSs provide four main functions: full and partial treatment of the body, tooth brushing, hair and nail cutting, and shaving. The Mir Complex Shower Unit, as shown in Figure 7–2, provides a full treatment of the body and is located in the Kvant–1 module.

1. Shower cabin
2. Sponge
3. Separator
4. Ventilator
5. Shower spray
6. Air distributor
7. Heater
8. Ventilator
9. Mixer
10. Gauze filter
11. Mixer
12. Washing solution tank
13. Pump handle
14. Deodorant
15. Separator
16. Gauze filter
17. Foot restraints

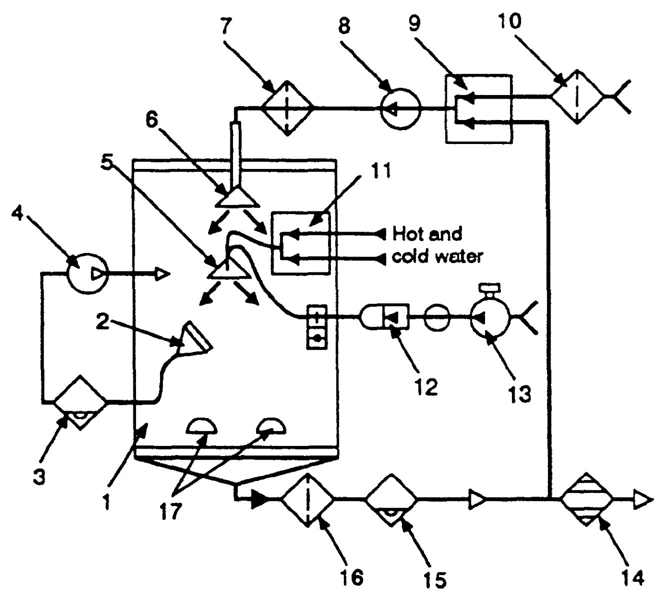


Figure 7–2. Shower unit

The unit can be folded if required to save space. Cosmonauts may shower about once per week for about 3 to 4 minutes. Water consumption varies between 2.5 kg to 8 kg per shower. The shower compartment is made of a flexible, transparent material that attaches to structural points in the module when unfolded. A foot restraining device keeps the cosmonaut in place. Water supply and temperature control are done manually by a mixer. A washing solution is available for cleansing. Cabin air is circulated in the shower to help dry the unit and allow for the measurement of CO_2 concentration. A sponge or towel is also used to dry off. The Station shower design is similar to the Mir Complex except for the CO_2 measurement component, and the Shuttle does not have a shower unit. The Station shower is a fixed unit, however. While the Shower Unit works with only minimal leakage, cosmonauts rarely, if ever, use it. It has been known to be more troublesome than the simple wash rags that are typically used for full–body cleansing.

The Space Wash Stand, as shown in Figure 7–3, provides partial body treatment in terms of: localized cleaning and washing, tooth brushing and oral hygiene, hair and nail cutting, and shaving. The water controls and drying procedures are very much the same as for the shower installation. Typically, teeth are brushed two times a day in either the wash stand or using a special electric tooth brush. This specialized tooth brush is equipped with forced water, tooth paste supply, and a mouth ejector (suction device) to remove the water. A pump is used to suction waste water, hair, nails, and air through a filter and separator to a deodorizer where the air is injected back into the cabin. While the Shuttle does not have a wash stand facility, Space Station has one similar to the Mir Complex component. It is important to have such facilities because studies have shown that, besides cleaning one's body, the shower or washing provides a feeling of psychological comfort and contributes to the lessening of stresses.

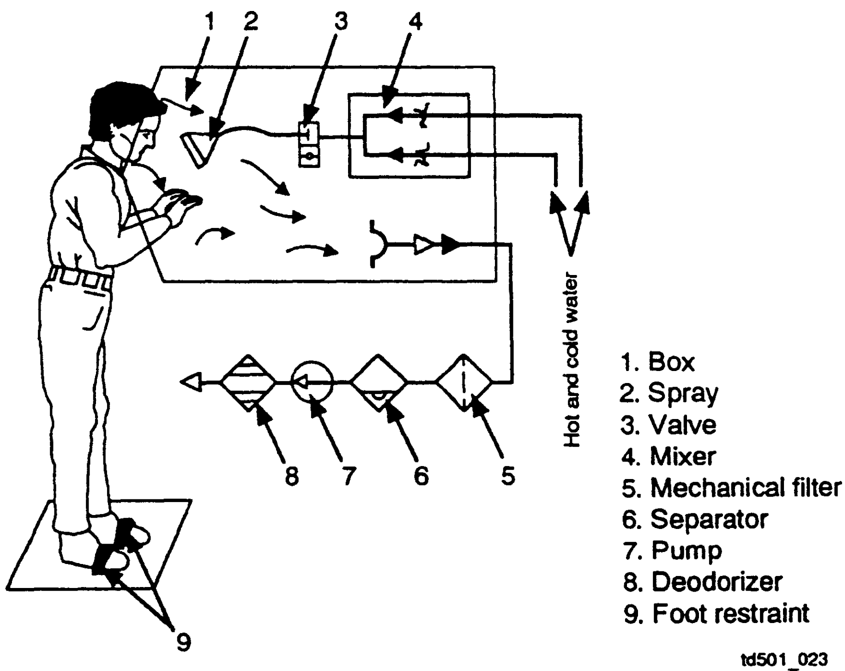


Figure 7–3. Space wash stand

7.3.3 Habitability

A certain amount of separation exists between working and living on the Mir Complex, with different areas available for working, sleeping, resting, recreation, and privacy. The majority of the sleeping, recreation, and privacy availability resides in the Mir. The module contains two privacy cabins that can be used for resting or sleeping, and the exercise equipment which cosmonauts are required to use every day. Although Station may eventually have similar privacy compartments, plans are currently to velcro sleeping bags to the walls, much the same way it is done nominally on the Shuttle. The Shuttle can also be configured with sleeping quarters.

Location coding of equipment and lockers on the Mir Complex has similarities to both the Shuttle and Station methods. The location code is a three digit number, the first digit being the side number. Shuttle and Station both use a letter to indicate the wall, floor, or ceiling racks.

Side 1 is considered to be the floor in all modules and side 3 is the ceiling. The locations are numbered sequentially beginning at the end of the cabin closest to the multiple docking module, and side 4 will always be on the crewmember's right when facing the multiple docking module with their feet on the floor. Side 2 will be on their left. See Figures 7–4 through 7–7 for examples of location coding on the Mir module.

The numbering sequence is designed so that when a cosmonaut is walking from Kvant–1, through the Mir, and into Kvant–2, the relative "floor" remains the same (compare this path to a person walking across a flat roof, then down the side of the house). Thus, the up–down orientation remains the same for the cosmonaut. Another example would be going from the Mir module into Kristall; this is similar to walking across the floor, then up the side of a wall. These four sides are color coded to give the crew a psychological sense of up and down.

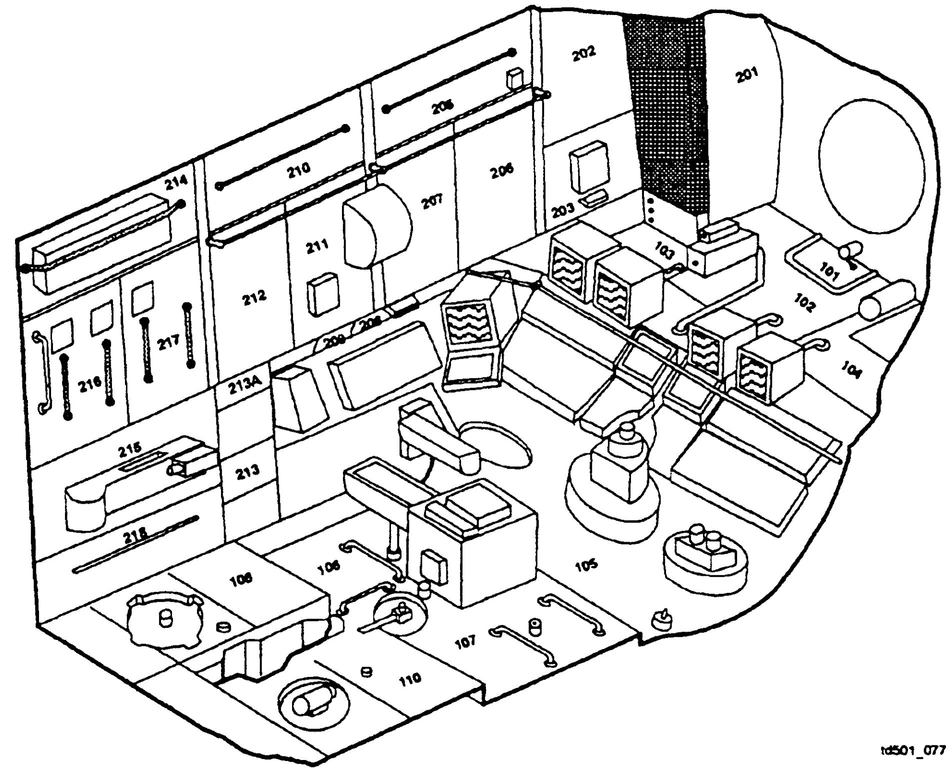


Figure 7–4. Location coding side 2 looking forward

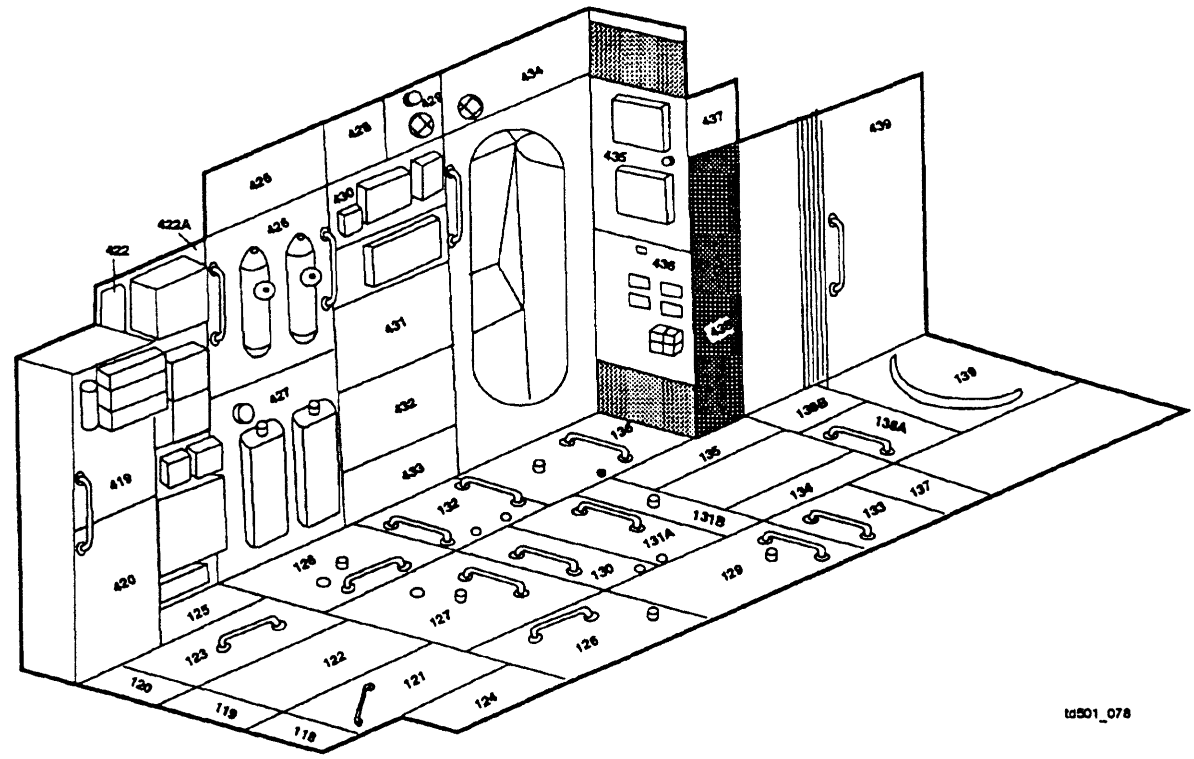


Figure 7–5. Location coding side 4 looking aft

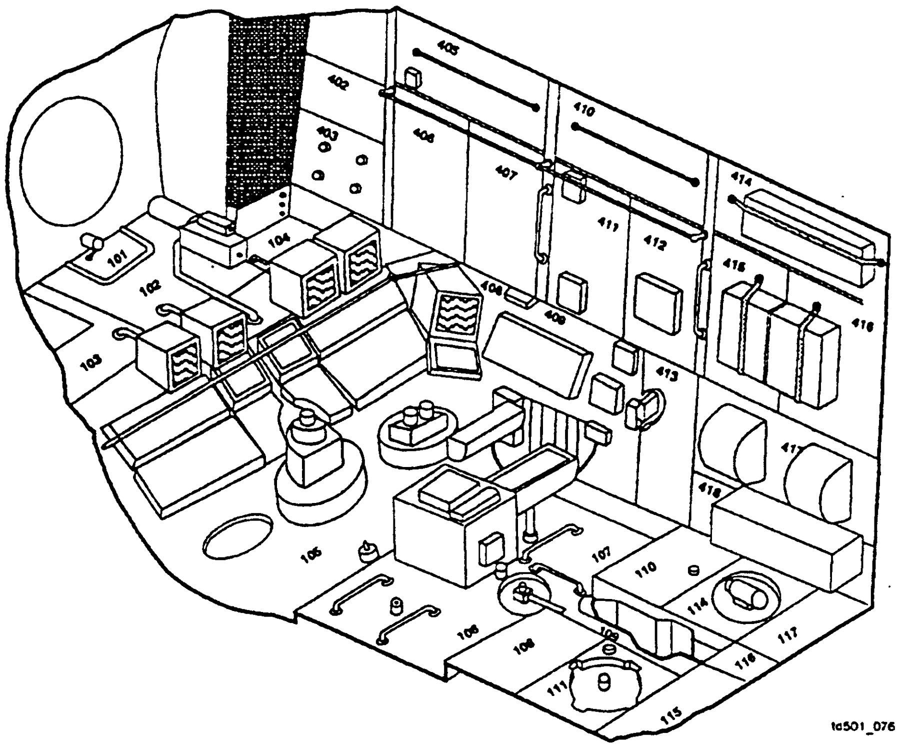


Figure 7–6. Location coding side 4 looking forward

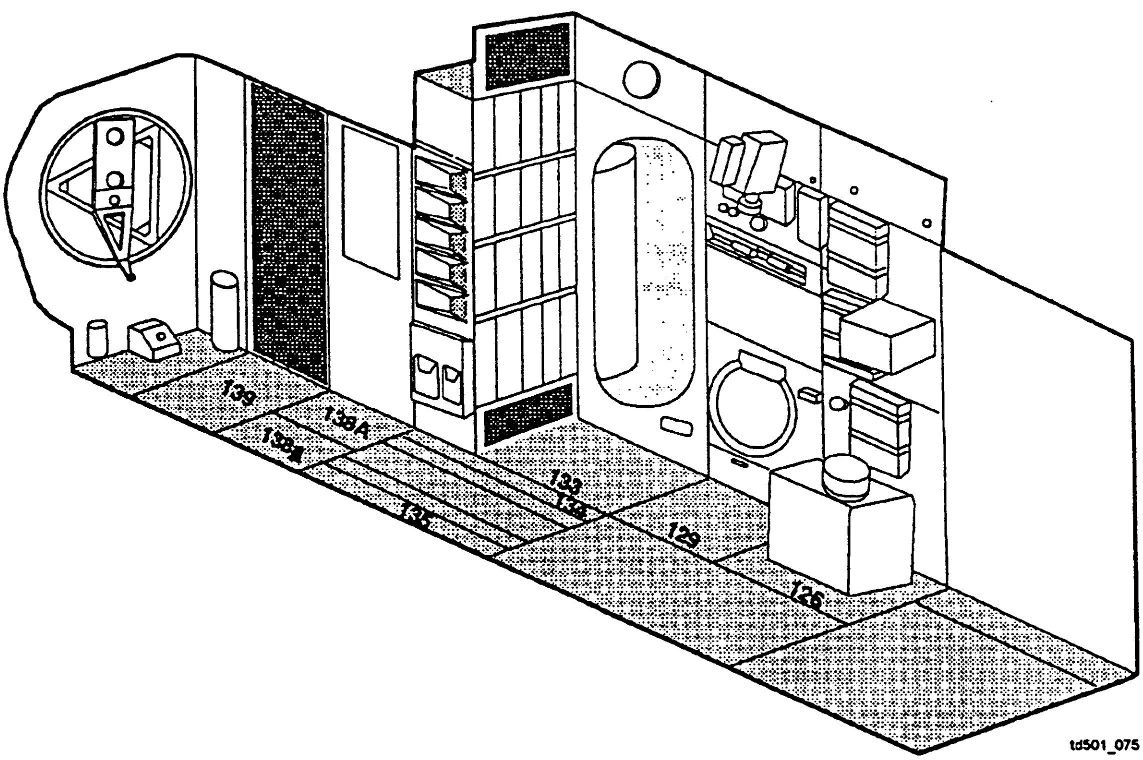


Figure 7–7. Location coding side 2 looking aft

7.4 CREW HEALTH CARE SYSTEM

The Mir Complex CHeCS consists of countermeasure devices and methods, radiation monitoring equipment, and emergency medical treatment equipment. Because the Russian Space Program supports a carefully structured health/bioscientific research and development program, substantial custom health care and health maintenance activities are provided.

7.4.1 Countermeasure Devices

A number of countermeasure devices, procedures, drugs, and diet options are available onboard the Mir Complex. Twelve different countermeasure devices include "penguin", "chibis" vacuum, and anti–gravity suits; a bracelet device; an electrostimulation device; an ergometer; a treadmill; chest expanders; a Cuban boot; head restraints; artificial gravity; and "Alpha–Ritm." The "penguin" suit contains rubber bands that provide a passive load on the antigravity muscle groups. It is designed to be worn continuously (12 to 16 hours per day) and has been positively endorsed by the cosmonauts.

The "Chibis" vacuum suit is a lower body negative pressure suit used once every 4–days for 20 minutes and for 50 minutes per day in the last 2 weeks of flight. Results have shown that the suit is only partially beneficial. This suit is similar to the Lower Body Negative Pressure device worn experimentally on several of the Shuttle flights.

The antigravity suit is a positive lower body suit that operates in the opposite sense of the "Chibis" suit. Positive pressure is applied to the crewmember's lower body to prevent the pooling of blood and to aid in maintaining circulating blood volume. It is similar to the anti–g system used by U.S. astronauts during Shuttle launch and entry.

The bracelet device is a tourniquet attached to the cosmonauts thigh to control excess blood flow to the upper extremities. It is a possible replacement for the "Chibis" suit during early phases of adaptation to weightlessness.

Use of the electrostimulation device on muscles is intended to alleviate and/or prevent the atrophy caused by disuse. This has been demonstrated with animals, but is effective only if the induced muscle contractions are vigorous.

The ergometer and treadmill are the same bicycle and walking type devices used by U.S. crewmembers.

Chest expanders are spring, rope, and capstan type devices used for physical conditioning. They are considered only partially effective due to limited muscle groups being exercised.

The Cuban boot is a device that applies pressure to the bottom of the feet, thus simulating the sensation of standing. It is reported to reduce the severity of spatial illusions and motor disturbances thought to be caused by motion sickness. Head restraints are caps with cords attached to the shoulders to limit relative head–shoulder movement. Flight tests indicate the system was helpful in controlling space sickness. However, a centrifugally established gravity field (artificial gravity) is considered the ultimate countermeasure solution.

"Alpha–Ritm" is a device designed to provide therapy to reduce the stress caused by undefined lighting and noise conditions. Users develop an immunity by receiving controlled levels of exposure. It is reportedly used by Russian pilots, drivers, equipment operators, rescue workers, and athletes.

7.4.2 Countermeasure Procedures

Seven different countermeasure procedures are practiced. Similar to the U.S. space program, exercise onboard a space vehicle is considered a must. Cosmonauts workout for 2 hours a day 6–days a week. Adhering to work and rest schedules is a productive way to counter the effects of fatigue and distraction. Cosmonauts have a 5–day work week with weekends off. This is similar to the schedule designed for Station; however, the time off given to Shuttle crewmembers is minimal and depends on individual flight objectives. Selecting cosmonauts with the least propensity to deconditioning is one preventive countermeasure procedure used by the Russian space program. Russian research has shown that biofeedback or the autogenic regulation of physiological functions can result in faster normalization of conditions, reduce anxiety, and enhance performance under stress. Acupuncture has also been investigated, but results are not available. Yoga has been practiced in orbit by a cosmonaut to offset the discomforts from weightlessness, and other cosmonauts continue to show an interest in the potential. Finally, there is a variety of ground based research on strains (lactobacteria) that develop or stimulate the human immune system. The Russians feel that this research could result in countermeasure applications.

7.4.3 Countermeasure Drugs

A number of countermeasure drugs are available to Cosmonauts. Securine is used to counter cardiovascular deconditioning. Phenibut is being researched to determine its effect on orthostatic tolerance. "Adaptogen" (or something that is good for any ailment) substances include ginseng, eleutherococcus, arilia manshuria, rantarine, rhodiola, rosea, shizandra, Gipkos, likorin, gipreks, and freeze dried juices. Vitamins in use are aerovit, undevit, dekamevit, genedivit, and pangeksavit. Research on these and other vitamins is continuously being performed. Motion sickness drugs, which are commonly used by U.S. crewmembers as well, include endorphins, metaclopromide, and a scopolamine/amphetamine mixture.

7.4.4 Countermeasure Diets

As in the U.S. space program, the Russians feel that a proper diet can serve to assist in the countermeasure function. The diet must compliment and supplement deconditioning trends. Food not only sustains physiology, but has psychological affects on the cosmonauts as well. The growth of fresh vegetables in space is a developing capability pursued by the Russian program to accommodate the goals associated with long duration space flight.

7.4.5 Radiation Monitoring Equipment

From the beginning of the Russian space program, space radiation has been regarded as a serious hazard to the cosmonauts and one of the more limiting constraints to long–term manned space activities. Radiation protection is an integral part of the overall space biomedical program. A number of experiments have taken place on manned and unmanned spacecraft and in ground based facilities, some contributed by the U.S. and France.

A variety of ionization radiation monitoring (dosimetry) equipment has been used in the Soviet space program. The Pille thermoluminescent dosimeter is a portable, accurate system used to measure individual crew dose and dose distribution within the spacecraft. It is used during an EVA or when the spacecraft passes through radiation intense areas such as the South Atlantic Anomaly. The Pille was used on Salyut–6, Salyut–7, and Mir. The PPD–2, Mini–Dose 178, and Integral Unit devices were all used on Salyut–6.

PPD–2 is placed in various locations in the manned modules for fixed periods of time to measure the total dose of ionizing radiation. The Romanian Mini–Dose 178 dosimeter was used to study the trapped proton environment of the South Atlantic Anomaly. The Integral Unit is self contained in a rigid container and does not require a power supply. It consists of thermoluminescent crystal phosphorous and glass, plastic track detectors, and photographic plates. The experiment was used to study the distribution of the absorbed dose of cosmic radiation and the fluency of heavy charged particles over extended periods of time.

The Lyulin dosimeter is a portable, self–indicating dose–rate–meter used to take high resolution measurements of the flux and dose rate along the track of the Mir spacecraft in real–time. It is a standard Soviet silicon lithium–drifted detector with a microcomputer unit. The French developed dosimetry system called CIRCE is a real time, dose equivalent meter that uses a low–pressure, cylindrical, tissue–equivalent, gas proportional counter and microdosimetric techniques. It has been used onboard the Mir Complex since December 1988 and has worked well. Finally, the "Spin–6000" spectrometer experiment is cross between a Geiger counter and the x–ray astronomy observatory "Astron" and was delivered to the Mir Complex in Progress M–2. It is intended to assist in materials selection and design approaches for future spacecraft.

The Shuttle and Station radiation instrumentation consists of similar dosimeters that provide the capability for operational real–time monitoring of radiation exposure conditions inside the cabin during flight.

7.4.6 Emergency Medical Treatment Equipment

While some biomedical monitoring devices and onboard medical kits are contained in the Mir Complex, major emergencies require either a launch visitation crew or the termination of the mission. For future long duration space flights, the Russians intend to have a doctor present at all times to provide immediate diagnosis and treatment of simple ailments and injuries. This is consistent with the plans to have a Crew Medical Officer onboard Station. A variety of equipment will be available on Station to provide diagnostic, first aid, life support, stabilization, transport, and some dental functions. Looking beyond the planned capability, both the Russians and the U.S. have discussed approaches for in–space surgery including instruments, anesthesia, etc., which would be required to address the treatment of major traumas or illnesses during long duration flights such as a Mars mission.

The current emergency services on the Mir Complex are not nearly as extensive as those onboard Station. Basic medical support is provided by blood dynamic measurement equipment, an electrocardiogram, an ultrasonic Doppler cardiogram, and lung ventilation equipment. Additional care is supplied by onboard Medical kits that include disposable syringes, miscellaneous pills, bandages, topical anesthesia, antibiotics, and antiseptics. The Shuttle

Orbiter Medical System provides similar medical care for minor illnesses and injuries as described onboard the Mir Complex.

Since infectious diseases can develop and spread quickly leaving little leeway for diagnosis and treatment, preventative measures become important. House cleaning protocols are part of the daily routines on the Mir Complex just as onboard Station and Shuttle. Biological filtration of the atmosphere and the use of lactobacteria to supplement the human immune system are also used as preventative measures on Mir Complex. Station will have a Trace Contaminant Control System that provides a similar filtration of the atmosphere.

7.5 CREW HEALTH CARE AND MAN SYSTEMS SUMMARY

CHeCSs onboard the Mir Complex provide similar functions to those on the Shuttle and Station. Since the cosmonauts have longer duration experience in space than the U.S. astronauts, they have had the opportunity to experiment with a wider variety of countermeasure devices and methods. Results from their learning experiences may be used to refine the design of the new Space Station and may influence changes to some of the equipment used on the Shuttle. Both the Soviet and U.S. space programs are committed to the bioscientific research necessary to help understand and solve health–related problems on Earth while at the same time preparing for the goal of a future manned mission to Mars.

QUESTIONS

1. Which statement best reflects the Russian approach to Man Systems onboard the Mir Complex?

   a. The Mir Complex contains Man Systems equipment that is very similar to that of the Space Station and Shuttle programs.

   b. Man Systems on the Mir Complex deal only with the cosmonauts diets and exercise regimens.

   c. Cosmonauts on the Mir Complex do nothing with regards to Man Systems that is comparable to the U.S. activities.

2. The Russians do not place much emphasis on countermeasure devices on the Mir Complex.

   a. True

   b. False

3. The Body WMS on the Mir Complex interfaces with the following systems

   a. EPS and TCS

   b. Computational system and thermal system

   c. EPS and environmental system

4. Which statement is most accurate about the CHeCS on the Mir Complex?

   a. There are extensive emergency medical services on the station.

   b. A large number of countermeasure devices are used on the station.

   c. The cosmonauts' diets are not utilized as a countermeasure.

SECTION 8
COMMUNICATIONS, TRACKING, AND DYNAMIC OPERATIONS

8.1 PERFORMANCE OBJECTIVES

By the end of this section, the reader should be able to:

- Identify the function of the C&T system
- Describe the capabilities and constraints of the C&T system
- Describe the C&T system interfaces to other Mir systems
- Briefly describe any functional similarities/differences between the Russian C&T systems and the equivalent Space Shuttle systems
- Trace the normal communication pathway for voice and data between Mir Complex and the MCC–M

8.2 INTRODUCTION

The C&T systems currently used by Russia in support of Mir has many functional similarities to U.S. manned space program C&T systems. Due to philosophical differences in operational strategies, such as redundancy and crew responsibilities, the C&T systems are utilized by MMC–M quite differently than MCC–H . This section will cover the C&T capabilities and limitations of the Mir, Soyuz–TM and Progress vehicles, as well as phase of flight information.

8.3 FUNCTIONS OF THE C&T SYSTEM

The basic function of any C&T system is to provide a reliable pathway of telemetry between the spacecraft and the ground control center. Some subsets of this function are to provide communications between crewmembers onboard (intercom) and networks between the control center and ground stations. The C&T system historically has included two–way voice, downlink data, uplink commands and downlink video capability.

The Figure 8–1 depicts a comparison between Shuttle functionality and current Russian space program functionality. The most significant difference, which is not apparent from the drawings, is the reliance by the Russian space program on direct communication from a ground station to the orbiting space vehicle. Currently, Russia does not rely on a satellite system since they have only one available satellite. This results in very limited data and voice communication between the ground and the vehicle. By comparison, the U.S. manned space program relies heavily on the Tracking and Data Relay Satellite System (TDRSS), and has communication with the Shuttle for the majority of an orbit.

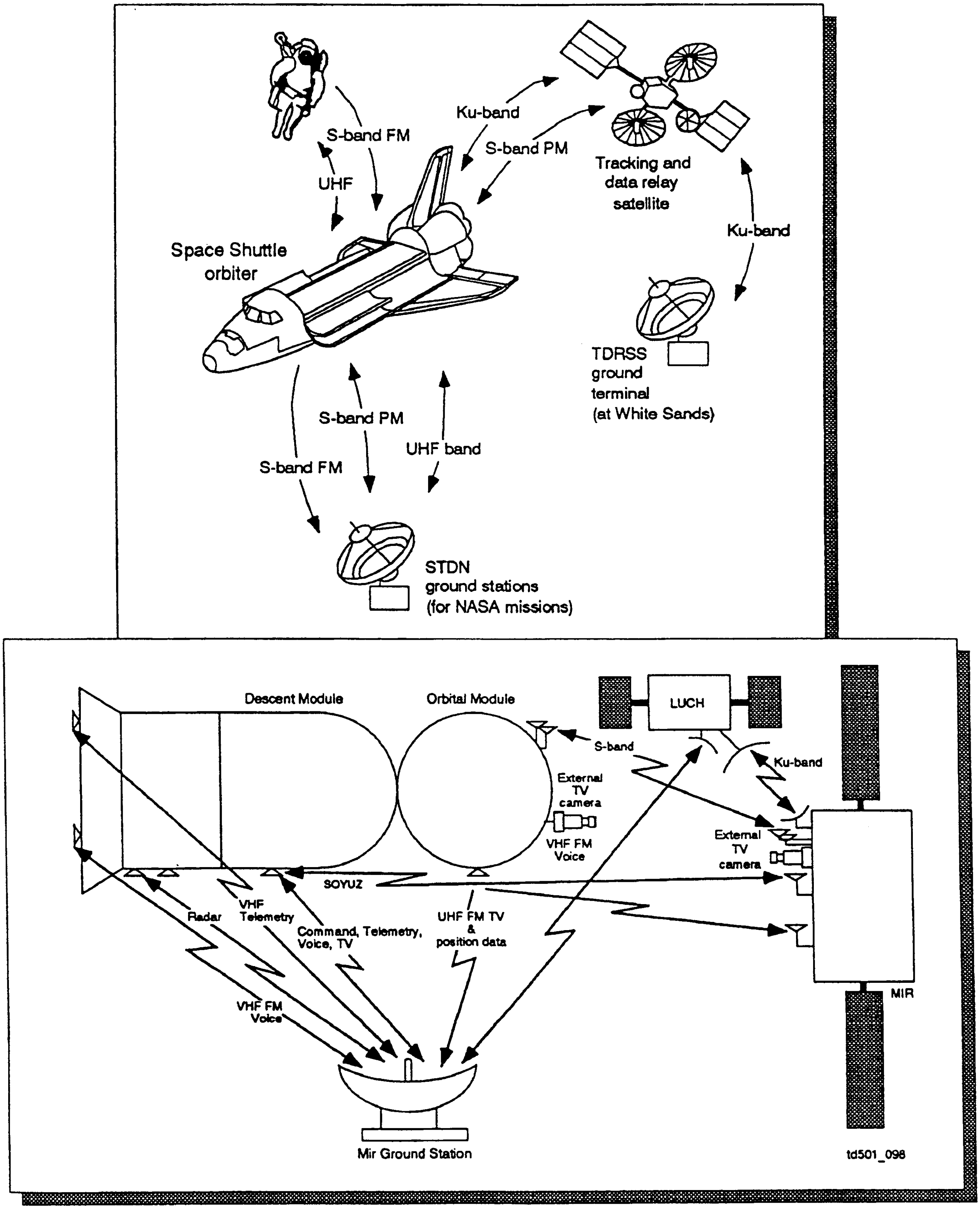


Figure 8–1. U. S. Shuttle comparison to Russian Mir/Soyuz–TM

8.4 DESCRIPTION AND LOCATION OF THE C&T SYSTEM

Since the Mir Complex is for the most part a collection of space vehicles as opposed to a single integrated vehicle, the C&T system is actually multiple C&T systems. This architecture philosophy provides a method of redundancy, since a C&T failure on one element of the Mir Complex generally will not effect the C&T capability of another element, unless the one element is the Mir Core element. The negative side of this architecture is the lack of integration across the vehicle. Additionally, different C&T capabilities exist on different elements, which potentially requires added training for crews and controllers.

The best way to understand the Mir Complex C&T systems is to learn the capability of each vehicle separately. For that reason, the descriptions have been broken down into the C&T system of each spacecraft, and then, in some instances, subdivided into the phases of operation.

8.4.1 Soyuz–TM C&T System Description and Location

The Soyuz–TM C&T design is based on the need to have communications for ascent, on orbit, return, and post–landing operations. As discussed previously, the Soyuz–TM is a modular construction, with an orbital module, a descent module and a service module, each designed to primarily support a certain phase of flight. See Figure 8–2.

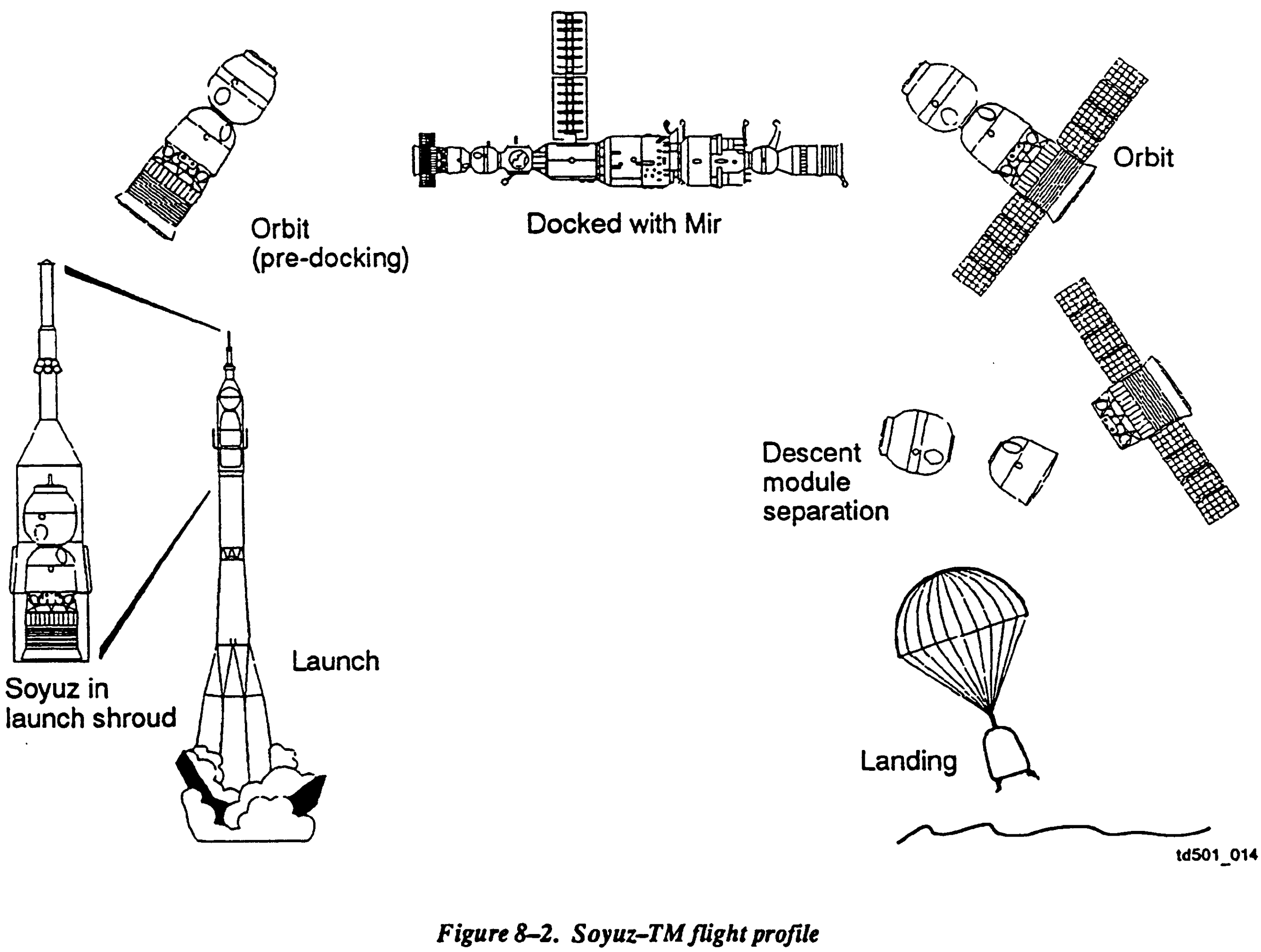


Figure 8–2. Soyuz–TM flight profile

The Soyuz–TM does not directly use any satellite system for C&T during any phase of flight. Ground stations, which require a direct unobstructed line called "line of sight" limitations, are the only direct link to the Soyuz–TM. Coverage from ground stations was of a limited duration, but was expanded in the past by the use of communications ships in the Atlantic and Pacific. Russia has, however, sold the vessels that had this capability. See Figure 8–3.

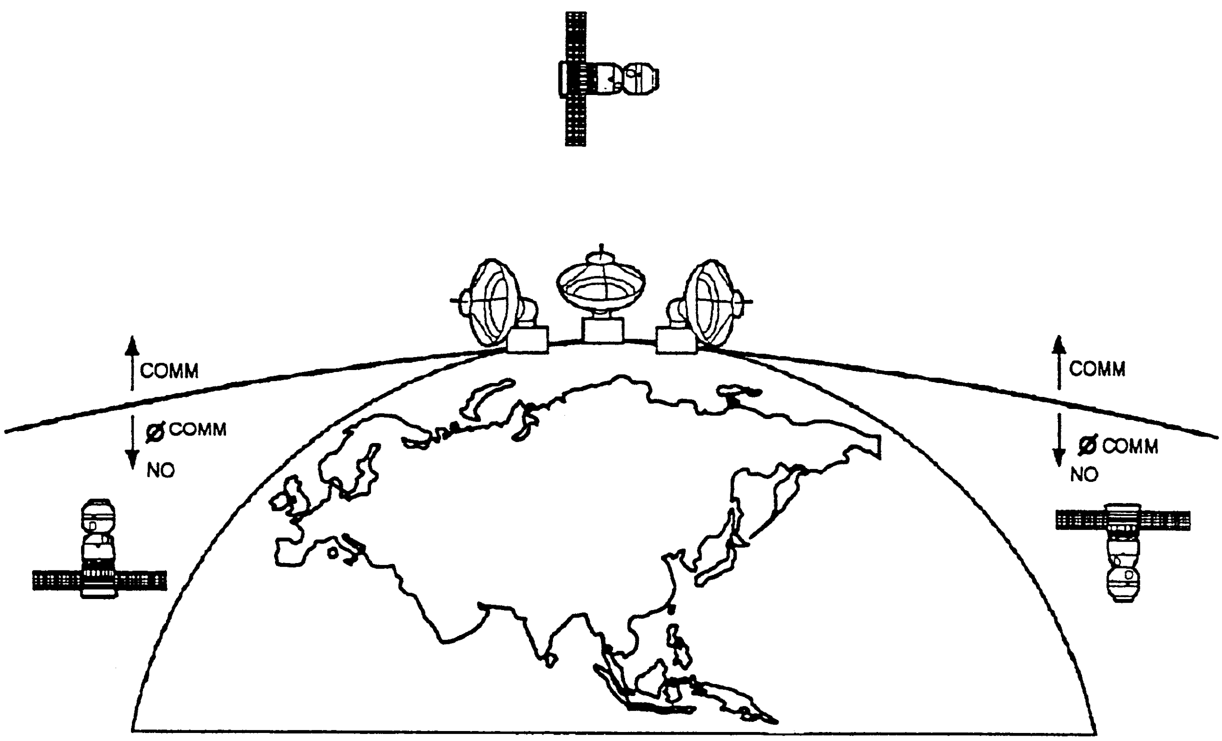


Figure 8–3. Line of sight limitation

a. Launch/Ascent

During launch operations, telemetry is available for MCC–M via ground tracking stations. Limited data is available on the composition, type, and pathway for this telemetry. It is believed that tracking data, voice and all vehicle parameters are available during this timeframe. Video cameras are located within the Descent Module, which is used for ascent also, and potentially available during launch and ascent. It is unknown if the camera system is used during launch/ascent operations.

The telemetry system for the Soyuz TM, which is used for all telemetry until separation prior to reentry, is located in the service module (also called instrument module). The system is designated as the BR–9CU–3 telemetry system. The system is a Frequency Modulation (FM) system and has downlink capability only. Reportedly, the system transmits at 166 MHz, 256 kbps or 922 MHz, 256 kbps.

The tracking system, called 38G6, is also located in the instrument module, and transmits a signal for reception by ground tracking stations (beacon). The tracking system uses a two–way link, also used during the orbit and rendezvous operations, that provides slant and range data. Frequency, accuracy, and bandwidth data are presently unavailable.

The avionics responsible for accepting ground commands to the Soyuz–TM are also located within the instrument module (service module). This system, called Kvant (not to confused with the spacecraft by the same name) interfaces with the onboard computer system, the Television (TV) system, and the BR–9CU–3 telemetry system. Presumably an FM system, it reportedly operates between 700 and 900 MHz. See Figure 8–4.

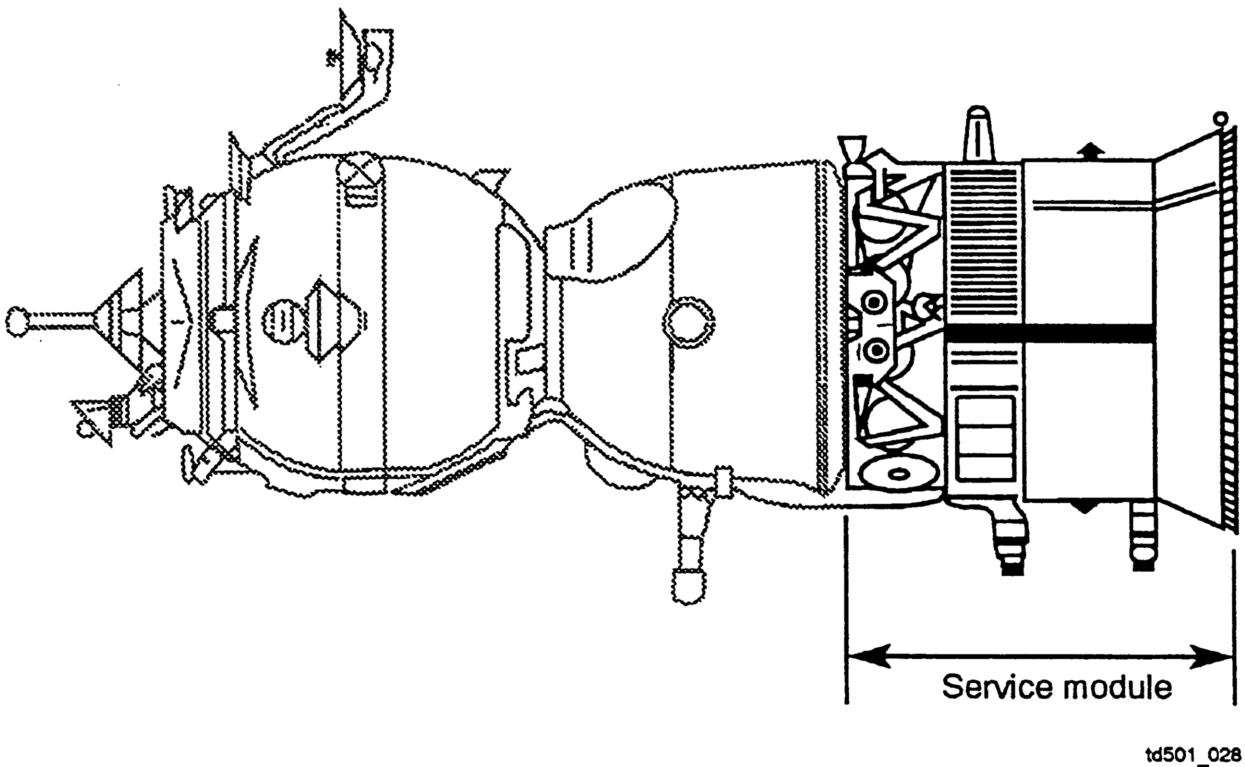


Figure 8–4. Service module location

The Rassvet system (17V12), available during all flight phases, provides the voice link between the ground and Soyuz–TM crews, and between the Mir Soyuz –TM crews. Since the Rassvet system is available during all phases, the system must be located within the descent module. Rassvet is advertised as a Very High–Frequency (VHF) system transmitting at 121 MHz and receiving on 130 MHz, and during entry and post landing can transmit a beacon signal for Search and Rescue (SAR) forces to use for crew recovery. See Figures 8–5 and 8–6.

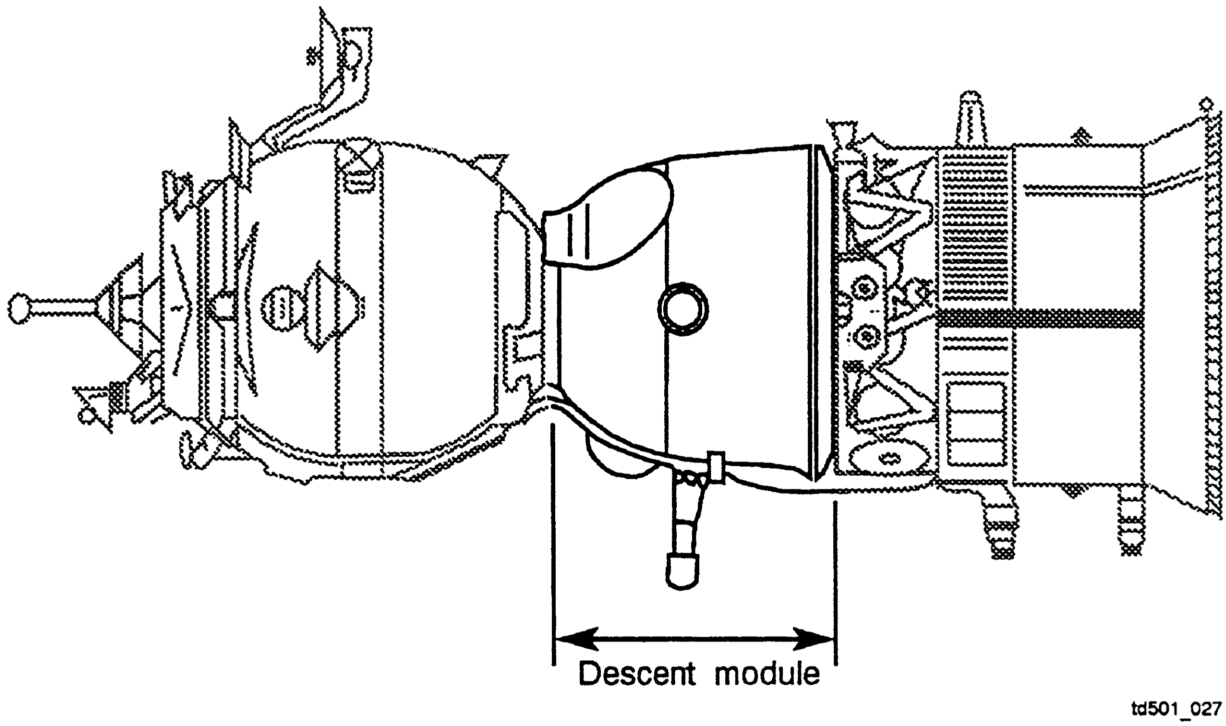


Figure 8–5. Descent module location

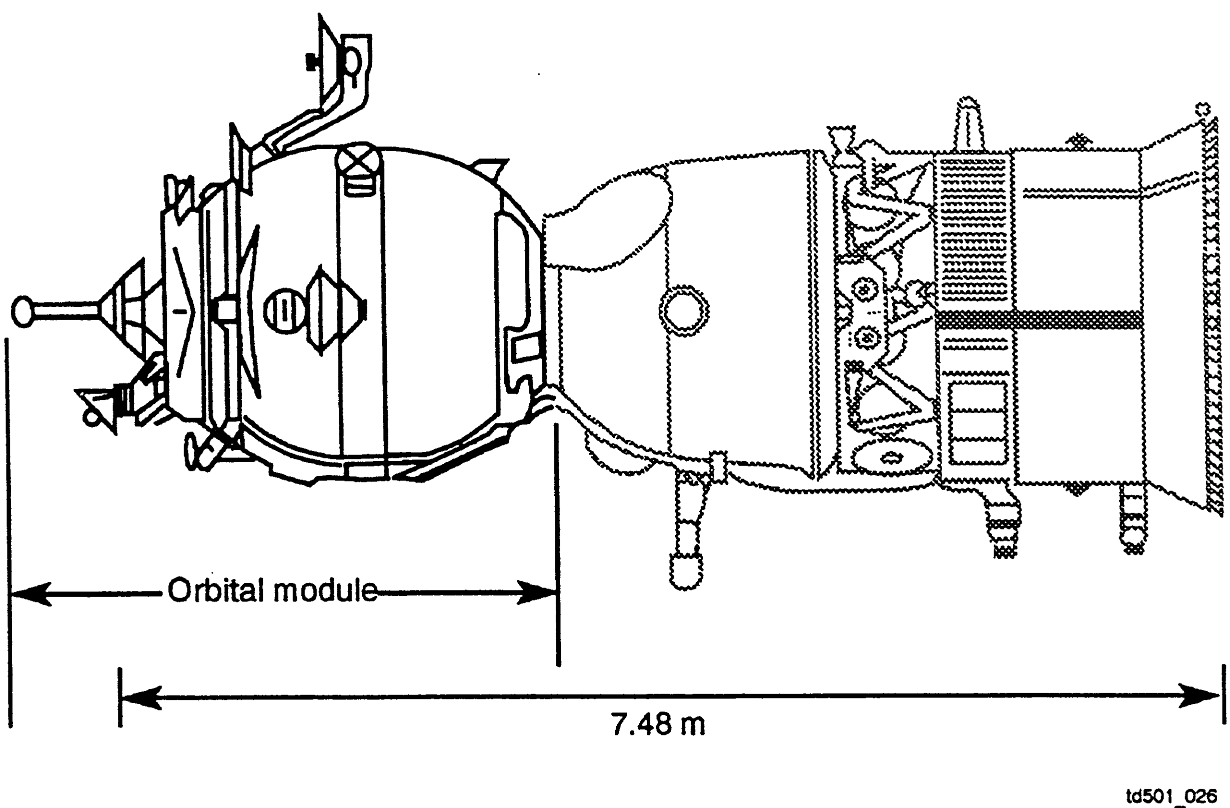


Figure 8–6. Orbital module location

b. Orbit

During on–orbit operations, when outside the range of the Mir Complex, the Soyuz–TM communicates solely through ground stations. The Soyuz–TM provides two–way voice through the Rassvet system (with each cosmonaut having a separate voice channel), downlink video, telemetry (BR–9CU–3 telemetry system), tracking (38G6 system), and uplink command capability (Kvant system) through these ground stations. The current capabilities do not allow for transmission directly to Russian satellites.

The uplink command capability from the MCC–M, either while the Soyuz–TM is autonomous or docked to the Mir Complex, allows for burn data, landing site availability, state vector updates, etc. The commands are packaged as single discrete commands, as opposed to a set of instructions (string of commands). It is unknown whether the command is echoed back for confirmation before execution, but information suggests that the command is executed at the time it is received by the vehicle. However, other past Soviet space vehicles and some current Russian vehicles are known to use a double transmission process for commands, with the onboard system sending a "receipt" message well after the duplicate set of command words are received.

While in orbit, an indirect satellite path does exist for Soyuz–TM data through the Mir. See Figure 8–7. When within an unspecified range of the Mir, and while docked to the Mir, Soyuz–TM data, video, and audio can be transmitted to the Mir. The Mir passes this to a satellite through its communication system. This communications technique, which has also been used by the U.S. space program, is termed a "bent pipe". The return path is limited to voice only. Commands to the Soyuz–TM must be sent directly to the Soyuz –TM by ground stations. When docked, a hard–wired (hard line) connection is used for passing data between the Soyuz–TM and the Mir.

The same bent pipe system allows two–way voice communication between the Mir and the docking Soyuz–TM. Operationally, during a docking/undocking operations, if the station is manned the Mir Complex onboard crew will retreat to the Soyuz–TM. In the event of a failure such as loss of cabin pressure, the Mir Complex crew would be safely located and able to return to Earth.

During docking operations, the Klest Television system is used. The Soyuz–TM utilizes one external SECAM camera (625 lines at 25 frames per minute) for docking, while the unmanned Progress uses two SECAM cameras. Two internal cameras, presumably within the Descent Module, and a crew monitor for the external camera are also part of this system. The Klest system is a analog, black and white system, and interfaces with the Kvant system. Klest video data is packaged with position data and downloaded at 463 MHz.

The system used for docking, which is an automated system, is designated as the Kurs (Russian for coarse) Tracking System. The Kurs system, also used on the Mir, is an improvement over the older Igla system, used on the Soyuz–T model. Designed as a fully automated docking system, the Kurs system allows the crew to manually dock in case the automated system fails. Failures requiring the crew to manually dock have been reported. The system makes contact with the Mir Complex at a range of approximately 200 km, with docking lock–on at 20 to 30 km. See Figure 8–8.

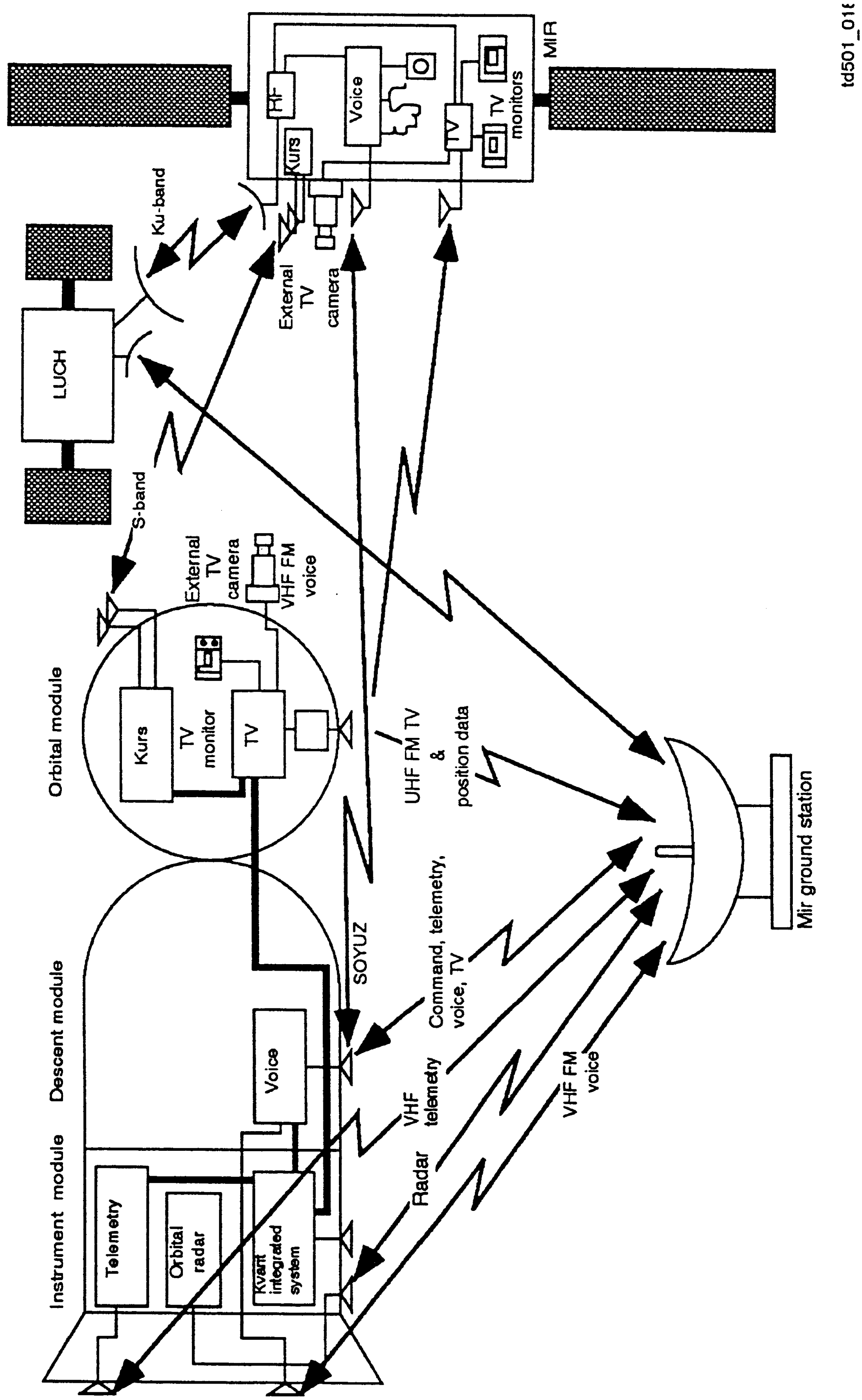


Figure 8-7. Communication pathways

Mir Complex

1 Soyuz-TM craft
2 Approach and rendezvous system (Igla) antenna
3 Mir work module
4 Rendezvous antenna
5 Telemetry antenna
6 Approach and rendezvous system (Igla) antenna
7 Transfer module
8 Luch relay satellite communications antenna (11/14 GHz)
9 Aft docking port, primarily for Progress resupply ferry craft
10 Docking target
11 Docking hatch
12 Transfer module
13 Station control consoles, provide access to the eight control computers
14 Multiple docking adapter, one aft docking port and four axial ports
15 Axial docking port

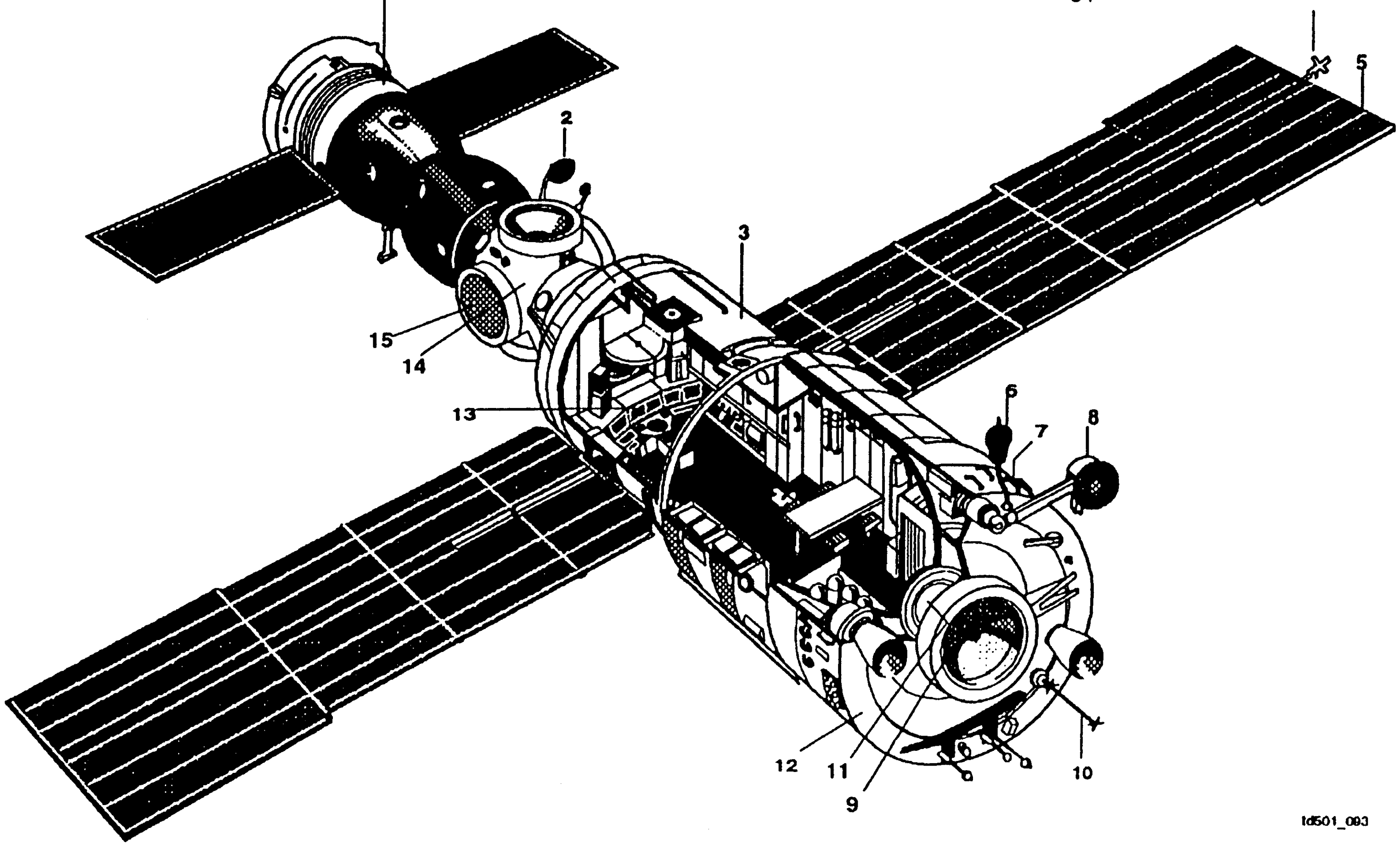


Figure 8–8. Mir Complex

The older Igla system required mutual maneuvering of both vehicles for docking, with the station adjusting attitude and the Soyuz –T adjusting altitude. With the improved Kurs system, the approaching Soyuz–TM adjusts both attitude and altitude, and the asymmetric Mir Complex holds position. An additional improvement of this system is that the Mir Complex does not have to provide radar information, which allows the Soyuz–TM to dock with a dead Mir Complex. The Kurs system provides rate and range information to the Soyuz–TM crew, an improvement over Igla. See Figure 8–9. The Kurs tracking system antennas consist of:

- 3 approach system omnidirectional antennas
- 1 approach system autotracking antenna
- 1 approach system high gain antenna
- 1 approach system pointing antenna

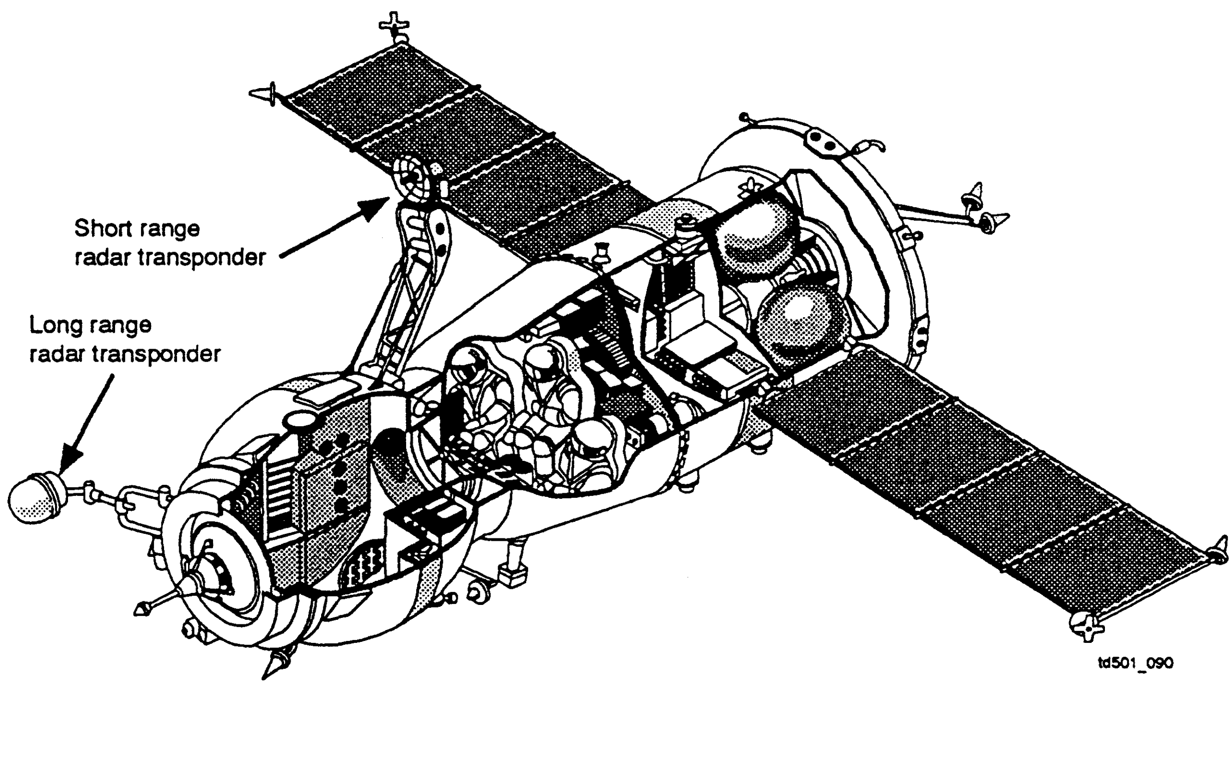


Figure 8–9. Soyuz–TM

Due to Mir docking system constraints, the Soyuz–TM will typically dock at the forward port of the Mir of the Mir Complex. The aft port is usually reserved for Progress docking.

While quiescently docked to the Mir and after the hard line is installed, normal operations monitoring of the Soyuz–TM is limited to a very small subset of the parameters, approximately 30 that are considered critical. This is considered the low data rate mode, and is routed through the Mir system.

Periodically, a high data rate mode is used, with approximately 1000 parameters being downloaded (256 kbps). This is accomplished only when a ground station is within view of the Mir Complex, since the Soyuz–TM telemetry system is activated to accomplish the high data rate. This rate is believed to be enabled once per day, for only a few minutes. Rationale given for using only low data rate nominally is that the Russian program has determined that is all that is required. However, due to power constraints from the Mir Complex, a more probable rationale may be that Mir Complex equipment operations must be sacrificed in order to receive the high data rate of the Soyuz–TM data.

c. Return

Once the Soyuz–TM departs the Mir Complex, the Soyuz–TM deorbits in the same manner as the shuttle, by performing a retrograde deorbit burn. During this portion, ground stations will still have two–way voice (Rassvet system), telemetry (BR-9CU-3 telemetry system), tracking (38G6), and uplink command capability (Kvant system). At approximately 32 minutes (140 km altitude) after the burn, the three modules separate in preparation for reentry. See Figure 8–10.

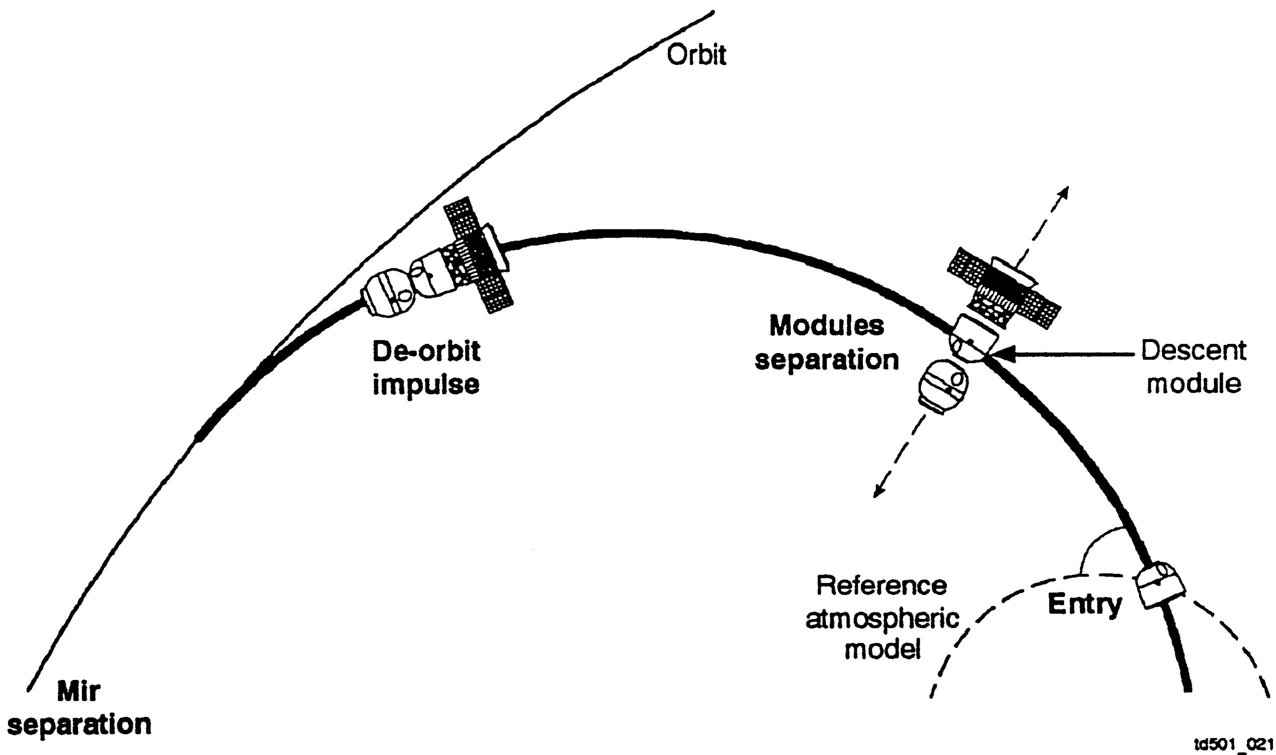


Figure 8–10. Descent module entry

After separation, a significant portion of the communication system is lost, since the telemetry, tracking, and uplink command equipment are contained within the Instrument Module. The only communication available is voice, since the Rassvet system is located in the Descent Module. See Figure 8–11.

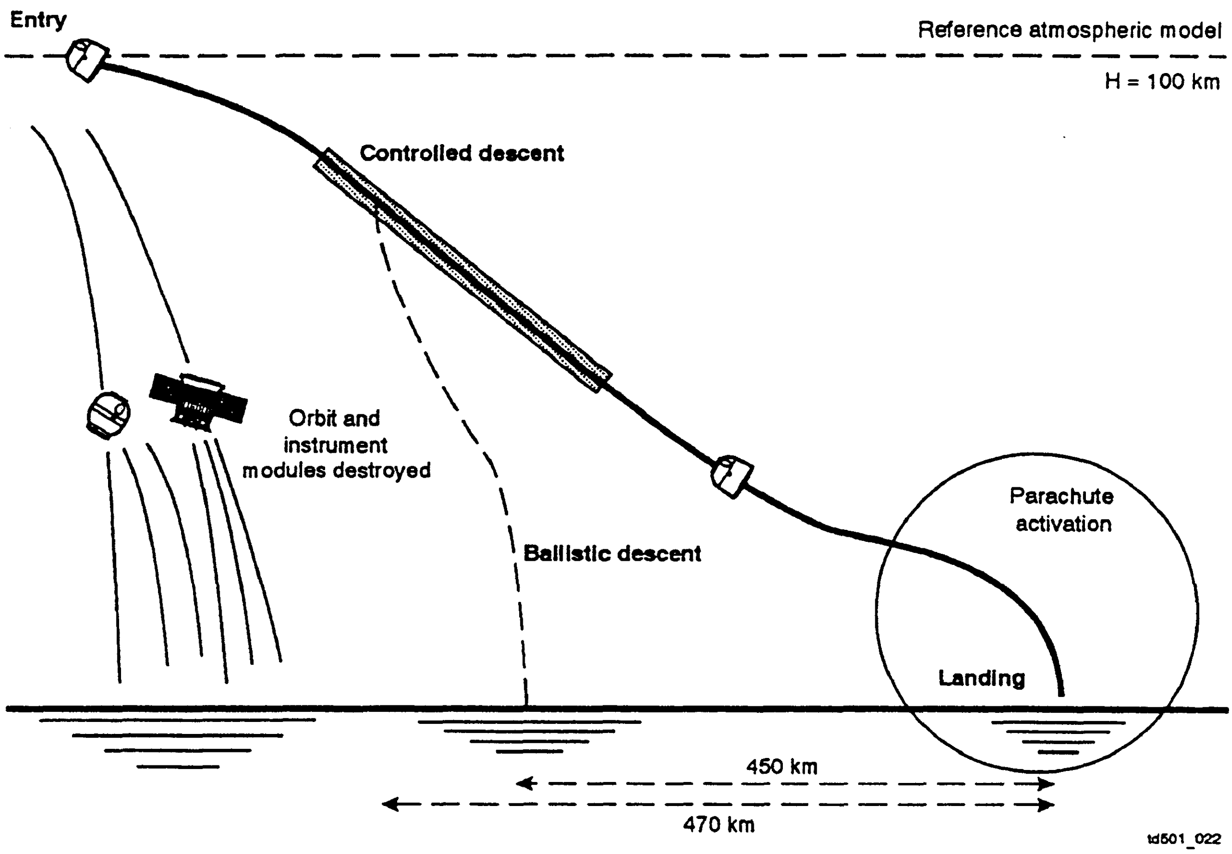


Figure 8–11. Descent module entry within atmosphere

As with the Shuttle, a communications blackout occurs during reentry. At some point during reentry, the Rassvet system initiates a beacon signal over the Rassvet voice channels. This beacon is for use by SAR Forces, and continues through landing. The crew can still have voice communication with SAR personnel, although probably not MCC–H personnel due to ground station limitations, by simply keying the microphone.

The Soyuz–TM also uses a radiation source–based altimeter located in the base of the descent module to determine altitude. The altimeter is used for activation of the descent rockets that brake the vehicle. Details about the altimeter are considered proprietary by the Russians.

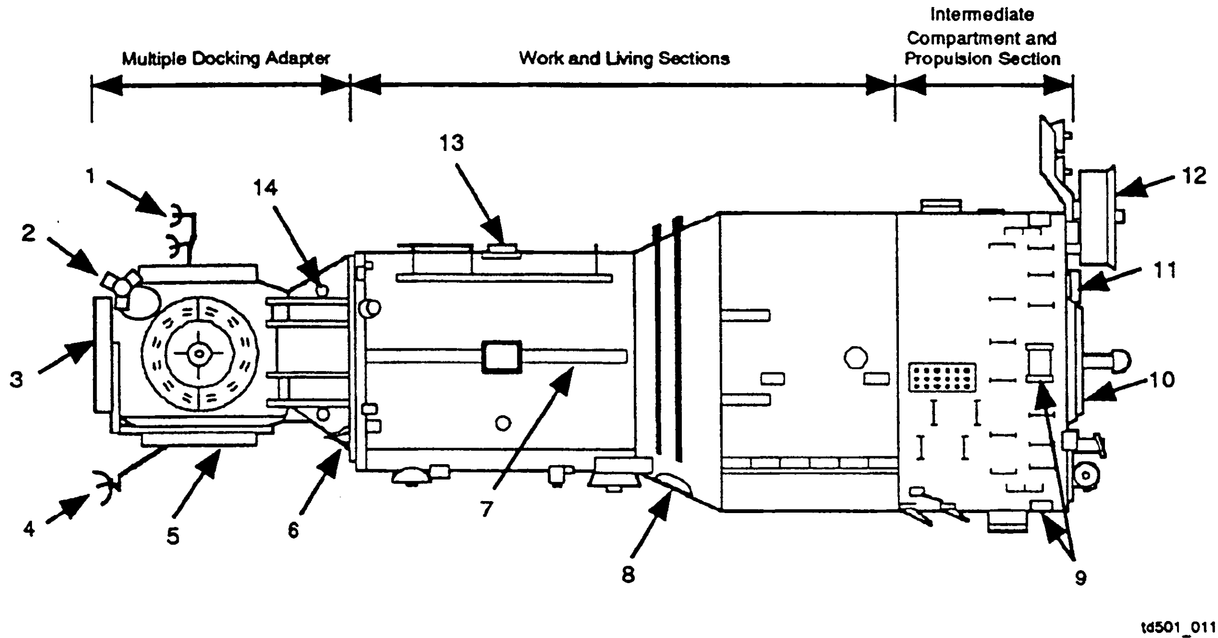
d. Post–landing

SAR Forces, while based in the target landing area, are not necessarily immediately available. The Soyuz–TM is equipped with a hand–held two–way radio for both voice and beacon communication with SAR Forces. If the crew remains inside the descent module, the hand–held can be interfaced with the Soyuz–TM antenna(s) through a patch panel. If the crew leaves the module, the hand–held radio has its own antenna.

8.4.2 Communication and Tracking System Description and Location

Many of the Mir capabilities are the same as its immediate predecessor, the Salyut station. Some improvements were made over Salyut, since the Mir is designed to be expanded. These improvements included docking system changes and replacing the Transfer Compartment with a Multiple Docking Adapter.

The forward docking port, located at the Multiple Docking Adapter, is equipped with the Kurs rendezvous system for Soyuz–TM docking (see Soyuz–TM description in previous section). The aft docking port is equipped with both the Kurs docking system and the older Igla docking system. The Igla system requires cooperative docking between the Mir and the approaching vehicle. The antennas that are located at the end of the Mir solar arrays are also part of the rendezvous system. See Figure 8–12.



1. Kurs rendezvous antenna
2. Manipulator grapple
3. Forward docking port
4. Kurs rendezvous antenna
5. Bottom docking port
6. Docking target
7. Solar array
8. Solar array
9. Attitude control thrusters
10. Aft docking port
11. Main engine
12. SDRN antenna
13. Solar array attach port
14. Port hole

Figure 8–12. Mir Complex

The forward portion of the Mir has a Multiple Docking Adapter fitted with grapple fixtures, with a total of five docking ports. Up to four expansion modules can be placed here and still allow Soyuz–TM docking. Rather than have five Kurs docking systems, and perform complex–hazardous docking, expansion modules are first docked to the Forward Docking Port. Through the use of the Liappa manipulator system (see Structures section), the module is then transferred (rotated) to the desired location, leaving the Forward Docking Port free for further docking operations. See Figure 8–13.

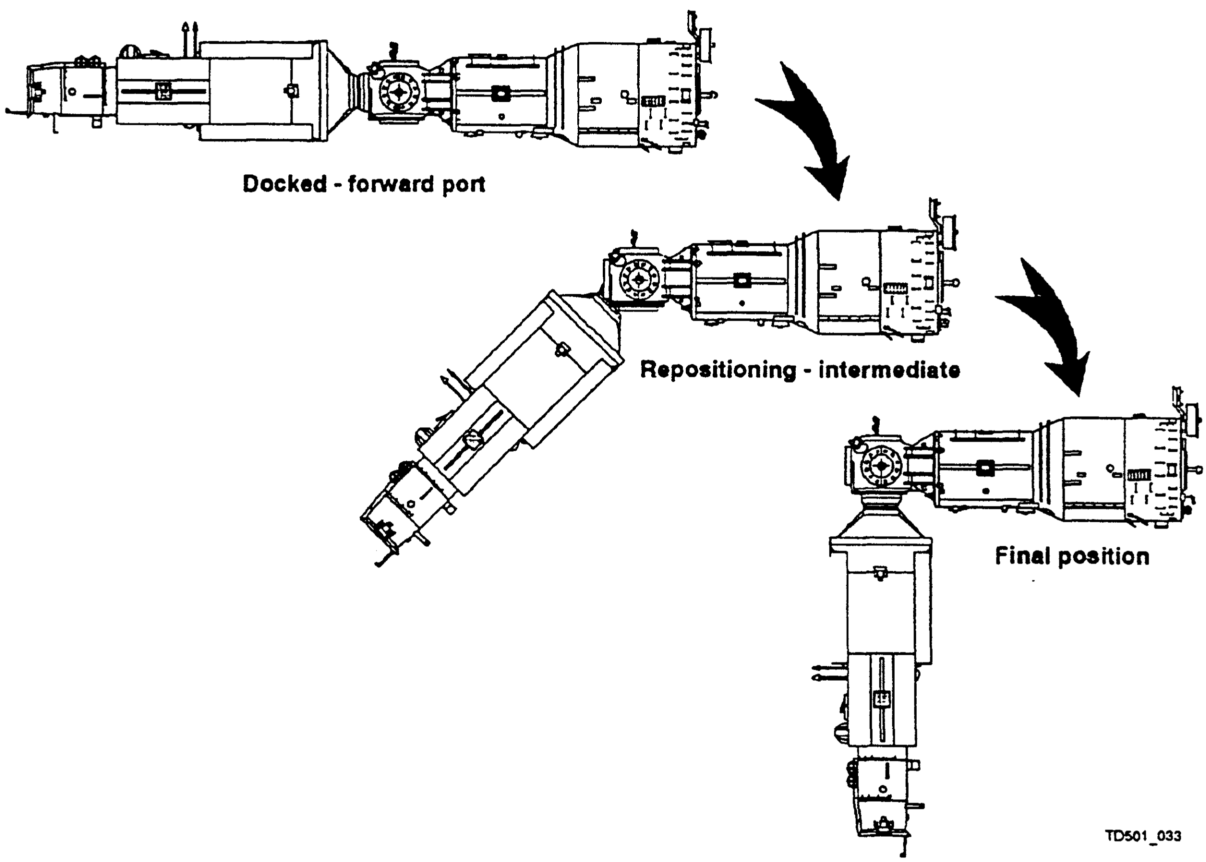
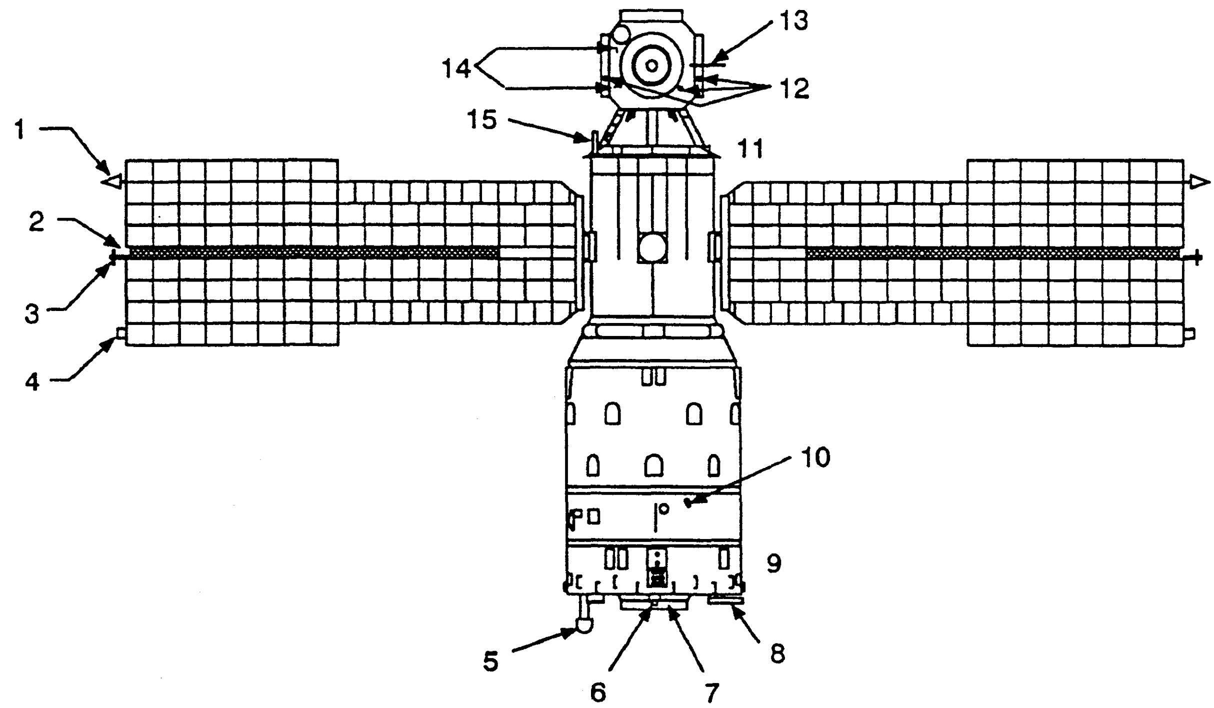


Figure 8–13. Expansion module repositioning

Also near the aft docking port is a small, Ku–band dish antenna (selectable for either 11 or 14 GHz), used to communicate with the Luch satellite, Altair. The Luch system has Ku–band capability, and provides functionality similar to that of a Tracking and Data Relay Satellite (TDRS). Currently, the Russian Space Agency (RSA) has only one available satellite in this system, which results in only limited orbital communications coverage.

At the time that Mir Complex was originally launched, communications was through a satellite located a 95° East and designated as Cosmos 1700. The Soviets announced that this satellite was for Luch; however, the nearest location that had been reserved for Luch was 90° East. The Cosmos 1700 occupied the location reserved for a Statsionar–14 (STDN) satellite. It is unclear if the Luch system is another designation for the STDN system.

Telemetry, voice, and TV from the Mir is believed to be available through both the Luch system and directly from ground stations. While docked to the Mir, data on expansion modules, "nominal" Soyuz–TM data and "nominal" Progress data are routed through the Mir Complex system. For high data rates from the Soyuz–TM and Progress, ground stations establish communication links directly with the C&T systems on the respective vehicle. See Figure 8–14.



1. Radio command antenna
2. Navigation light
   Port - Red
   Stb - Green
3. Rendezvous antenna
4. Rendezvous beacon
5. Rendezvous antenna
6. Rear axial docking unit
7. Highly directive "Luch" communications antenna
8. Attitude control thrusters
9. Radio telemetry communications antenna
10. Window
11. Lateral docking ports
12. Rendezvous antennas
13. Telemetry antenna
14. Docking target

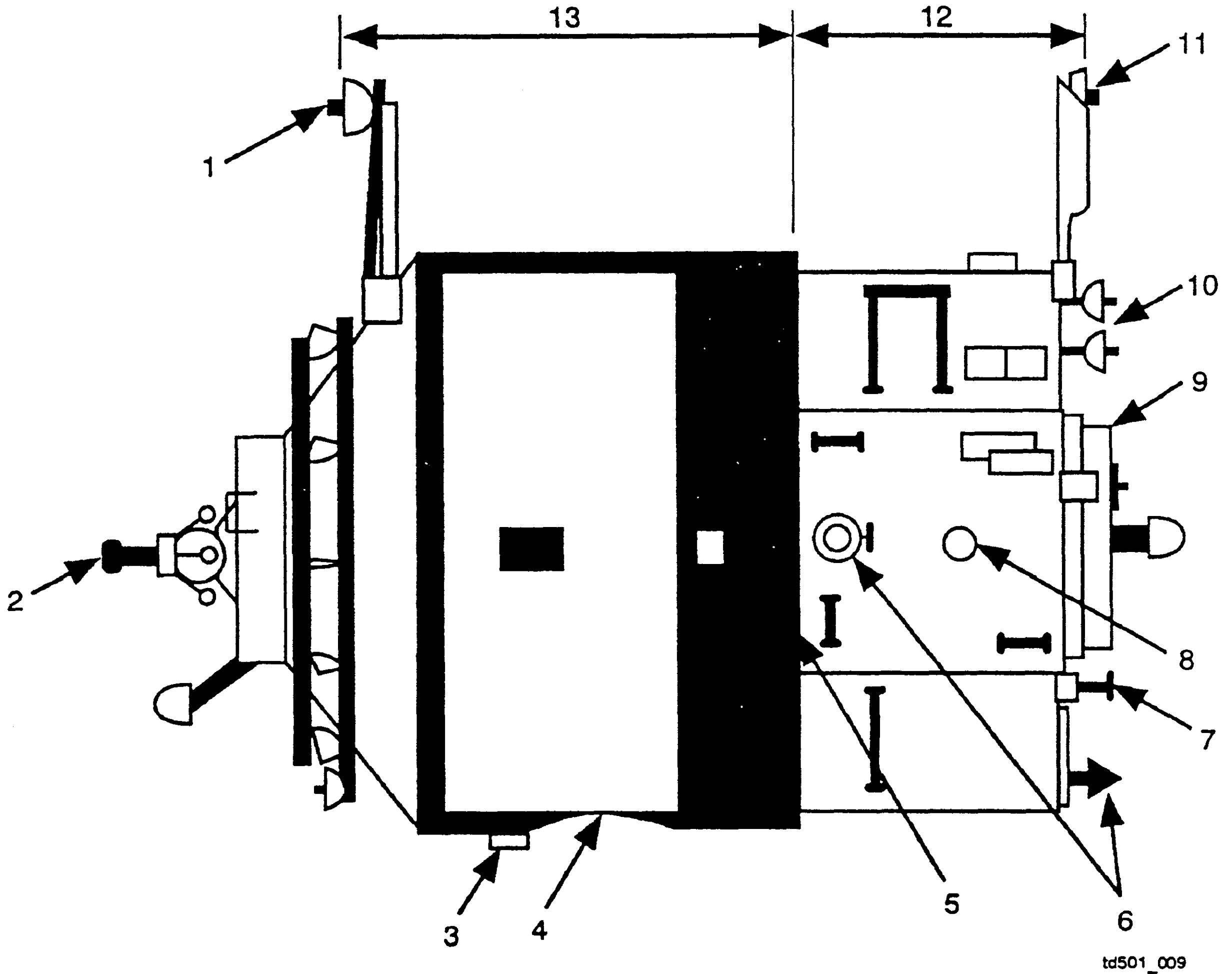
td501_032

Figure 8–14. Mir antenna locations

The Mir is also equipped with teleprinter capability. Detailed information about teleprinter operations is unavailable.

8.4.3 Kvant–1 Astrophysics Module C&T System Description and Location

The word Kvant, Russian for quantum, has been used for multiple applications in the Russian space program. In this context, it refers to the first expansion module, Kvant–1. Kvant–1 is also called Astrophysics Module. See Figure 8–15.



1. Igla docking antenna
2. Docking probe
3. Orientation device
4. Camera port
5. Launch shroud
6. Transponders
7. Docking target
8. Star tracker
9. Rear docking port
10. Kurs docking antennas
11. Igla docking antennas
12. Instrument section intermediate compartment
13. Work section

Figure 8–15. Kvant–1 module

The Kvant–1 module uses the Igla rendezvous system to dock with the Mir, and experienced difficulties during the original docking with the Mir. During the approach, at about 200 m the thrusters on the Kvant–1 failed to slow the vehicle and resulted in the Kvant–1 flying past the Mir. After 4 days, a second attempt was made at docking, but resulted in only a softdock, due to trash caught in the docking mechanism. A hard dock was achieved after removal of the material by an EVA crewmember.

The Kvant–1 is equipped to allow fluid (propellant) transfer between a docked Progress and the Mir. Presumably, the Kvant–1 is connected to the Mir computational system, and telemetry is routed through the Mir C&T system. Internal crew communication is also interconnected, but only limited data on the system is available. Reportedly, the system in general has similar capabilities to the Orbiter Audio Terminal Units (ATUs). See Figure 8–16.

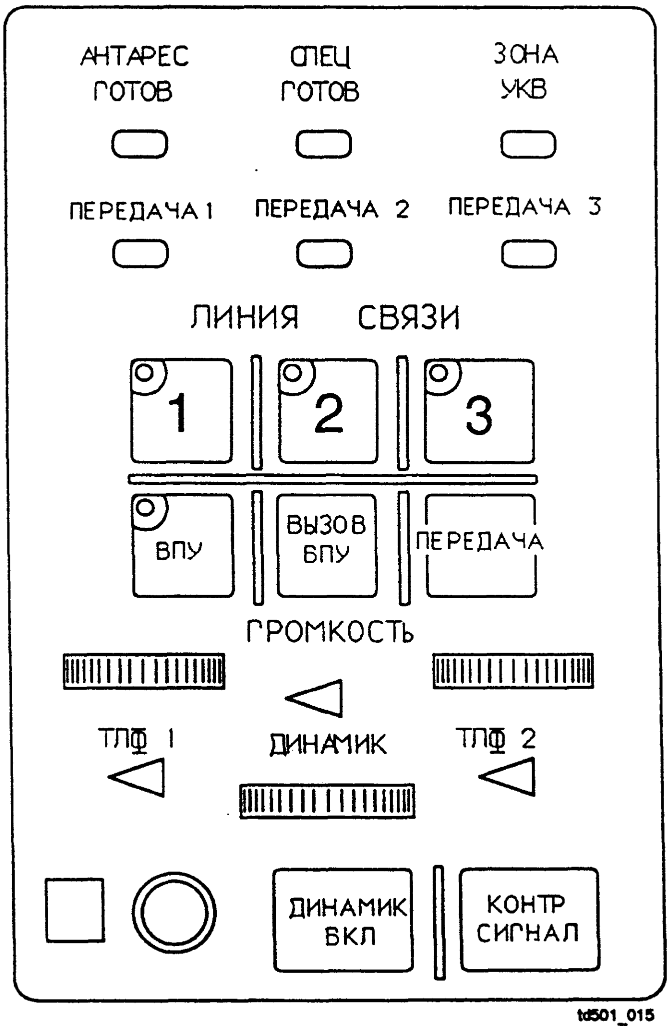


Figure 8–16. Panel

The stern of the Kvant–1 is equipped with a docking port, primarily used by Progress resupply ships. The port has both Kurs and Igla rendezvous systems, which potentially allows for another expansion module, a Progress or a Soyuz–TM to dock at that location.

8.4.4 Kvant–2 Scientific and Airlock Module C&T System Description and Location

The Kvant–2, also called D module and specialized module, is designed to provide additional EVA capability. The Kvant–2 docked at the forward port of the Mir Complex, with the Kurs docking system, and then was moved by the Liappa manipulator system to a radial port location. See Figures 8–17 and 8–18.

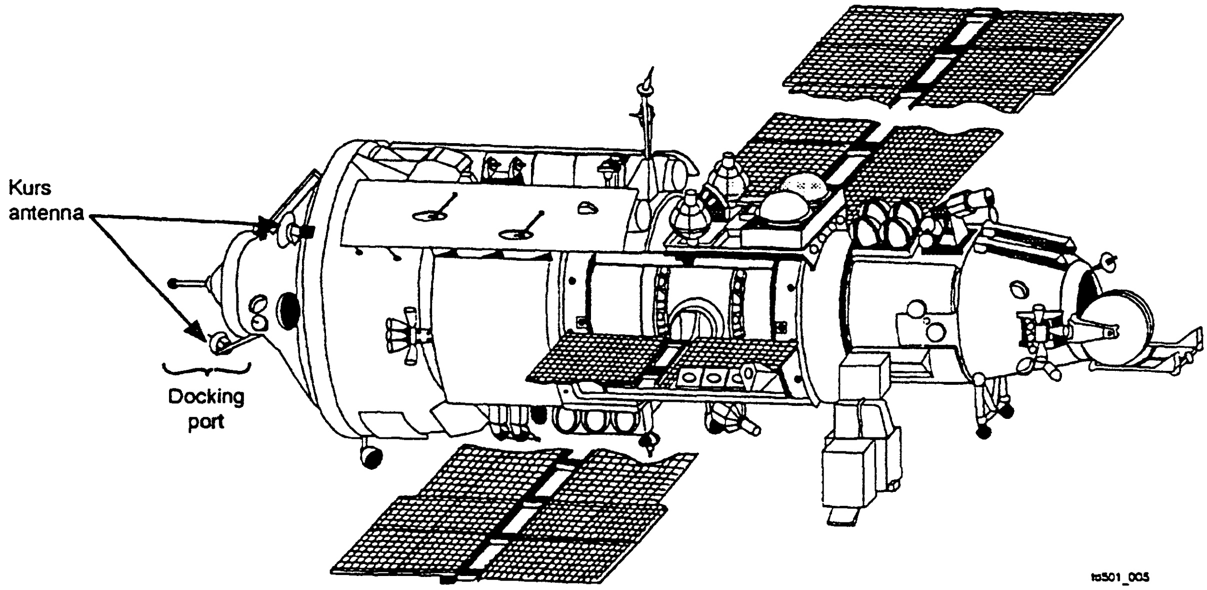


Figure 8–17. Kvant–2

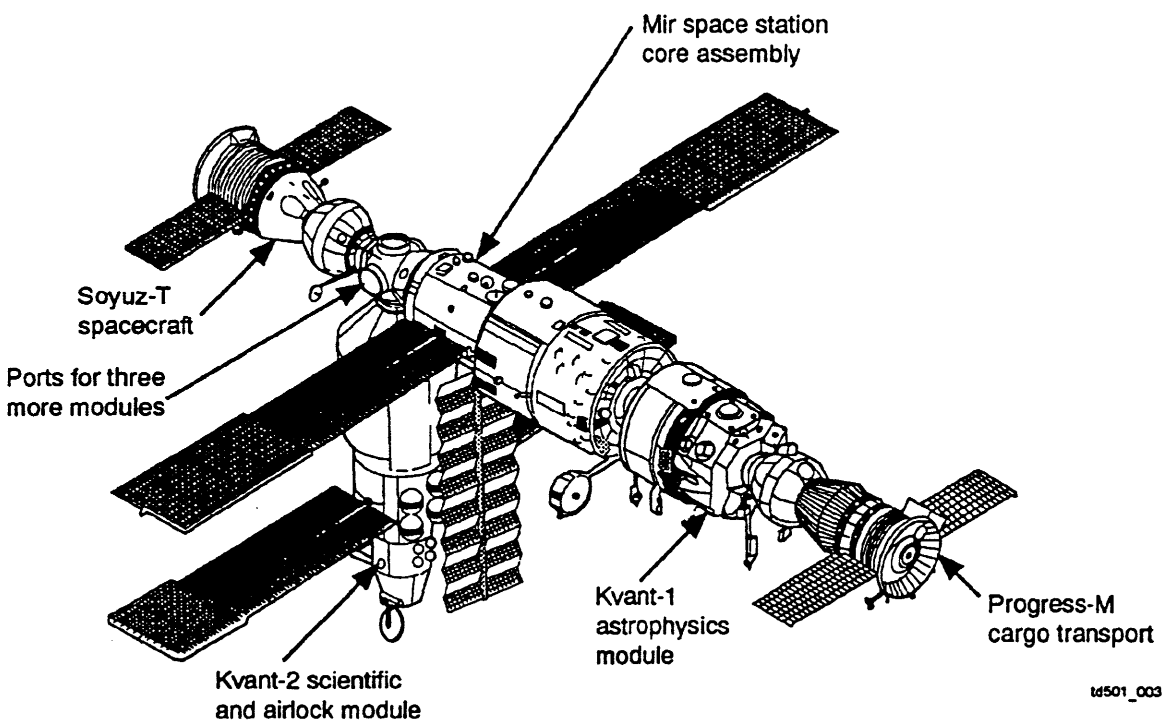


Figure 8–18. Kvant–2 in final position

As with the Kvant–1, limited other data on the Kvant–2 C&T system exists. References suggest that Kvant–2 data and voice are connected to the Mir system and routed through the Mir C&T system.

8.4.5 Kvant–3 Module C&T System Description and Location

The Kvant–3 (Kristall) module is outfitted with multiple docking ports at one end and a single port at the other end. The Kvant–3, also called Kristall, T module, and the specialized module, docked with the Mir at the forward port, using the Kurs rendezvous system. After docking, the Kvant–3 was moved to a radial port. See Figure 8–19.

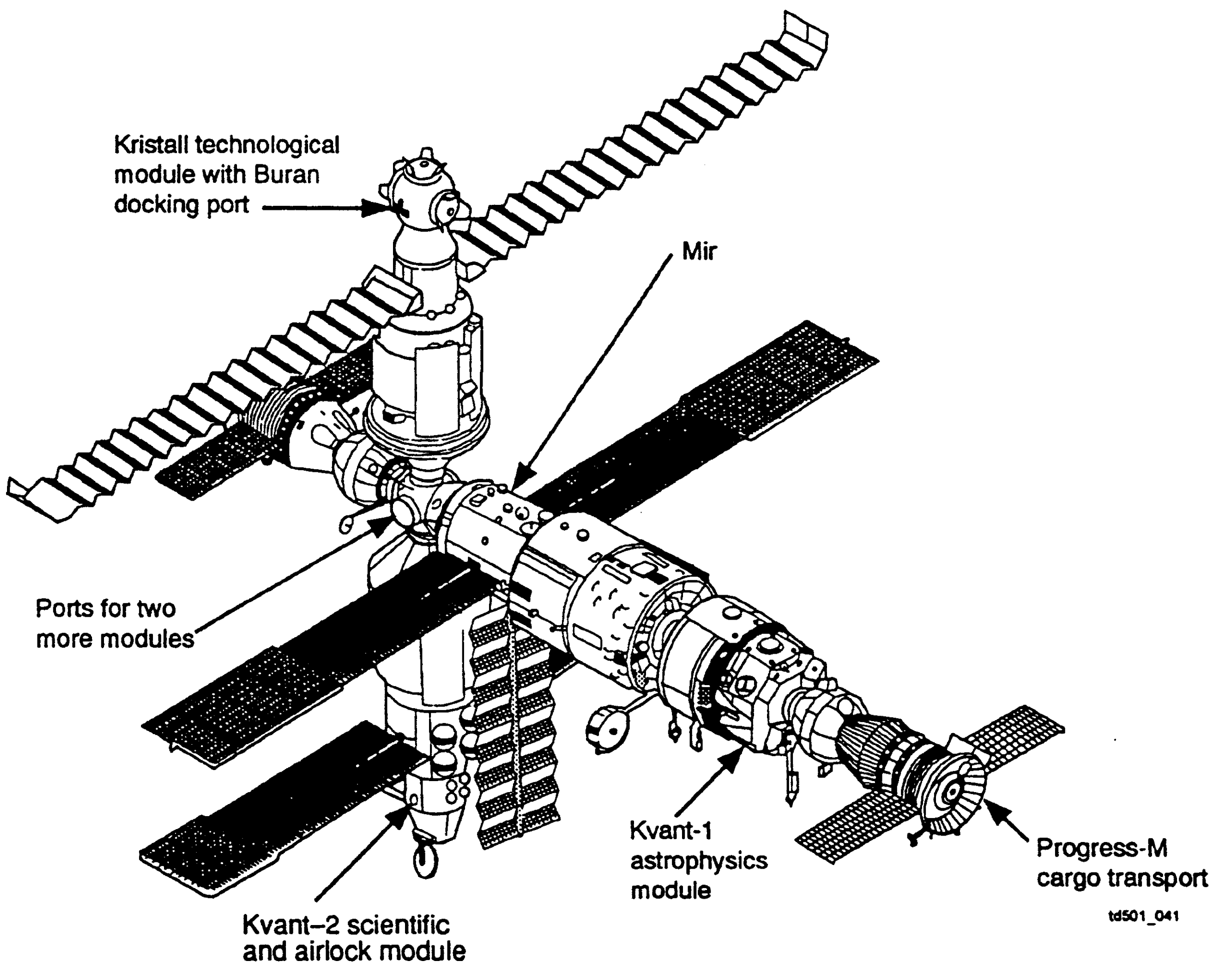


Figure 8–19. Mir Complex

The multiple docking port utilizes the APAS–89 androgynous docking mechanism system. Some figures of the Kvant–3 module have depicted three such mechanisms, one at the axial port, and one each at the two radial ports. However, the available technical descriptions state that there are only two APAS–89 docking mechanisms on Kvant–3, located at the radial locations. The APAS–89 system is the basis for the system to be used on the U.S. shuttle for docking with the Mir Complex. The APAS–89 system was designed for the Russian Shuttle, the Buran, to dock with the Mir Complex, an event that did not occur. See Figure 8–20.

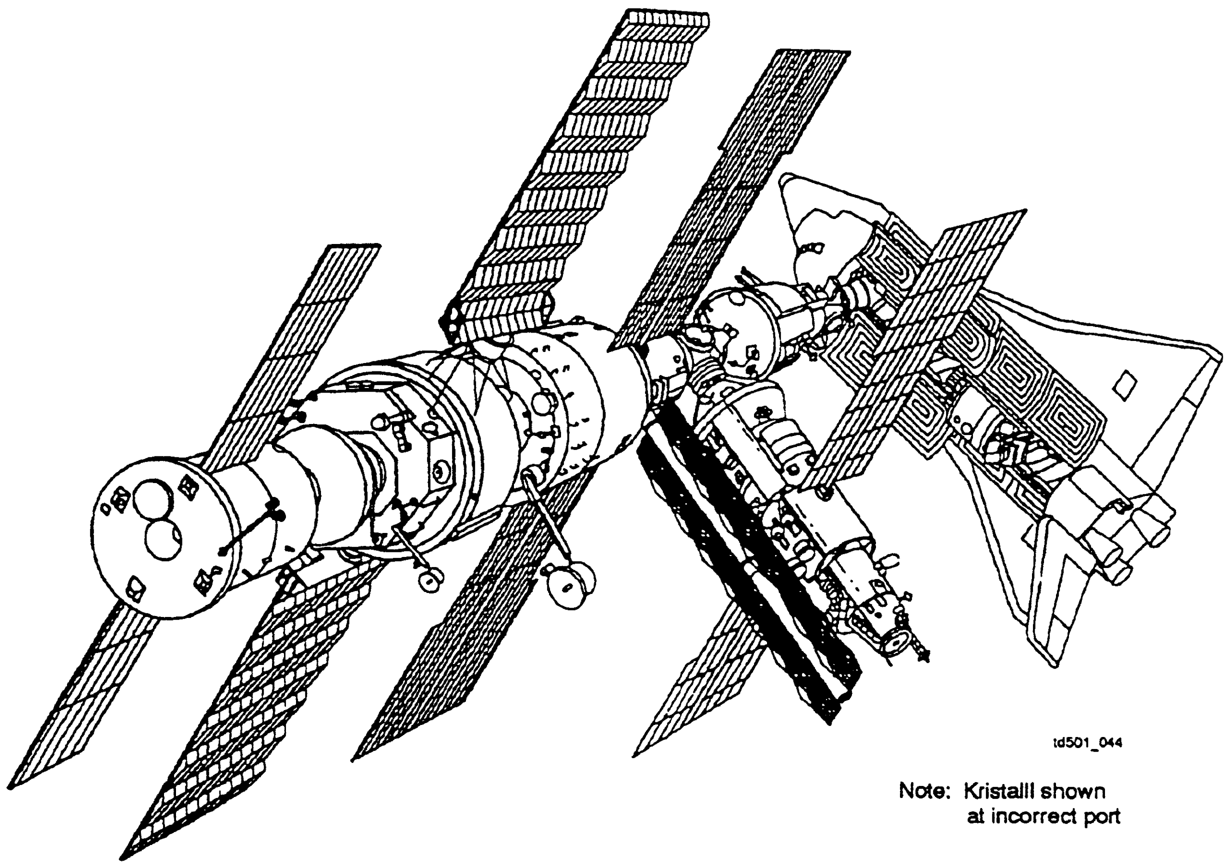


Figure 8–20. Buran docked with Mir Complex

8.4.6 Progress C&T Module C&T System Description and Location

The Progress vehicle was based on the same design as the Soyuz–TM, and shares a number of components. The design of the Progress was driven by the need for a resupply vehicle for the Salyut Station and Mir Complex. For unknown reasons, the designers decided that no return capability was needed, and the basic flight profile is to deorbit the Progress into the atmosphere for destruction. Since the original design, modifications were made to allow small payload return capability by use of a capsule inserted into the cargo section. When equipped in this fashion, the vehicle is designated as a Progress–M. The Progress–M designation has also been used to imply a modified Progress. See Figures 8–21 and 8–22.

The cargo section closely resembles the Orbital Module of the Soyuz–TM. The propellant section of the Progress takes the place of the Soyuz–TM Descent Module, and the instrument section is enlarged over that of the Soyuz–TM. The enlarged instrument section is required to contain the extra equipment needed for automatic docking, and the associated extra instrumentation required. The cargo section carries wet and dry cargo for removal by the crew after docking, and the propellant section is used to resupply the Mir with propellant.

Progress

This cutaway of the Progress resupply craft clearly shows its Soyuz derivation.

1 Short range radar transponder
2 Modified Soyuz orbital module with cargo for the Salyut crew
3 Long range radar transponder
4 Antenna
5 Soyuz instrument module
6 Soyuz KTDU-35 propulsion system
7 Equipment for the automatic control of Progress
8 Tanks for the propellant to be transferred to Salyut and nitrogen pressurant gas
9 Docking probe

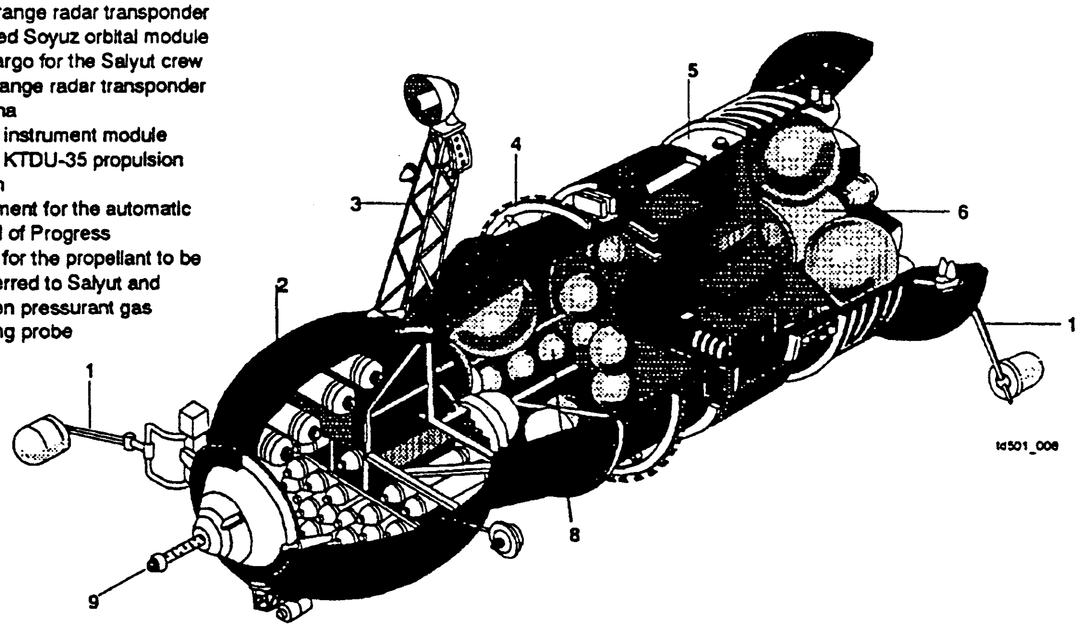


Figure 8–21. Progress

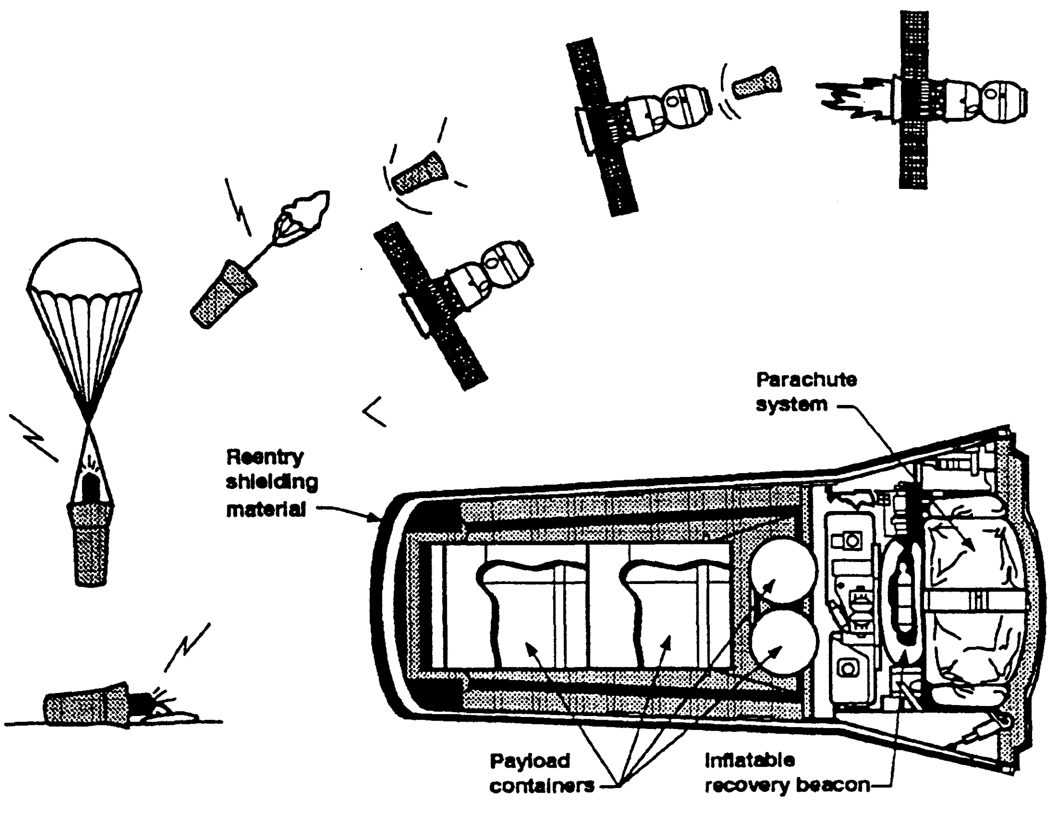


Figure 8–22. Progress recovery capsule

The Progress is equipped with an Igla rendezvous system, and always docks at the aft port of the Kvant–1. This location is the only port equipped with the propellant lines necessary for transferring the propellant from the Progress to the Mir.

Since the Progress is unmanned, the Progress has two cameras on the outside for use during docking, while the Soyuz–TM has just one. The two cameras are used by ground controllers to obtain a "stereo view" during the closing portion of docking, although the docking process is considered completely automated and the Russians reported a 100 percent success rate for docking. RSA has not supplied an updated success rate.

While docked, ground stations can establish a communications link directly with the Progress. Technical material suggests that Progress telemetry can also be passed to the Mir and routed through the Luch satellite.

After trash (waste, broken equipment, etc.), or in the case of the Progress–M, payloads have been loaded into the Progress, the vehicle undocks and transfers to a lower orbit. Usually after 2 days in free orbit, the MCC–M commands the Progress to deorbit once located over Russia, and burns up during reentry.

8.5 GROUND NETWORK AND INTERFACE TO MCC–M

The former Soviet Union had a substantial ground–based system for communications in support of their manned space program. This capability included a fleet of communications ships, with a presence in both the Atlantic and the Pacific oceans, and multiple ground tracking stations. Mobile communications trucks have been reported but not substantiated for manned space support, and insider reports state that none existed except as plans. See Figure 8–23.

At the present time, the ground–based capability of RSA is substantially less than that of the former Soviet Union. Six ground tracking stations, all within Russia, are currently used. RSA owned one additional ground station, which was located in the Ukraine, but has sold this station. RSA either sold or never owned the communications ship fleet and does not have access to this capability. See Figure 8–24.

The current ground tracking stations are:

- Ussurisk
- Petropavlovsk–Kamchatskiy
- Ulan–ude
- Dzhusaly (Jusaly)
- Yavpatoriya
- Tbilisi
- Zvenigorod

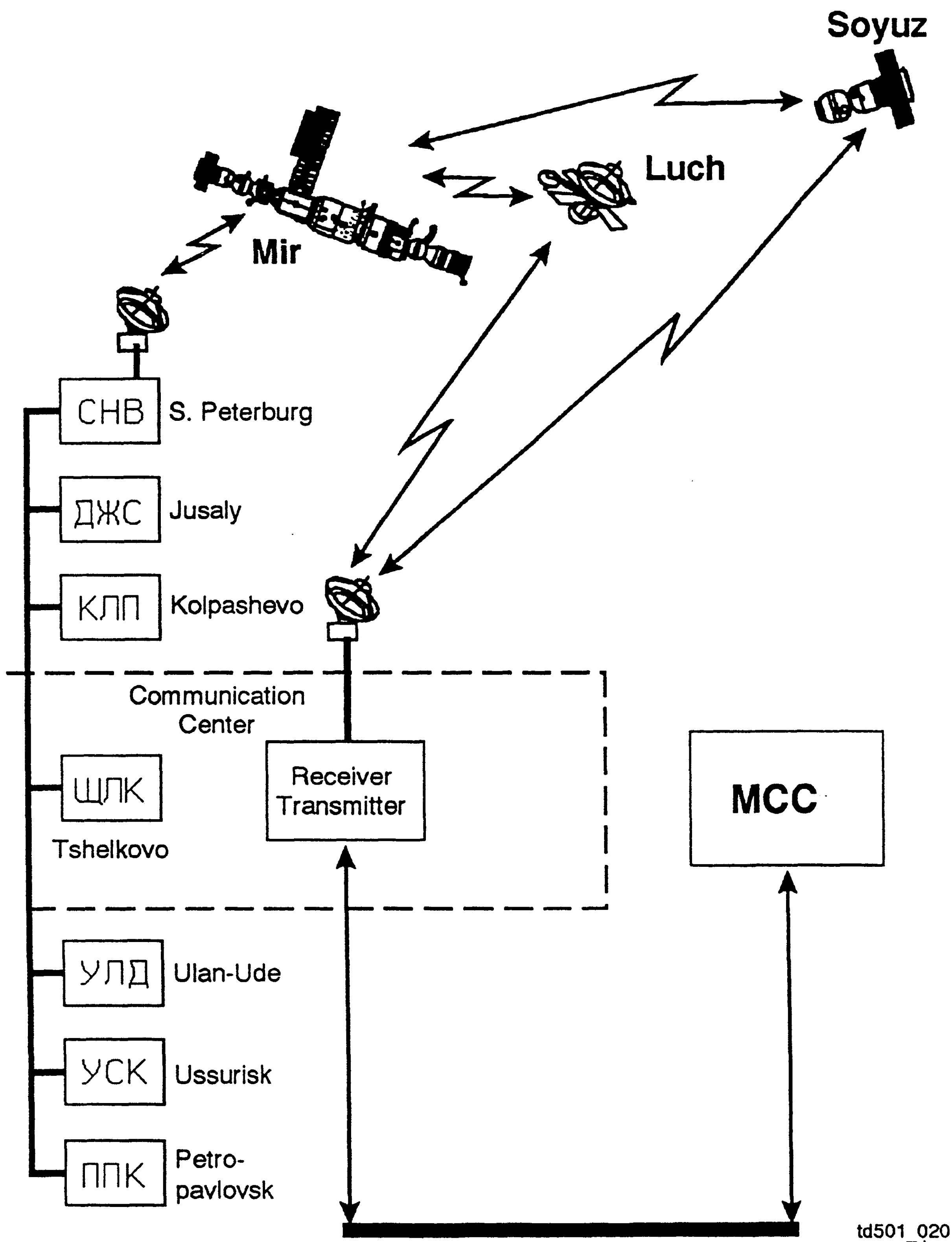


Figure 8–23. Telemetry pathways

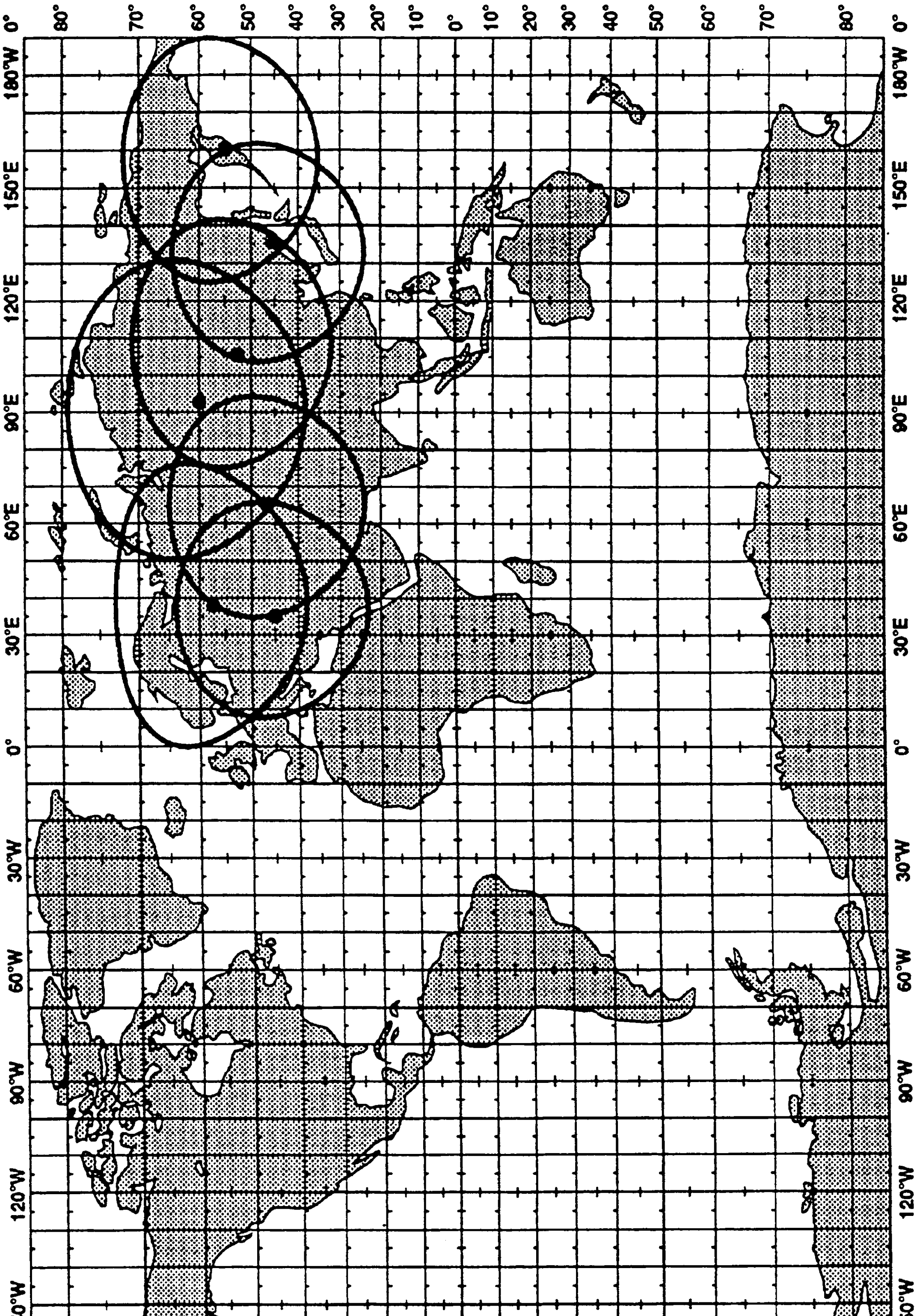


Figure 8–24. Ground site coverage

RSA currently has use of the one Luch (Russian for beam) satellite, called Altair, and has stated plans for placing a second upgraded Luch satellite in orbit some time in 1996. This currently limited satellite capability requires reliance on ground tracking stations. Ground stations typically provide between 5 and 25 minutes of communications per orbit for orbits that pass within coverage range. After the vehicle passes east of the site coverage, there are long periods of LOS (about four orbits, which are approximately 6–7 hours), an event that occurs very day. The Luch system and the Mir Complex currently is not compatible with the TDRSS.

8.6 C&T SYSTEM SUMMARY

The C&T systems used to support Mir Complex operations have functional similarities to that used in the U.S. Shuttle program. Current RSA/Mir Complex operational capabilities are, however, significantly less than that of the U.S.

Significant constraints exist on the Mir Complex communications system, due to reliance on ground stations and their line of sight requirements.

The incremental build strategy used by the Soviets resulted in communications systems that have remained stable and are reused on multiple vehicles in different programs.

QUESTIONS

1. The Mir Complex communications system uses a distributed, integrated architecture that shares components between elements.

   a. True

   b. False

3. The Mir Complex S–band can be configured to utilize the TDRSS satellite constellation.

   a. True

   b. False

4. Mir Complex tracking is accomplished by using the Russian equivalent to the Global Positioning System/Satellite.

   a. True

   b. False

5. The MCC–M normally commands directly to the Mir Complex through the Black Sea communications ship system.

   a. True

   b. False

6. Communications of voice and data

   a. Exists constantly, except for some minor ZOE dropouts

   b. Occurs once a day, for about 35 minutes

   c. Varies depending on available satellite time

   d. Is sporadic, compared to shuttle, and is about a few hours a day

   e. c. and d.

   f. b. and c.

7. The telemetry (up and down) for the Mir Complex is

   a. Small compared to Shuttle

   b. Equivalent to Shuttle

   c. Larger than Shuttle, due to the number of elements

   d. Based on a very different operations strategy than the U.S. uses

   e. c. and d.

   f. a. and d.

SECTION 9
GUIDANCE NAVIGATION AND CONTROL SYSTEMS

9.1 PERFORMANCE OBJECTIVES

By the end of this section, the reader should be able to:

- Identify the function of the GN&C system
- Describe the capabilities and constraints of the GN&C system
- Describe the GN&C system interfaces to other Mir Complex systems
- Briefly describe any similarities/differences between this system and the equivalent U.S. Space Shuttle/Station systems

9.2 INTRODUCTION

The GN&C of the Mir Complex is provided by the Motion Control and Navigation System (MCNS). This subsystem is responsible for ensuring long term maintenance of the orbit, accurate pointing information for the solar arrays, communications equipment and payloads, and stability about a given coordinate system.

9.3 FUNCTIONS OF THE MIR COMPLEX GN&C SYSTEM

The orbital altitude of the Mir Complex varies between 300 and 400 km (160 to 215 nautical miles), with an orbital period of 90.3 to 93.4 minutes at a 51.6° inclination. The preferred orientation is a gravity gradient stabilized mode, with the longitudinal axis of the Mir perpendicular to the surface of the Earth. Other orientations are frequently used and can be commanded by the crew, the ground or automatically, using onboard software.

The components of the MCNS and the ODCC are capable of maintaining the orientation of the Mir Complex within 1.5° during the normal mode of control and between 1 and 15 arc minutes using the.exact control mode. The subsystem seeks to optimize the use of fuels, hence the two modes of operation.

9.4 DESCRIPTION OF THE GN&C SYSTEM

Each of the modules on the Mir Complex was intended to be capable of providing its own orbit maintenance, and thus are equipped with components of the navigation and propulsion systems. This provides the Mir Complex with a great degree of redundancy, both with hardware and software functions. Overall coordination is provided by the ODCC. Information from all sensors and commands to all effectors are normally routed to/from the central computer in the Mir. Figures 9–1 through 9–4 show locations of some of the GN&C sensors and effectors; note the variation in nomenclature for the various instruments.

1 Solar battery rotation drive
2 Devices and equipment of service systems
3 Orientation system engines
4 Central control post
5 Gyro plate
6 Mating unit

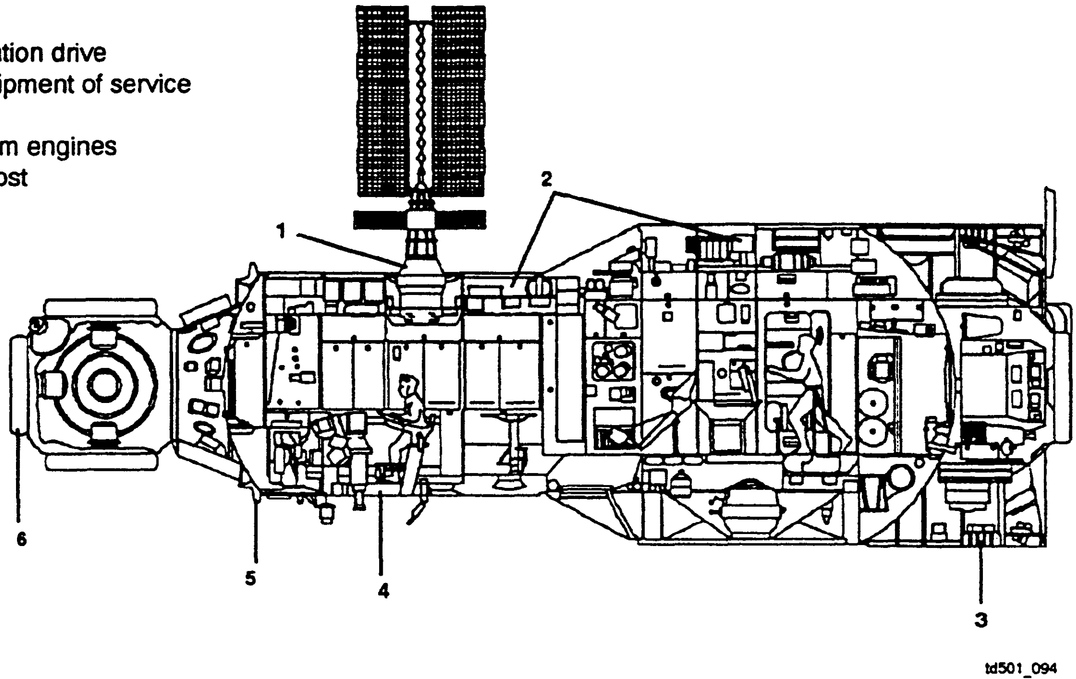


Figure 9–1. Base unit of the Mir Complex (longitudinal section)

1 Equipment of movement module
2 Gyrodynes
3 "Igla" radiotechnical mating system
4 Onboard complex control system unit
5 Active mating assembly
6 Control station
7 Optical unit of infrared vertical
8 Unit of "Pulsar" sensors
9 "Glazar" telescope
10 "Siren" spectrometer
11 Passive mating assembly
12 Magnetometer
13 "Kurs" radiotechnical mating system

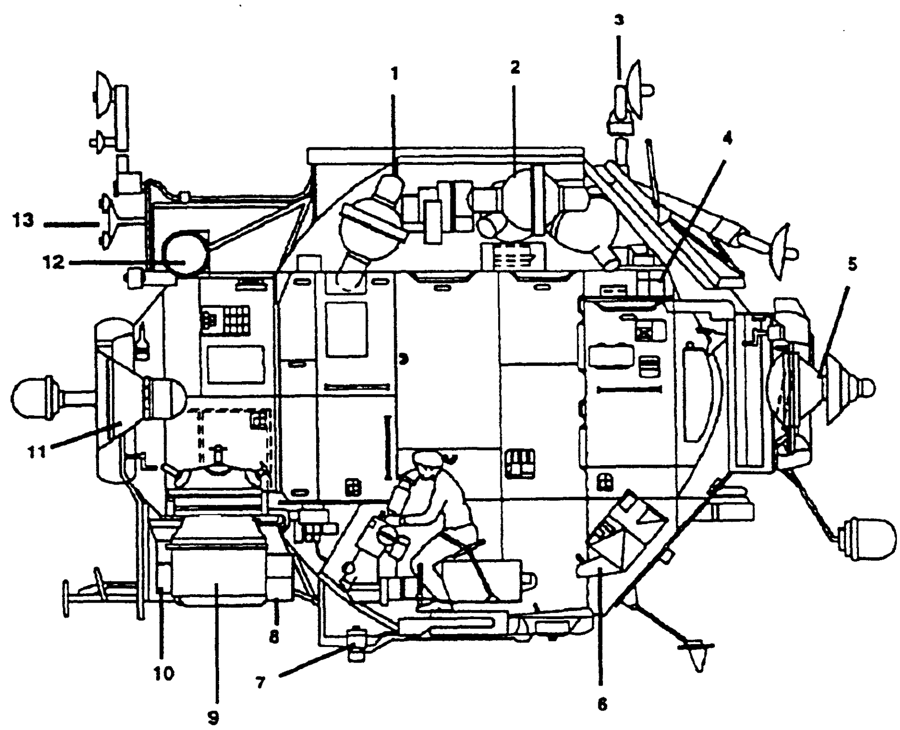


Figure 9–2. Kvant–1 astrophysical module (longituidnal section)

1 Active docking unit
2 Engine installation
3 Power stabilizers of liquid fuel by hydrogenation
4 Tank systems RODNIK
5 Cosmonaut motion equipment
6 Control post

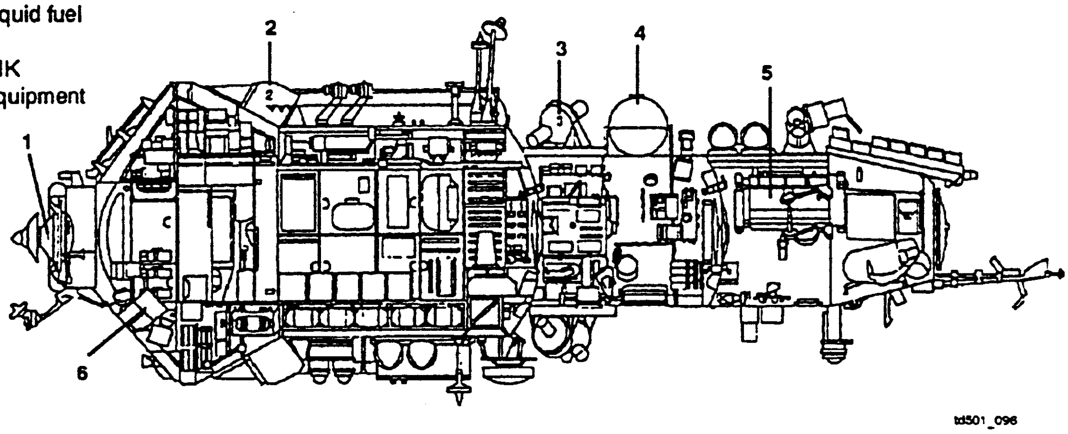
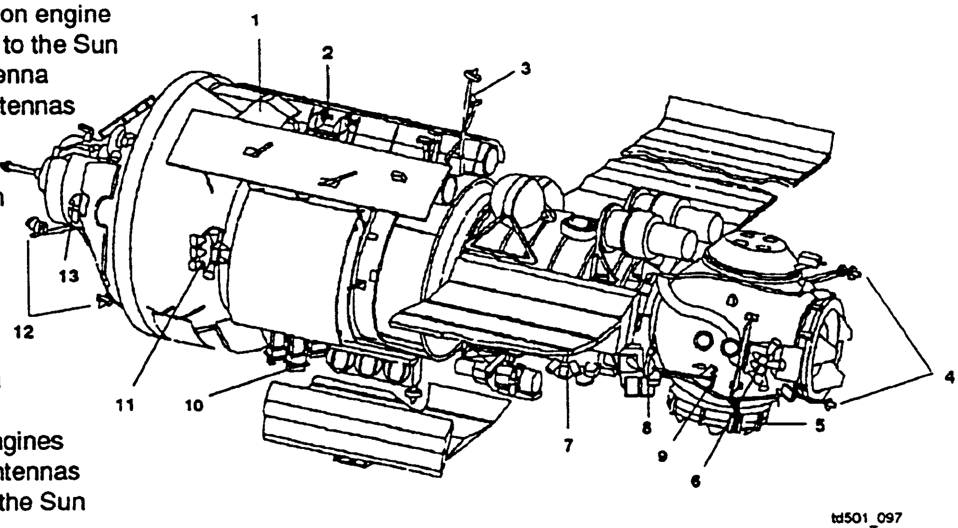


Figure 9–3. Kvant–2 module

1 Correction and stabilization engine
2 Instrument of orientation to the Sun
3 Command radio line antenna
4 "Kurs" mating system antennas
5 Androgine peripherical assembly of mating
6 Mooring and stabilization engines
7 "Kseniya" equipment
8 "Marina" equipment
9 Bench mark device of mating and hovering
10 Instrument of orientation to the Earth
11 Accurate stabilization engines
12 "Kurs" mating system antennas
13 Sensor of orientation to the Sun



Start - June 1, 1990
Mating with "Mir" orbital station - June 10, 1990

Figure 9–4. Kristall technological module

9.4.1 GN&C Sensors

The Mir Complex uses a combination of optical, magnetic, and infrared sensors to provide accurate orientation determination. The precise number and locations of the sensors is difficult to determine from available documentation; however, a brief description of each of the types of sensors is given below.

Infrared Sensor – Measures thermal radiation from the Earth, scanning the horizon to determine station attitude. These sensors (there appears to be at least one on several of the modules) are used to sense and correct deviations from local vertical.

Solar Sensor – Measures two angular coordinates of the Sun with respect to the sensor's internal coordinate system. Data is passed on to the ODCC to determine the angular coordinates of the Sun with respect to the coordinate system currently being used on the Station.

Star Sensor – Measures the angular coordinates of a predetermined star with respect to the sensor's internal coordinate system. The ODCC uses this data to determine the angular coordinates of that star to the currently used Station coordinate system.

Solar Threshold Photometer – Also known as an eclipse sensor, measures the presence of insolation by determining when the solar flux is equal to or greater than 6000 lux. If the intensity of insolation is less than 6000 lux, the Station is assumed to be in Earth's shadow.

Sextant – Measures the angular orientation of the Station with respect to known star systems during any portion of the orbit. The output is used to determine Station location and orientation. The sextant is the only sensor identified to have both automatic as well as manual modes of operation.

Magnetometer – Measures the intensity of the Earth's magnetic field as a vector of field strength projected along each of the sensors own axes. The position of the Station's axes can be determined from this measurement.

Gyroscopic Instruments – Measure projections of absolute angular velocity. These devices are hard–mounted and the measurements have components along each of the Station's orthogonal axes.

Accelerometer units – Measures linear and rate accelerations along the three orthogonal axes of the Station. These accelerations are used by the ODCC to provide motion control. It is also assumed that these devices are hard–mounted.

9.4.2 GN&C Effectors

Orbit and altitude corrections for the Mir were initially provided by two main thrusters and 32 attitude control thrusters, respectively. However, with the docking of the Kvant–1 module to the Mir, the use of the two main thrusters is prohibited. (They are located on the annular portion around the docking cone between the Mir and the Kvant–1.) Because it is desirable to minimize the use of fuels for maintaining orientations, the Mir Complex now uses a combination of gyrodynes, attitude control thrusters, and "corrective jet engines".

Jet Engines – Provide a thrust of 300 kg each and are used for maintaining altitude. There are two engines, and each can be gimbaled ±5°. Current information indicates that these engines are actually located on the Soyuz–TM and/or Progress vehicles.

Attitude Control Thrusters – Provide a thrust of 14 kg each and are used for pitch, roll and yaw maneuvers. There are 32 thrusters on each of the following modules: Mir, Kvant–1, Kvant–2, and Kristall. The thrusters and the engines use the same fuel, which appears to be a form of hydrazine. Fuel can be supplied from the Progress to any of the modules' storage tanks via plumbing that is routed throughout the complex.

Gyrodynes – Provide the primary means of momentum management. Gyrodynes are arranged in groups of six; there appears to be a group on each of the modules. Each gyrodyne is a single gimbal gyroscope, hard–mounted into a case along its horizontal axis. The precession axis is in the gyrodyne's vertical axis and is fixed with respect to the module's axes. Each gyrodyne can provide a moment of momentum equal to 1000 Nms and a torque equal to 200 Nm.

The gyrodynes provide the majority of the Mir Complex attitude control, thereby reducing the amount of propellant used. Thrusters are primarily used in the event that the gyrodynes become saturated. Saturation of a gyrodyne implies that the external torques on the Mir Complex have exceeded the ability of the gyrodyne; the gimbal has reached a limit in which it can no longer transfer its internal momentum to the Mir Complex. The thrusters can then be used to adjust the orientation of the Mir Complex, and the gimbals can be reset. Figure 9–4 shows a block diagram of a gyrodyne and Figure 9–5 shows a cutaway view of it. It should be noted that the gyrodyne uses an 8–pole magnetic bearing system for the rotor. The control moment of the gyrodyne is transmitted directly to the body of the station through the rotor bearings.

9.4.3 GN&C Hardware/Software Operations

Data from the sensors are fed to the ODCC where processing occurs. Signals from some of the sensors, specifically the gyroscopic instruments and the accelerometer units, are pre–processed in a peripheral computer prior to being sent to the ODCC. Some reference information suggests that there are redundant paths for data to be passed between the sensors/effectors and the ODCC.

Programs resident in the ODCC maintain the desired orientation mode for the Mir Complex. The orientation modes appear to be commanded from the ground, then executed by the onboard system. There is no information available at this time on the types of algorithms used for achieving or maintaining orientations.

It is known, however, that within the ODCC there is a back–up set of computers, operating on a separate loop, which can perform limited GN&C functions should the primary loop be lost.

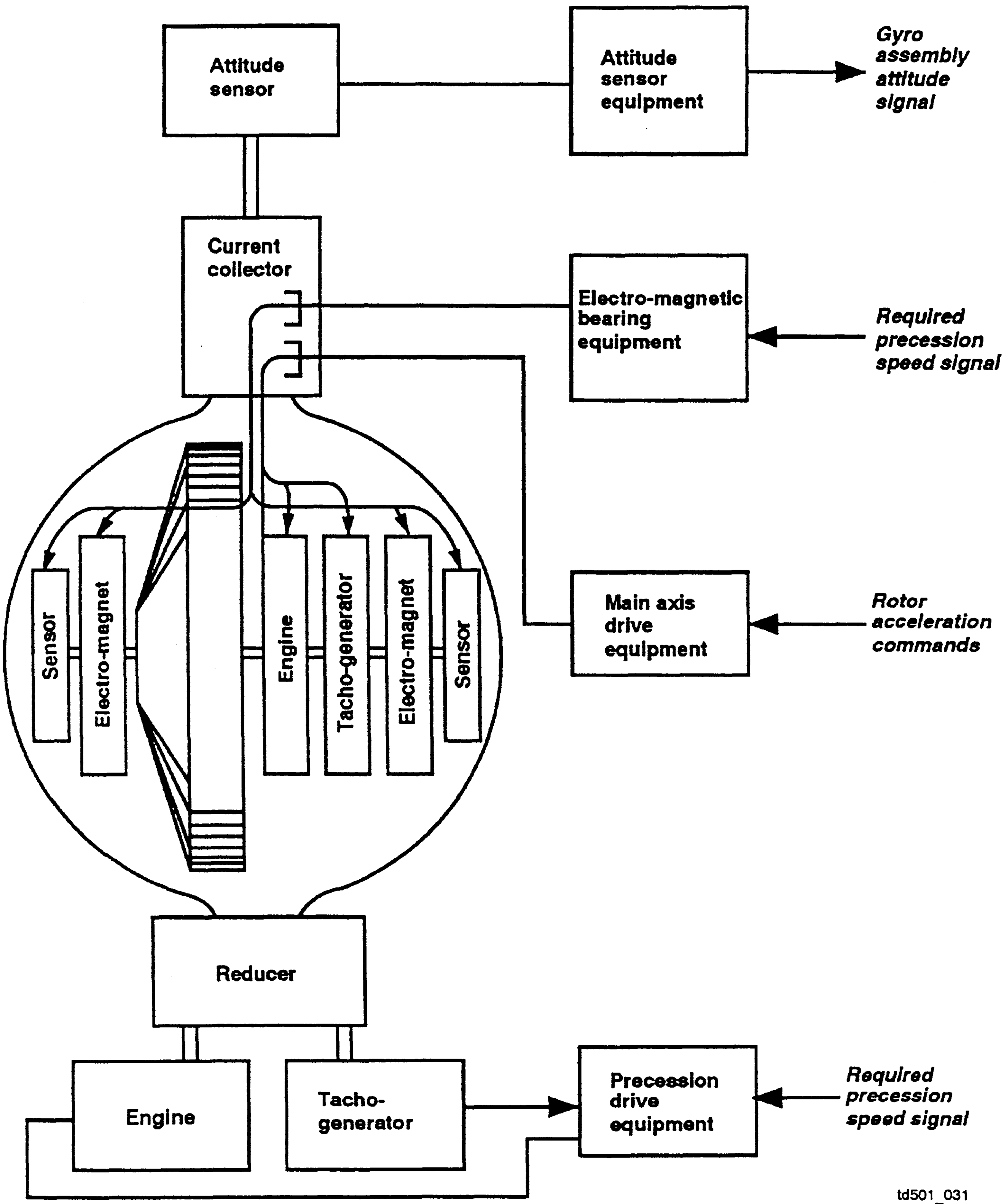


Figure 9–5. Gyrodyne block diagram

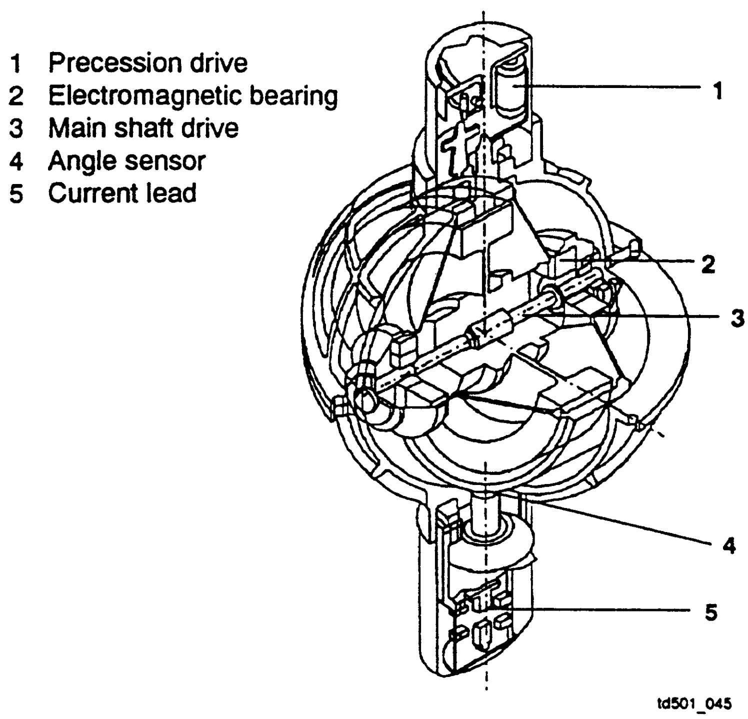


Figure 9–6. Cutaway of gyrodyne electromechanical unit

9.4.4 GN&C Modes of Operation

All attitude maintenance, correction and change procedures can be managed either from the ground, automatically using the onboard computer complex or with some crew interaction. The Mir Complex can be manually flown, although this mode of operation is relatively rare. Even for docking operations, the Mir Complex is automatically oriented to provide illumination on the port where docking will occur; the remainder of the docking maneuvers are performed by the approaching spacecraft in concert with the docking system on the complex's port.

The Mir Complex uses a variety of coordinate systems. These are briefly described below:

Orbital – One axis is oriented to local vertical (normally, this means perpendicular to the surface of the Earth), the second is in the direction of motion, and the third completes the orthogonal set. This represents the gravity gradient orientation.

Geocentric inertial equatorial – Two axes are in the plane of the equator, with one being oriented along the vernal equinox line. The third axis is directed toward the north pole.

Solar – One axis is oriented towards the Sun; the other axes are arbitrary.

Magnetic – One axis is oriented along the magnetic meridian with the second axis pointed towards the Earth's center.

On the other space object – This orients one axis toward an approaching spacecraft. It is assumed that this orientation presents the docking port to the spacecraft.

Arbitrary turns – Orients the axes of the Mir Complex to predetermined angles with respect to any given reference system.

The multiple pre–defined coordinate systems allow the Mir Complex to operate in various different modes for orientation and velocity management.

9.5 GN&C SYSTEM CAPABILITIES AND CONSTRAINTS

9.5.1 Known Capabilities of the GN&C

As mentioned previously, the GN&C system is capable of providing stable orientations to within 1 minute of arc. The system exhibits tremendous redundancy, so losses of a single sensor or effector do not appear to cause interruptions in the functioning of the system.

One of the objectives of the ODCC programs is to conserve fuel. It has been stated that the Mir Complex has been able to meet this objective by using the gyrodynes to provide corrections to attitude. The single–gimbal gyrodynes are supplied in sets of six, and are reported to have a high–precision life–time of 5 years. The gyrodynes also boast low energy consumption (90 W during low rate turning increments) and relatively low weight (approximately 165 kg each).

9.6 GN&C SYSTEM INTERFACES

The GN&C relies on the ODCC to provide the programs necessary to interpret the sensor data and generate commands to the effectors. The GN&C functions are partitioned within the main computer complex so that if the primary system (group of computers) is unavailable a back–up system (a smaller commuter) is available.

Although not explicitly stated, the GN&C interfaces with the EPS for all sensors and effectors. In addition, there is an indirect interface in that orientation data provided by the GN&C sensors is used to provide pointing vectors for the solar arrays. Thermal constraints and requirements for any of the GN&C system were not available at this time.

Information regarding the orientation of the Mir Complex is available to the crew at any of the command stations. This information is also down–linked to the control center. The crew can participate in the attitude control operations using the optical star sensors for alignment. The crew can also manually "fly" the vehicle, although there are no specifics on how this is accomplished. State vector updates to the Mir Complex, as well as changes in operation modes, are uplinked from the control center.

9.7 GN&C SYSTEMS SUMMARY

The Mir Complex GN&C system provides the sensor and effector operations necessary to maintain an acceptable orbital altitude and orientation for long duration space flight. The system is generally autonomous, requiring little or no interface by the crew. The ground can provide updates to the state vector and can also command the Mir Complex into different orientations.

Sensors on the Mir Complex include a variety of optical, mechanical and magnetic instruments which provide means of measuring the Mir Complex orientation with respect to the Earth, the Sun and predefined stars. Each of the modules contains sensors for the GN&C subsystem.

The effectors primarily responsible for maintaining Mir Complex orientation are the gyrodynes, which use single gimbal gyroscopes to transfer turning energy to the Mir Complex. In the event of saturation of the gyrodynes, attitude control thrusters are used. There are effectors located on each of the modules. The orbital altitude is maintained using large thrusters on the Progress and/or Soyuz–TM vehicles.

QUESTIONS

1. The functions of the GN&C system on the Mir Complex are

    a. Accurate attitude determination and control

    b. Orbit correction

    c. Determining the mass moments of inertia for the changing configurations

    d. a. and b. only

    e. a. and c. only

    f. a., b., and c.

2. Gyrodynes are capable of

    a. Transferring up to 1000 Nms of momentum directly to the station

    b. Providing 14 kg of thrust to maintain station attitude

    c. Altering the station orbital altitude by providing momentum changes along the vertical axis

3. The primary determination of station orientation and commands to correct or change attitude is provided by

    a. Peripheral computers associated with the sensors and effectors

    b. The ground

    c. The ODCC

SECTION 10
STRUCTURES AND MECHANISMS

10.1 PERFORMANCE OBJECTIVES

By the end of this section, the reader should be able to:

- Describe the mechanical functionality of the docking/berthing mechanisms used on the Mir Complex
- Describe the mechanical functionality of the hatches used on the Mir Complex
- Describe the mechanical functionality of the Ljappa Arm
- Describe the mechanical functionality of the Kristall solar array mechanisms

10.2 INTRODUCTION

The Mir Complex contains a variety of structures and mechanisms that perform specialized functions. This section discusses purpose and functionality of four classes of mechanisms that include docking and berthing mechanisms, hatches, mechanical arms, and solar array mechanisms.

10.3 MIR COMPLEX DOCKING AND BERTHING MECHANISMS

The purpose of the Mir Complex docking and berthing mechanisms is to provide the capability for Soyuz and Progress spacecraft to mate and demate with the Mir Complex. These mechanisms also provide the capability for the modular buildup of the Mir Complex.

The Mir Complex uses two mechanisms for docking and berthing operations. These devices are referred to as the Probe and Drogue and Androgynous docking mechanisms. The Probe and Drogue mechanism is employed on the axial and radial ports of the spherical docking adapter, the axial port on the Kvant–1 module, and the axial port of the Mir which is connected to Kvant–1. The Kristall module also contains one Probe and Drogue docking mechanism. The Kristall also includes two Androgynous docking mechanisms. The locations of these docking mechanisms are shown on Mir Complex Isometric in the Mir section.

The Probe and Drogue mechanism can mate with the Soyuz and Progress space craft as well as with the berthing ports, which are used to attach the Kvant–1, Kvant–2, and Kristall modules to the Mir Complex. The Androgynous docking mechanism has the capability of mating with the Buran orbiter.

10.3.1 Probe and Drogue Docking Mechanism

The Probe and Drogue mechanism is shown schematically in Figure 10–1. The active or probe side contains a capture latch, which is located at the tip of a rod or probe. The probe begins at a conically shaped angular limiter. The passive or drogue side contains a receiving cone that angles down to a socket that is designed to contain the capture latch mechanism on the end of the probe.

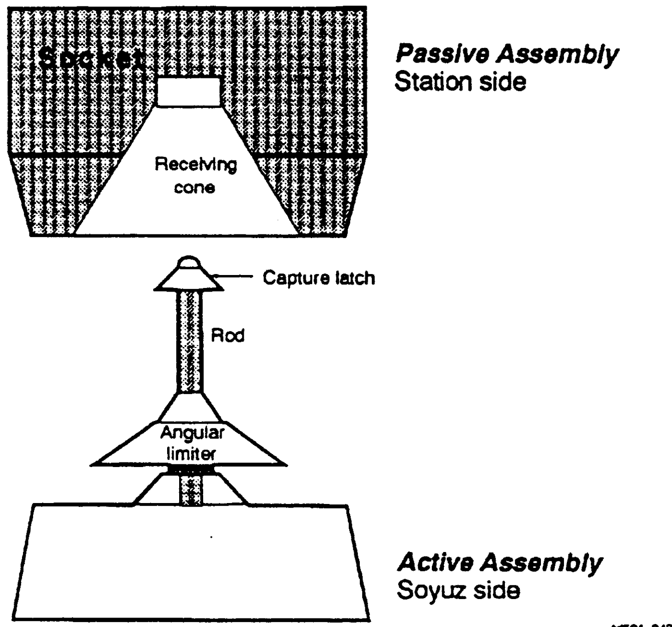
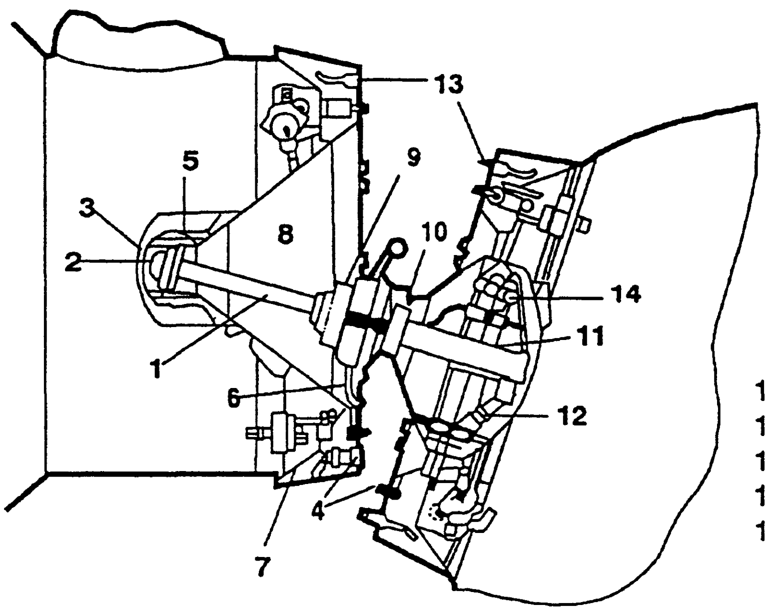


Figure 10–1. Current Soyuz and Progress docking system – Probe and Drogue

Figure 10–2 shows a more detailed schematic of the Probe and Drogue mechanism. When a docking action is necessary, the probe head with capture latches (2) which is located on the end of the probe (1) is inserted into the drogue cone (8) with the eventual goal of mating with the drogue (3). The probe mechanism includes an electric drive (9) which will retract the probe and pull the two sides of the docking mechanism together until the mechanical stop (5) is reached. The probe unit is connected to the probe guide (11) by a ball joint (10). When the probe is initially captured by the drogue, electromechanical dampers (14) damp out axial motion. Lateral motion is damped by the lateral shock absorbers (12). When the stop has been reached umbilicals for hydraulics (4) and electrical power (13) are made. Information is not available as to how much of this process is automatic or manual.

Figure 10–3 shows the Probe and Drogue mechanism in the fully mated condition. When the mechanical stop has been reached, active hooks (7) serve to mate the active and passive docking halves together about the docking interface seal (2). Passive hooks (8) are available for increased structural rigidity if required. Once this seal has occurred, the probe mechanism is moved out of the way to allow crew access to the spacecraft hatches.



1 Probe
2 Probe Head with Capture Latches
3 Drogue
4 Hydraulic umbilical connector
5 Stop
6 Alignment Pins
7 Docking Structural Ring
8 Drogue Cone
9 Electric Drive for Retraction of Probe Stem
10 Ball Joint
11 Probe Guide
12 Lateral Shock Absorber
13 Electrical Umbilical
14 Elctro-mechanical Damper

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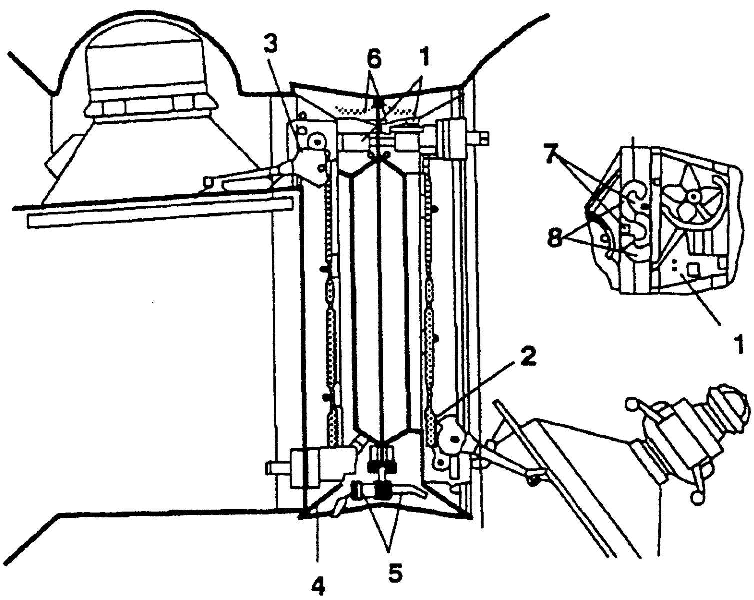
Soyuz probe and drogue after initial capture

Figure 10–2. Soyuz docking mechanism



1 Peripheral Latch
2 Docking Interface Seal
3 Hatch Cover Drive
4 Docking (structural) Ring
5 Hydraulic umbilical
6 Electrical Umbilicial
7 Active Hooks
8 Passive Hooks

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Figure 10–3. Typical docking mechanism used on all Soyuz spacecrafts

10.3.2 Androgynous Docking Mechanism

The Androgynous Docking system is shown in Figure 10–4. The Androgynous Docking Mechanism is designed to dock with another copy of the mechanism (i.e., no male or female section, but both, hence androgynous). The mechanism is made up of three alignment guides which each contain one capture latch. The capture latches are 120° apart. Located 60° from each of the alignment guides is a body mounted latch. Both the capture latches and body mounted latches are attached to an alignment guide ring which can be extended or retracted. Twelve structural latches are located at 30° increments around the circumference of the alignment guide. Connectors for power and fluids are also located along the circumference of the ring.

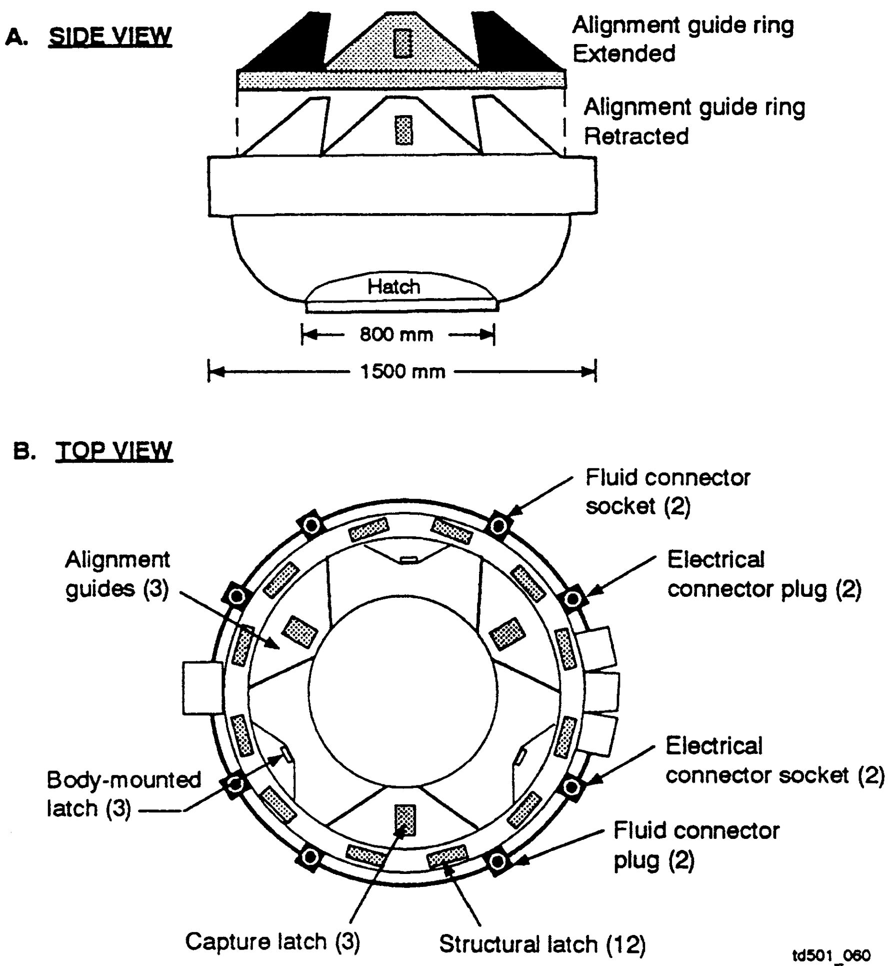
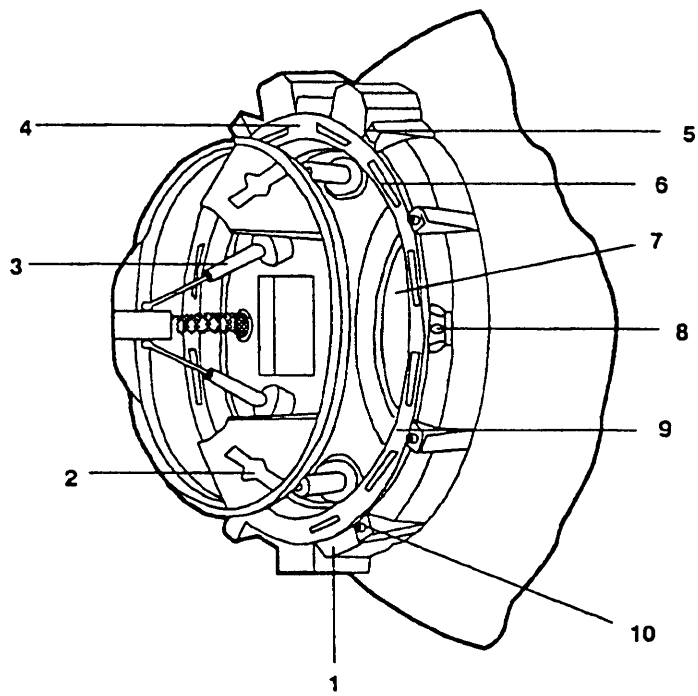


Figure 10–4. Androgynous peripheral attachment system

During a docking activity, the alignment guide ring is extended outward as shown in Figure 10–4. The ring is extended until it reaches the extended, ready–to–capture position. The vehicle, which is docking, has an Androgynous Docking Mechanism that is rotated 60° in reference to the Mir Complex Androgynous Docking Mechanism. The capture latches on the alignment guides of the docking vehicle mate with the body mounted latches of the Mir Androgynous Docking Mechanism. The alignment guides include shock absorbers (3) as shown in Figure 10–5. Three seconds after capture, three electromagnetic brakes are energized to damp relative motion as are three low–energy dampers which damp lateral and rotational motion. After 60 seconds, it is assumed that all relative motion has been sufficiently damped out to allow the docking ring to be extended to its full forward position. Once this position is achieved, the ring is pushed against mechanical hard stops for 10 seconds to achieve alignment.



Androgynous peripheral docking unit APAS-89

1 Frame; Hull
2 Ring latches
3 Shock absorbers
4 Docking frame
5 Hydraulic section
6 Latches; Bolts
7 Hatch cover
8 Latches on frame
9 Joint compress/tightener
10 Electrical section

td501_049

Figure 10–5. Docking equipment on the Kristall module and future Soyuz applications

Once this alignment is achieved, the docking ring is retracted and sensor readings are given to indicate a ready–to–latch condition. The latches (8) are commanded to hook and drive close. Partial closure results in a sensor reading which stops further retraction of the docking ring. Full closure compresses pressure seals. After full closure, the capture latches are opened and the ring is retracted to its final position.

10.4 MIR COMPLEX HATCHES

Information on the Mir Complex hatch design and mechanism is not available at this time.

10.5 MIR COMPLEX MECHANICAL ARMS

The process of building up the Mir Complex requires the use of the Ljappa Arm. During Mir Complex construction operations, new modules are docked to the forward Mir docking port and moved to one of the radial docking ports as shown in Figure 10–6. The Ljappa Arm is located on the docking mechanism of the particular docking module (1). The arm is deployed mechanically onto a socket that is located on the Mir Complex multiple docking assembly (2). Once this attachment is made, the modules main docking probe is retracted, which allows the arm to raise the module (3) and pivot it 90° to where it can be docked to one of the radial docking ports (4).

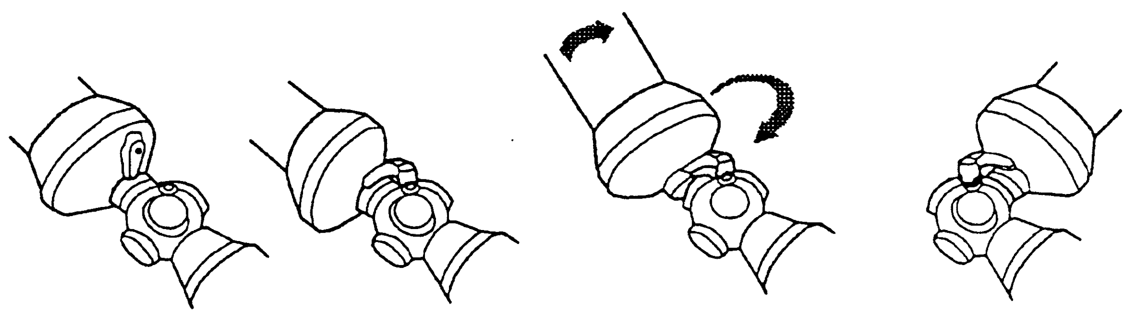


Figure 10–6. Transfer of the Kvant–2 module using the Ljappa Arm

Figure 10–7 shows a more detailed view of the Ljappa Arm and socket. The arm includes a rotational drive (1) and a transfer drive (2) which allows the arm to be appropriately positioned so it can mate with the socket. The mating ring (3) has three guides which are analogous to those used in the androgynous docking adapter. The arm has a probe drove (4) which will mate the probe (5) with the structural latches within the socket. The socket contains a redundant rotational drive (6) and a redundant structural latching and unlatching drive.

10.6 MIR COMPLEX SOLAR ARRAY MECHANISMS

Information on the solar array mechanisms is unavailable.

10.7 STRUCTURES SUMMARY

The Mir Complex employs docking and berthing mechanisms, hatches, mechanical arms, and solar array deployment mechanisms. The Mir Complex uses the Probe and Drogue Docking Mechanism for Soyuz and Progress visits and module connection. The Mir Complex provides the Androgynous Docking Mechanisms for the Buran orbiter. Hatches serve to separate each module into a distinct pressure vessel and are necessary in docking and berthing/EVA operations. Mechanical arms are used to reposition Mir Complex modules from axial docking ports to permanent radial docking ports. Scissor mechanisms are used for solar array deployment on the Kristall module.

1. Rotational drive
2. Transfer drive
3. Mating ring with three guides
4. Probe drive
5. Probe with two latches
6. Redundant rotational drive
7. Redundant structural latching and unlatchibng drive

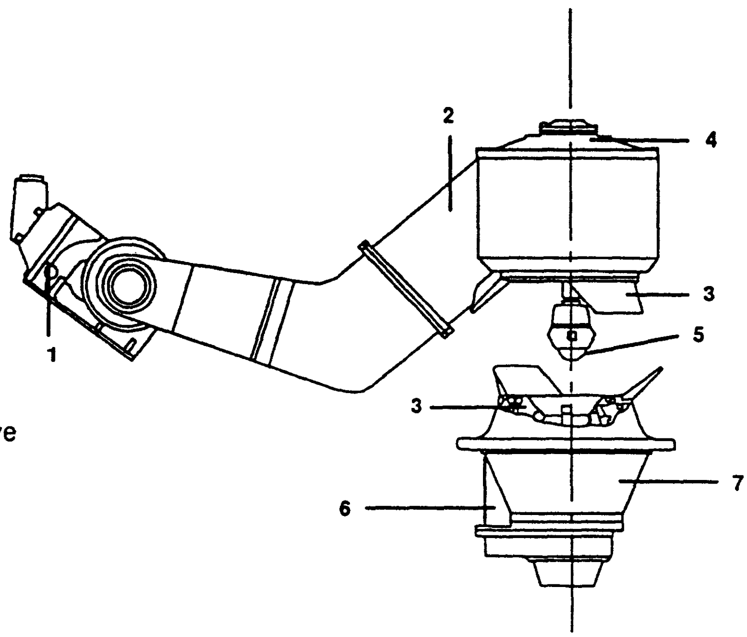


Figure 10–7. Electronically driven manipulator arm.

QUESTIONS

1. The purpose of the Mir Docking Mechanism is to

   a. Allow docking of the Progress spacecraft

   b. Allow permanent module buildup

   c. a. and b.

2. The purpose of the Ljappa Arm is to

   a. Transfer Mir Complex modules from axial to permanent radial docking ports

   b. Provide robotic capability for performing Mir Complex repairs

3. The Mir Complex utilizes two docking mechanisms.

   a. True

   b. False

4. The Androgynous docking mechanism cannot dock with itself

   a. True

   b. False

5. The progress spacecraft docks with the Probe and Drogue mechanism.

   a. True

   b. False

6. The Mir Complex docking mechanisms interface with the TCS in order to account for thermal expansion and contraction.

   a. True

   b. False

SECTION 11
EXTRAVEHICULAR ACTIVITY SYSTEM

11.1 PERFORMANCE OBJECTIVES

By the end of this section, the reader should be able to:

- Identify the function of the Mir Complex EVA system
- Describe the capabilities and constraints of the Mir Complex EVA system
- Briefly describe any similarities/differences between the Mir EVA system and the equivalent U.S. Space Shuttle/Station systems

11.2 INTRODUCTION

The Mir Complex EVA system consists of the space suits, the Manned Maneuvering Unit (MMU), and the airlock. The Mir Complex EVA suit is a semi–rigid suit which provides the similar life support functions necessary to operate outside the space vehicle as the Shuttle Extravehicular Mobility Unit (EMU), but it is designed slightly different. The EVA space suit used onboard Station will be the same as the one used on the Shuttle. The Soviet Manned Maneuvering Unit (SMMU) is also similar in functionality to the Shuttle MMU. Details on the Mir Complex airlock are not available at this time. However, the function of the Mir Complex airlock, which is to allow for the egress and ingress from the pressurized modules, is also similar to that of the Shuttle and Station airlocks.

11.3 MIR COMPLEX EVA SPACE SUIT

The function of the Mir Complex suit is to provide life support in the extreme, vacuum environment of space. Similar to the EMU, functions provided by the Mir Complex EVA suit include at least 6 hours of autonomous activity, a habitable, pressurized environment, a pure O_2 atmosphere, a secondary O_2 supply, CO_2 removal, temperature and humidity control, body cooling using a water lining, communications capability to the spacecraft, biomedical monitoring, ventilation for cooling, power supply for operation, joint mobility required to complete the specified task, and emergency notification capability if a problem occurs. The designs of specific portions of the suit differ from the EMU, but the basic functionality is the same.

The Mir Complex EVA suit consists of an inner, liquid cooled garment and the pressurized, protective outer suit just like the EMU. The Mir Complex EVA suit, however, has two pressure bladders for safety reasons. If the outer garment is punctured, the secondary bladder provides support. Successful operation of this back–up mode enabled the completion of two EVA activities on Salyut and Mir Complex when the primary pressure bladder was damaged. The EMU has a single pressure design due to the extreme strength of the suit's material (it is almost impossible to cut). The Mir Complex suit, on the other hand, can be punctured much easier than the EMU.

Unlike the EMU, which maintains a suit pressure throughout the EVA, the Mir Complex suit maintains the suit pressure between 3.8 and 5.7 psi. The higher pressure capability is to reduce the amount of prebreathe time required by the cosmonauts before exiting the vehicle. It is also capable of functioning at the lower pressure when strenuous work is required. The lower pressure results in more flexibility and less physical exertion by the crewmember. Adjustable suit pressure is a capability that the EMU is not designed to do.

Both versions of the suit use a liquid cooling garment to extract metabolic heat. Water is used as a coolant and the temperature is controlled by a switch on the exterior of the EVA suit. The ambient thermal loads, water cooling fluid flow rates, and total metabolic capacities of the suits are almost identical. Ventilation fans are also used, especially within the helmet, to provide some cooling and O_2 circulation.

The outer layer of the Mir Complex suit is a semi–rigid outfit which is entered from the rear as shown in Figure 11–1. This suit does not accommodate as wide a range of crewperson sizes as the EMU, but it is designed to be easily adjustable on orbit to fit different crew members. This design also allows for fewer suit sizes to be developed and maintained, as opposed to the detailed, custom–made EMUs that require hundreds of bodily measurements. U.S. astronauts are capable of resizing the EMU on orbit, but it is a time consuming effort. The arm of both suits is outfitted with a mirror to allow the crew member to read and operate components on the from of the suit.

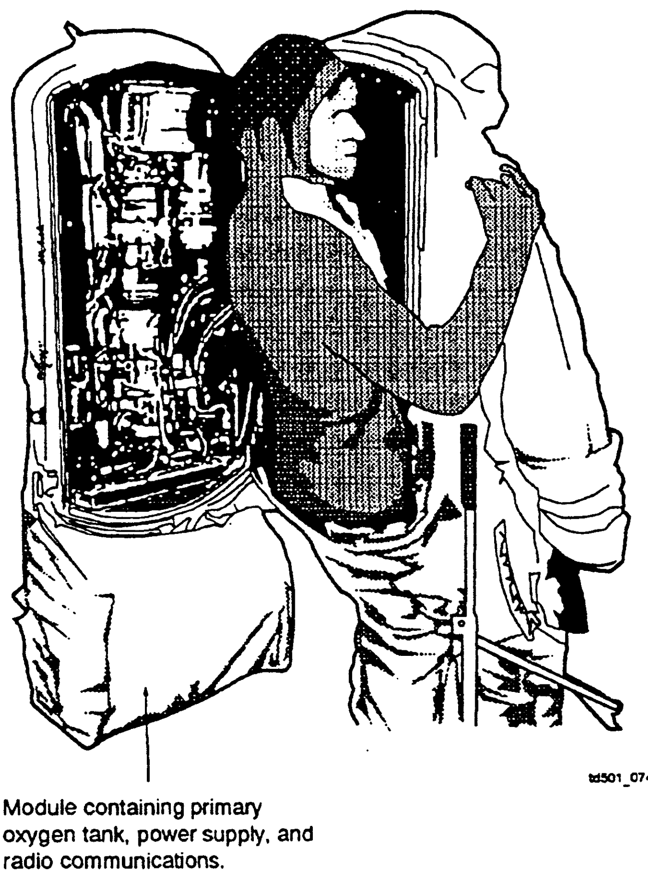
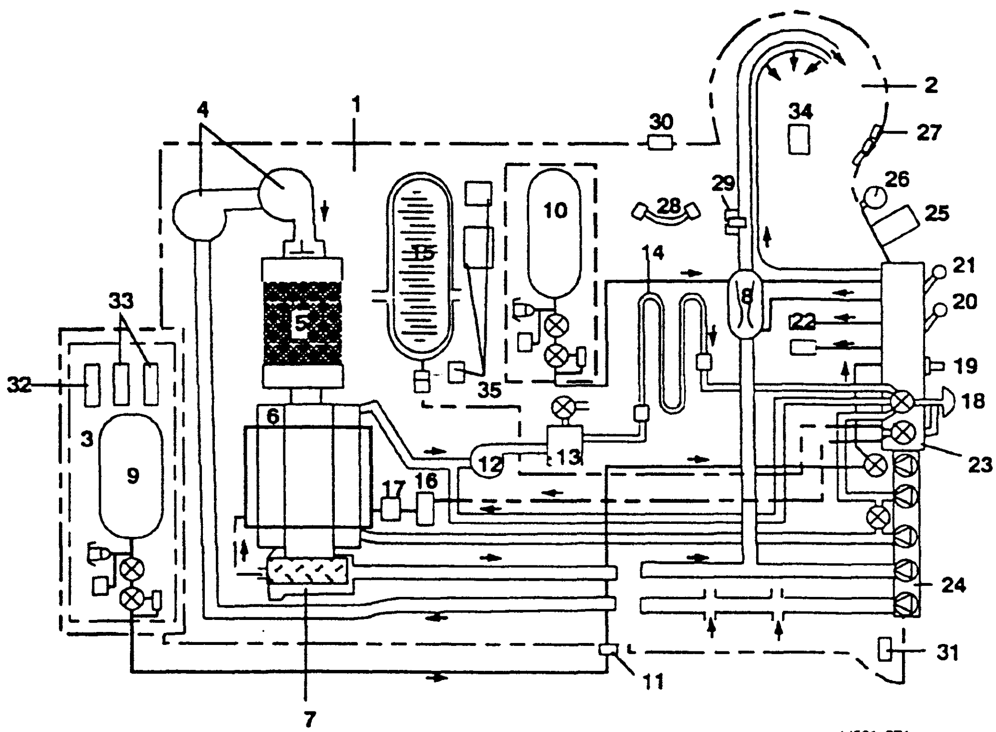


Figure 11–1. The PLSS of the Mir Complex EVA suit

Also shown in Figure 11–1 is the Portable Life Support System (PLSS) (known as the PLSS for U.S. suits), contained in a backpack similar to the EMU. The Mir Complex suit's backpack is hinged to allow for easy ingress and egress of the suit, with a cable lanyard available for self–closure of the backpack. The majority of the suit's weight (231 lb for the Mir Complex suit compared to 264 lb for the EMU when both are fully charged) resides in the backpack, as the backpack contains all the necessary components to operate autonomously in the extreme environment of space. Figure 11–2 details these individual items.



1 SS Backup Cavity
2 SS Helmet
3 Module
4 Ventilation Fans
5 CO_2 Absorber Canister
6 Heat Exchanger
7 Moisture Separator
8 O_2 Injector
9 Primary O_2 Bottle
10 Reserve O_2 Bottle
11 Bulkhead Connector
12 Water Pump
13 Hydraulic Accumulator
14 Water Cooling Garment
15 Water Tank
16 Reducer
17 Flow Limiting Filter
18 Temperature Control Valve
19 Reserve O_2 Control Switch
20 SS Presure Switch
21 Injector Control Switch
22 Pressure Regulators
23 Pneumatic and Hydraulic System Control Panel
24 Pneumatic and Hydraulic Connector
25 Monitoring and Control Panel
26 SS Pressure Gage
27 Emergency Operating Mode Indicators
28 Physiological Transducer Harness
29 Ventilation Gas Flow Gage
30 SS Pressure Relief Valve
31 Reserve Bladder Valve
32 Electrical Power Supply
33 Radio Transceiver and Antenna
34 Communications Equipment
35 Automatic Monitoring and Control Devices

Figure 11–2. Mir EVA suit – PLSS

And although the Mir Complex suit is actually larger than the EMU, it is capable only of delivering only a 6–hour EVA, compared to 7–hours for the EMU. Within this life support system, the Mir Complex suit uses primary and secondary O_2 tanks that are replaced, silver zinc (AgZn) rechargeable batteries, and replaceable CO_2 cartridges. The only difference for the PLSS is the fact that the O_2 tanks are recharged, and not changed out. Both suits use a sublimator to remove condensation from the air and have radio/telemetry equipment in the lower portion of the backpack.

A major difference between the EVA suits is their operational life. After 10 EVA missions, the Mir Complex suit is put into the Progress spacecraft which reenters the atmosphere and is destroyed. The EMU, on the other hand, is designed to be serviced after each EVA flight, but will be certified for 25 EVAs when utilized on Station.

While both the U.S. and the Russians have studied hard suits, neither plans on deviating from the current design in the near future. A comparison of U.S. and Russian EVA experience reveals that the total EVA time is almost the same (~ 250 hours) with about half of the U.S. EVA time occurring on the Shuttle. A majority of Russian experience happened between 1990 and the present. The U.S. has accumulated more EVAs than the Russians (59 to 47 as of January 1993), but over half of the U.S. EVAs occurred before Shuttle.

Like the EMU, the Mir Complex EVA suit is designed to be compatible with the SMMU.

11.4 MIR EVA MMU

The function of the Mir Complex SMMU is to provide the cosmonaut the opportunity for "free flight" (with a safety tether option) and the reliable means of extravehicular activity around the external proximity of the Mir Complex. The SMMU has six degrees of freedom which provide excellent maneuverability in space. It is designed to be highly effective in rescue, repair, trouble prevention, and inspection of small objects such as satellites and large spacecraft like the Buran which have delicate tiles. The unit has been tested on orbit twice and is currently stowed on the Mir Complex. Prior to the arrival of the Kvant–2 module, which has an integrated airlock with larger hatches than the Mir Complex, the SMMU could not be used due to its size. The Shuttle MMU provides the same functions and looks very similar to the SMMU.

The SMMU weighs 400 kg (880 pounds) and contains 32 thrusters, mounted in pairs, which receive propellant from tanks installed on the back of the unit. Unlike the Shuttle MMU which uses Gaseous Nitrogen (N_2) as propellant, the SMMU utilizes compressed air. The propulsion and orientation jets of the unit can be operated in either semi–automatic or direct control mode. In the semi–automatic mode, two types of maneuvering are possible: propellant saving or boosted. (Details about these modes of operation are unavailable.) The independent operation time is 6 hours. It has a characteristic velocity of 30 m/sec (98 ft/sec) and a maximum distance from the Mir Complex of 60 m (196 ft) when tethered or 100 m (328 ft) when untethered. The SMMU has an attitude stabilization rate of +2 deg/sec. Similar to the Shuttle MMU, the SMMU has two hand controllers. The rotational hand controller is located on the right arm of the unit and the translational hand controller is located on the left arm. Figure 11–3 details the locations of components on both the Shuttle and Russian MMUs.

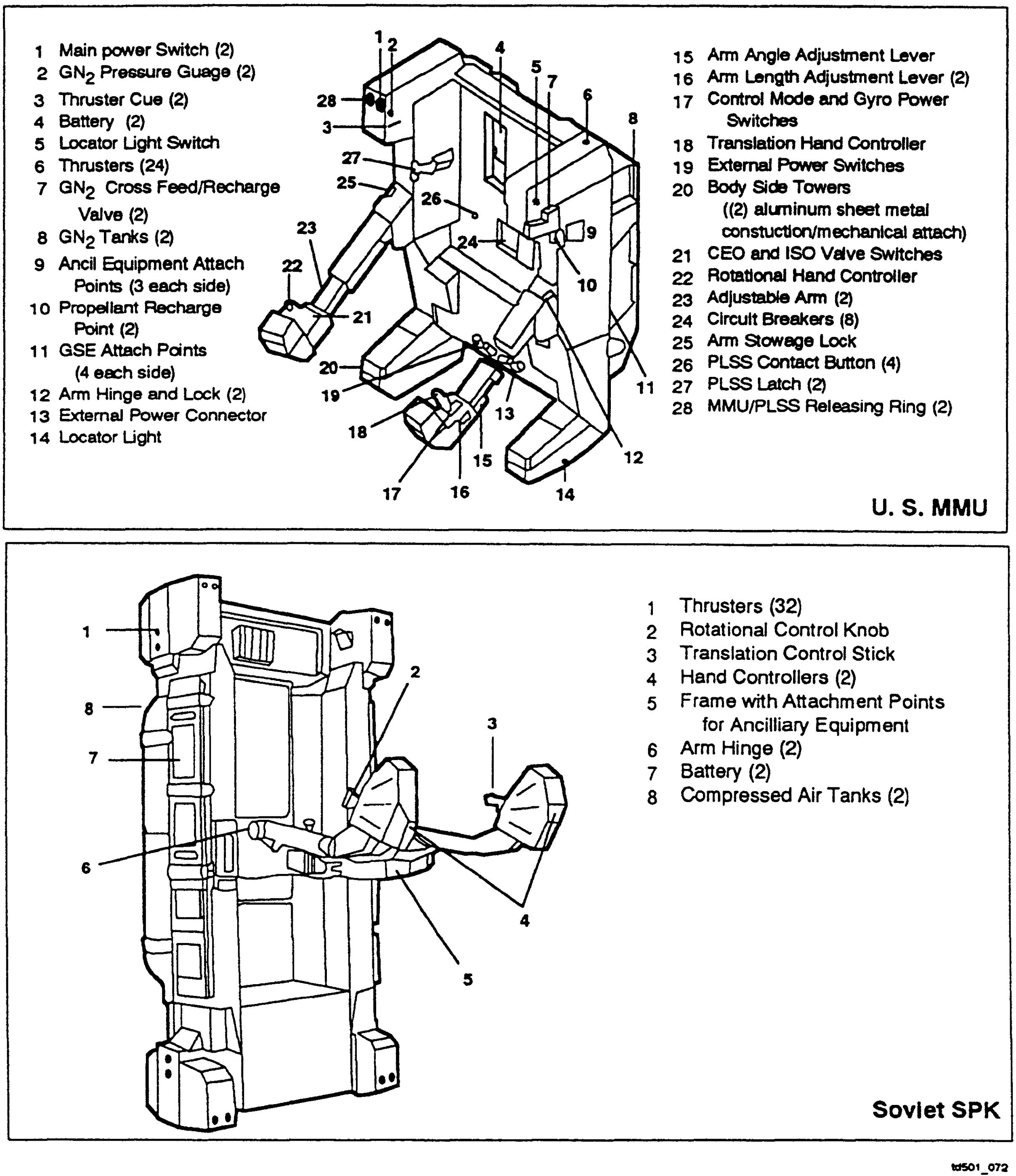


Figure 11–3. Comparison between U.S. and Russian MMUs

11.5 EVA SYSTEMS SUMMARY

The functions of the EVA systems on the Mir Complex are similar to those required on the Shuttle and Space Station. However, specific designs are unique to the Mir Complex EVA suit and the SMMU. The major differences between the Shuttle and Mir Complex EVA suit designs are the variable pressure capability on the Mir Complex suit, the suit garment design (Shuttle's flexible, durable coating design versus the Mir Complex double bladder, semi–rigid outfit), and the operational life of the EVA suits (reservicable EMU versus disposable Mir Complex suit).

The different manned maneuvering units are more similar in design than the EVA suits. They are very similar in appearance and have virtually the same controls in the same places. The largest difference is in the gases used for propulsion, N for the Shuttle model and compressed air for the Mir Complex version. The functions provided by the two units are virtually identical.

QUESTIONS

1. One of the functions of the Mir Complex EVA suit is to

   a. Provide a method of "free flight" propulsion for cosmonauts to maneuver around the station

   b. Provide a sea–level atmosphere for the cosmonauts to operate in outside the station

   c. Provide at least 6 hours of autonomous flight outside of the station for the cosmonauts

2. A major difference between the Russian and U.S. EVA suits is that the Russian suit

   a. Uses a water lining garment to cool the cosmonaut

   b. Can provide at least 6 hours of autonomous flight

   c. Has a life span of only ten EVA missions

3. A major similarity between the Russian and U.S. EVA suits is that both suits

   a. Have the ability to operate in a pressure range from 3.8 to 5.7 psi

   b. Utilize a single bladder construction for pressure maintenance

   c. Control the humidity within the suit with a sublimator

4. The most correct statement about the Russian MMU is that

   a. It utilizes the same propellant, N_2, as the U.S. MMU

   b. It utilizes two hand controllers for flight control

   c. It has seen extensive testing and utilization in orbit

SECTION 12
PAYLOADS

12.1 INTRODUCTION

Payloads and experiments are considered the same by the RSA and are referred to as payloads in this section. The Mir Complex is used for both scientific and industrial payloads. There are several long term goals of the Mir Complex with respect to payloads; make the human body and mind able to adapt to long term space flight and zero gravity (0–G), produce drugs and materials in the 0–G environment, astronomy, remote Earth sensing, and agriculture.

The following information gives a high–level overview of the types or classifications of payloads and briefly describes what is done within each type of payload on the Mir Complex. The types of instrumentation used with the payload are briefly described along with some real world examples of actual payloads flown on the Mir Complex. A lot of the specific up to date information about the payloads is not available.

12.2 TYPES OF PAYLOADS ON THE RUSSIAN SPACE STATION

The exact space allotted on the Mir Complex for payloads and the amount of time the cosmonauts spend for payloads is unknown. Payloads are sent to the Mir Complex using the Soyuz–TM or the Progress. These vehicles are also used to bring the results or data from the payloads back from the Mir Complex.

There are five basic types of payloads on the Mir Complex:

- Medical/psychological
- Biological
- Earth resource/atmospheric
- Astrophysical
- Material processing

These types of payloads are described briefly in the following sections along with the instrumentation used and some specific examples.

12.2.1 Medical/Psychological Payloads

Medical/Psychological type of payloads appear to be the most prevalent on the Mir Complex. The main objective of this type of payload is to determine the physical and psychological effects of long duration space missions. One of the specific areas of payloads is how the human body adapts to the 0–G environment. Medical/psychological experiments are done in the Mir Complex. The Mir Complex also utilizes the Mir for medical emergencies.

a. Medical/Psychological Instrumentation

The Gamma–1 medical equipment is referred to often for medical experiments and routine medical checkups. (The Mir Complex has significant medical facilities according to reference materials but the specific instrumentation is not identified). An ultrasound cardiogram, used to monitor the heart, and an electrophoresis device, used to fractionate DNA, are also cited in the reference material.

b. Medical/Psychological Payloads Examples

Examples of the Medical/Psychological payloads are

1. Recording of sleep patterns at various times during the mission
2. Removal of bone marrow while on orbit (for later analysis on the ground)
3. The effects of colors, exercise, sound levels, music, radiation, and long term 0–G exposure on the human mind and body

12.2.2 Biological Payloads

Biological payloads on the Mir Complex fall into two categories, animal and plant. The main objectives of biological payloads are to produce plant growth in space and research the effects of 0–G on animals. The majority of biological payloads are plant–based.

a. Biological Payload Instrumentation

The biological payloads are done in the Kvant–2 and Kristall modules. The Kvant–2 module houses the Inkubator–2 which is used to incubate and hatch Japanese quail eggs. The Svetbloc–M is located in the Kristall module and serves as a horticulture hot house for cultivating lettuce, radishes, and other food crops.

b. Biological Payload Specific Examples

The Japanese quail eggs hatched and incubated in the Inkubator–2 are tested to determine the effects of 0–G on the development of quail embryos. This has been an ongoing experiment for several years.

Several cosmonauts have commented on the necessity of plant life on the Mir Complex for the psychological effects as well as the food and O_2 that plant life provides.

12.2.3 Earth Resources/Atmospheric Payloads

Earth resource and atmospheric payloads provide an Earth remote sensing capability for the Mir Complex. The objective of this type of payload is to monitor the condition of the Earth's surface and atmosphere.

a. Earth Resources/Atmospheric Payload Instrumentation

There are a variety of sensors used for remote sensing onboard the Mir Complex. The data from remote sensing is used for weather prediction, ozone depletion sensing, pollution level sensing, global warming, and other research. The following listing gives the instrumentation found on the Kvant–2, and Kristall modules.

1. Kvant–2 module

(a) MKF– GMA – multi–spectral camera system (Infrared and visible spectrum)

(b) Priroda–5 – Earth observation camera

2. Kristall module

Priroda–5 – Earth observation camera

b. Earth Resources/Atmospheric Payload Specific Example

Earth resource/atmospheric payloads instrumentation generated remote sensing data used to support studies of the spring run off in the spring of 1989.

12.2.4 Astrophysical Payloads

Astrophysical payloads use sophisticated telescopes and spectrometers to obtain data from space. The specific type of data obtained from space is x–ray data.

The following are six astrophysical instruments, all of which are found on the Kvant–1 module:

a. Pulsar Kh–1 – hard x–ray telescope/spectrometer

b. Gekse Instrument – high energy x–ray collector

c. Fosvich – high energy scintillation telescope/spectrometer

d. TTM Shadowmask X–Ray telescope

e. Siren–2 – Gas Scintillation Proportional Spectrometer (GSPS)

f. Glazar – wide angle ultraviolet (UV) telescope.

Data from astrophysical payloads are collected and sent to research institutes in Russia. The exact information on the nature of the astrophysical research done in Russia is unavailable.

12.2.5 Material Processing Payloads

Material processing payloads are used for scientific and industrial research and production. This type of payload requires a large amount of power to perform due to the power required to operate material heating furnaces. The main objective of this type of payload is to perform research on and produce materials (mainly alloys and crystals) utilizing the 0–G environment. There are three main areas of payloads for materials processing, producing materials, testing materials, and application of coatings to materials.

a. Material Processing Payloads Instrumentation

Most of the material production is done in the Kristall module, which is an experimental test bed for the production of materials in space. The instrumentation in the Kristall used for materials payloads are the following:

1. Kristallizer crystal growth unit
2. Gallar furnace
3. Krater–V melting zone
4. Zona–02 furnace and the Zona–03 furnace

Material testing is done inside the Kristall module, and also outside the module in a specially designed airlock. Materials are subjected to the space environment, then retrieved utilizing this airlock. The testing of such materials is a regular activity on the Mir Complex but specifics regarding the instrumentation is unavailable.

b. Material Processing Payloads Specific Examples

GaAs has been consistently produced on the Mir Complex for several years while crystals and alloys are usually produced for specific experiments. A specific example of a coating payload is coating tungsten–aluminum on a polymer coating during Progress 39.

12.3 PAYLOADS SUMMARY

The types of payloads found on the Mir Complex are medical/psychological, biological, Earth sensing/atmospheric, astrophysical, and material processing. Each of the types of payloads have high level objectives and require instrumentation onboard the Mir Complex. The high level objectives for Mir Complex payloads are: the effects of the 0–G environment on humans, plants and materials, remote sensing of the Earth and Earth's atmosphere; and x–ray astronomy and material production in space.

The Mir Complex continues to do payloads like those described in this section and upgrades the payloads regularly. In depth information on the current payloads of the Mir Complex is unavailable.

APPENDIX A
ACRONYMS AND ABBREVIATIONS

ACH	Attitude Control Handle
ACS	Atmosphere Control and Supply
ACSSA	Attitude Control System for Solar Array
ADI	Attitude Direction Indicator
AOS	Acquisition of Signal
AR	Atmosphere Revitalization
AaZn	Silver Zinc
ac	Alternating Current
ATU	Audio Terminal Unit
BCDU	Battery Charge/Discharge Unit
C	Celsius
CAPCOM	Capsule Communicator
CC	Center Computer
CDRA	Carbon Dioxide Removal Assembly
CS	Control System
CHeCS	Crew Health Care System
CO	Carbon Monoxide
CO_2	Carbon Dioxide
CPU	Central Processing Unit
CRL	Command Radio Link
CRT	Cathode Ray Tube
C&T	Communication and Tracking
CS	Computational Systems
dc	Direct Current
DDCU	Direct Current–to–Direct Current Converter Unit
DCSU	Direct Current Switching Unit
deg/sec	Degrees Per Second
DMS	Data Management System
DPS	Data Processing System
ECLSS	Environmental Control and Life Support System
EMU	Extravehicular Mobility Unit
EPS	Electrical Power System
EVA	Extravehicular Activity
EVM	(additional computer within the ODCC)
ft	Foot
ft^2	Square Foot
ft^3/min	Cubic Feet Per Minute
FCR	Flight Control Room
FDF	Flight Data File
FDS	Fire Detection and Suppression
FM	Frequency Modulation

GaAs	Gallium Arsenide
GCC	Ground Control Complex
GHz	Gigahertz
GN&C	Guidance, Navigation, and Control
GPC	General Purpose Computer
GPS	Global Positioning System/Satellite
GSPS	Gas Scintillation Proportional Spectrometer
H_2	Hydrogen
H_2O	Water
Hz	Hertz
IOP	Input/Output Processor
K	Kelvin
KB	Kilobyte(s)
Kg	Kilograms
kJ	Kilojoule
km	Kilometer
KOH	Potassium Hydroxide
kPa	Kilopascal
lb	Pound(s)
LOS	Loss Of Signal
lux	One Lumen per Square Inch
m	Meter
m^2	Square Meter
m^3	Cubic Meters
MCC	Mission Control Center
MCC–M	Mission Control Center – Moscow
MCC–H	Mission Control Center – Houston
MCNS	Motion Control and Navigation System
MCS	Motion Control System
MDSM	Mission Deputy Shift Manager
MHz	Megahertz
MMU	Manned Maneuvering
MOD	Mission Operations Directorate
m/sec	Meters Per Second
MTBF	Mean Time Between Failure
N_2	Nitrogen
$NaClO_3$	Sodium Chlorate
NiCd	Nickel Cadmium
NiH	Nickel Hydrogen
NM	Network Management
Nms	TBS
O_2	Oxygen
OCCMS	Onboard Complex Control and Management System
OCCS	Onboard Complex Control System

OCS	Onboard Computer System
ODCC	Onboard Digital Computer Complex
	Onboard Digital Control Complex
O–G	Zero Gravity
OJT	On–the–Job Training
PC	Peripheral Computer
PCA	Pressure Control Assembly
PHS	Personal Hygienic System
PLSS	Portable Life Support System
psi	Per Square Inch
PTT	Part Task Trainer
RAM	Random Access Memory
RHC	Rotational Hand Controller
ROM	Read–Only Memory
RSA	Russian Space Agency
SAR	Search and Rescue
SMMU	Soviet Manned Maneuvering Unit
SRC	Search and Rescue Complex
SSR	Systems Support Room
SSU	Sequential Shunt Unit
STDN	Stationar – 14 (Satellite)
TCS	Thermal Control System
TDRS	Tracking and Data Relay Satellite
TDRSS	Tracking and Data Relay Satellite System
THC	Temperature and Humidity Control
	Translation Hand Controller
THCS	Temperature and Humidity Control System
TM	Telemetry Mode
TMCH	Transitional Motion Control Handle
TMS	Telemetry Management System
TV	Television
U.S.	United States
UV	Ultraviolet
V	Volt
V dc	Volts Direct Current
VHF	Very High–Frequency
W	Watt
WCS	Waste Containment System
WM	Waste Management
WMS	Waste Management System
WRM	Water Recovery and Management

APPENDIX B ANSWERS

B.1 HISTORY OF THE MIR COMPLEX ANWERS

1. The Salyut program can best be described as

   c. A series of stations leading up to the Mir Complex

2. The Mir Complex is a "______ generation" space station.

   b. Third

3. The Mir Complex evolved in the following order

   a. Mir module, Kvant–1, Kvant–2, Kristall

4. Once in orbit, the Mir Complex has been re–supplied primarily using:

   b. Soyuz craft for cosmonauts and Progress craft for cargo

B.2 OPERATIONS PROFILE ANSWERS

1. Which of the following statements most accurately describes the activities of the Mir flight controllers?

   b. There is one shift per day, and each team works on 24–hour sht, then has 4 days off

2. The crewmembers spend most of their work day

   c. Performing housekeeping and maintenance tasks on the onboard equipment

3. The systems on the Mir are primarily operated by

   a. Autonomous software and hardware functions

B.3 STATION COMPONENTS ANSWERS

1. The Mir Complex currently consists of how many modules?

   b. Four

2. The Kvant–1 module is located on the axial port of the Mir Core Module?

   a. True

3. The Mir Core is made up of four compartments.

   a. True

4. The purpose of the Mir Core transfer compartment is to provide multiple docking ports for station modules or transport craft.

   a. True

5. The purpose of the Kvant–2 module is to provide data and observations for research into astrophysics.

   b. False

6. The purpose of the Kvant–1 module is to provide biological research data.

   b. False

B.4 COMPUTATIONAL SYSTEMS ANSWERS

1. The onboard computational systems on the Soyuz–TM are responsible for controlling GNC operations

   a. True

2. The Mir onboard computational system is comprised of OCS, ODCC, and TMS

   b. False

3. For the Soyuz–TM, the OCCS

   c. Controls all power switching to all systems

4. The reliability of the Argon class computers is

   b. Similar to current Orbiter GPCs

5. The Mir (core module) interfaces with the computers in expansion modules

   d. b. and c.

6. Each Mir expansion module has a control panel that replicates all functions as the main control panel in the Mir core.

   b. False

B.5 ELECTRICAL SYSTEMS

1. The Mir Complex uses which means to generate power during insolation?

    c. Solar arrays

2. The Mir Complex uses what to generate power during eclipse?

    d. Batteries

3. The Mir Complex EPS uses what material for the batteries?

    b. NiCd

4. The Mir Complex does pointing using what subsystems?

    a. GN&C or ACSSA

5. The Mir Complex EPS is most similar to which U.S. space vehicle?

    a. Space Station baseline

B.6 ENVIRONMENTAL AND THERMAL CONTROL SYSTEMS

1. The main customer for the Mir Complex ECLSS/TCS is the crew

   a. True

2. The purposes of the Mir Complex ECLSS include which of the following?

   e. a. and b.

3. The Mir Complex ECLSS provides CO_2 removal via a four–bed molecular sieve?

   a. True

4. Which is not one of the Mir Complex ECLSS functional groupings?

   c. EPS cooling

5. Which Mir complex systems interface with the Gas Recovery/Regeneration water electrolysis system?

   d. a. and b. EPS and TCS

6. Which Mir Complex system interfaces with atmospheric temperature and humidity control system liquid air condensing heat exchangers?

   b. TCS

7. The Space Station Baseline for temperature and humidity control used condensing heat exchangers

   a. True

8. The Space Station Baseline included water electrolysis for O_2 generation?

   b. False

B.7 CREW HEALTH CARE AND MAN SYSTEMS

1. Which statement best reflects the Russian approach to Man Systems onboard the Mir Complex?

   a. The Mir Complex contains Man Systems equipment that is very similar to that of the Space Station and Shuttle programs.

2. The Russians do not place much emphasis on countermeasure devices on the Mir Complex.

   b. False

3. The Body Waste Management System on the Mir Complex interfaces with the following systems:

   c. Electrical power system and environmental system

4. Which statement is most accurate about the Crew Health Care system on the Mir Complex?

   b. A large number of countermeasure devices are used on the station.

B.8 COMMUNICATIONS AND TRACKING SYSTEM

1. The Mir Complex communications system uses a distributed, integrated architecture that shares components between elements.

   b. False

2. The Mir Complex S–band can be configured to utilize the TDRSS satellite constellation.

   b. False

3. Mir Complex tracking is accomplished by using the Russian equivalent to the GPS system.

   b. False

4. The MCC–M normally commands directly to the Mir Complex through the Black Sea communications ship system.

   b. False

5. Communications of voice and data:

   d. Is sporadic, compared to shuttle, and is about a few hours a day

6. The telemetry (up and down) for the Mir Complex is

   f. a. Small compared to Shuttle and d. Base on a very different operations strategy than U.S. users

B.9 GUIDANCE NAVIGATION AND CONTROL SYSTEMS

1. The functions of the GN&C system on the Mir Complex are

    d. a and b only

2. Gyrodynes are capable of

    a. Transferring up to 1000 Nms of momentum directly to the station

3. The primary determination of station orientation and commands to correct or change attitude is provided by

    b. The ground

B.10 STRUCTURES

1. The purpose of the Mir Docking Mechanism is to

   c. a. Allow docking of the Progress spacecraft and b. Allow permanent module buildup

2. The purpose of the Ljappa Arm is to

   a. Transfer Mir Complex modules from axial to permanent radial docking ports

3. The Mir Complex utilizes two docking mechanisms.

   a. True

4. The Androgenous docking mechanism cannot dock with itself

   b. False

5. The progress spacecraft docks with the probe and drogue mechanism.

   a. True

6. The Mir Complex docking mechanisms interface with the TCS in order to account for thermal expansion and contraction.

   b. False

B.11 EXTRAVEHICULAR ACTIVITY SYSTEM

1. One of the functions of the Mir Complex EVA suit is to:

   c. Provide at least six hours of autonomous flight outside of the station for the cosmonauts.

2. A major difference between the Russian and U.S. EVA suits is that the Russian suit:

   c. Has a life span of only ten EVA missions.

3. A major similarity between the Russian and U.S. EVA suits is that both suits:

   c. Control the humidity within the suit with a sublimator.

4. The most correct statement about the Russian Manned maneuvering Unit is that:

   b. It utilizes two hand controllers for flight control.

APPENDIX C
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3. EK/R. Mendlowitz, OCCS figure descriptions and comparison table of Soyuz and Mir Complex computer to Shuttle GPC.

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7. Soviet Space Stations as Analogs – 2nd Edition; B. J. Bluth, Ph.D., Martha Helppie, Research associate, NAGW–659, August 1986 with Mir update 1987.

APPENDIX D
TECHNICAL SUPPORT

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APPENDIX E
MIR GRAPHICS

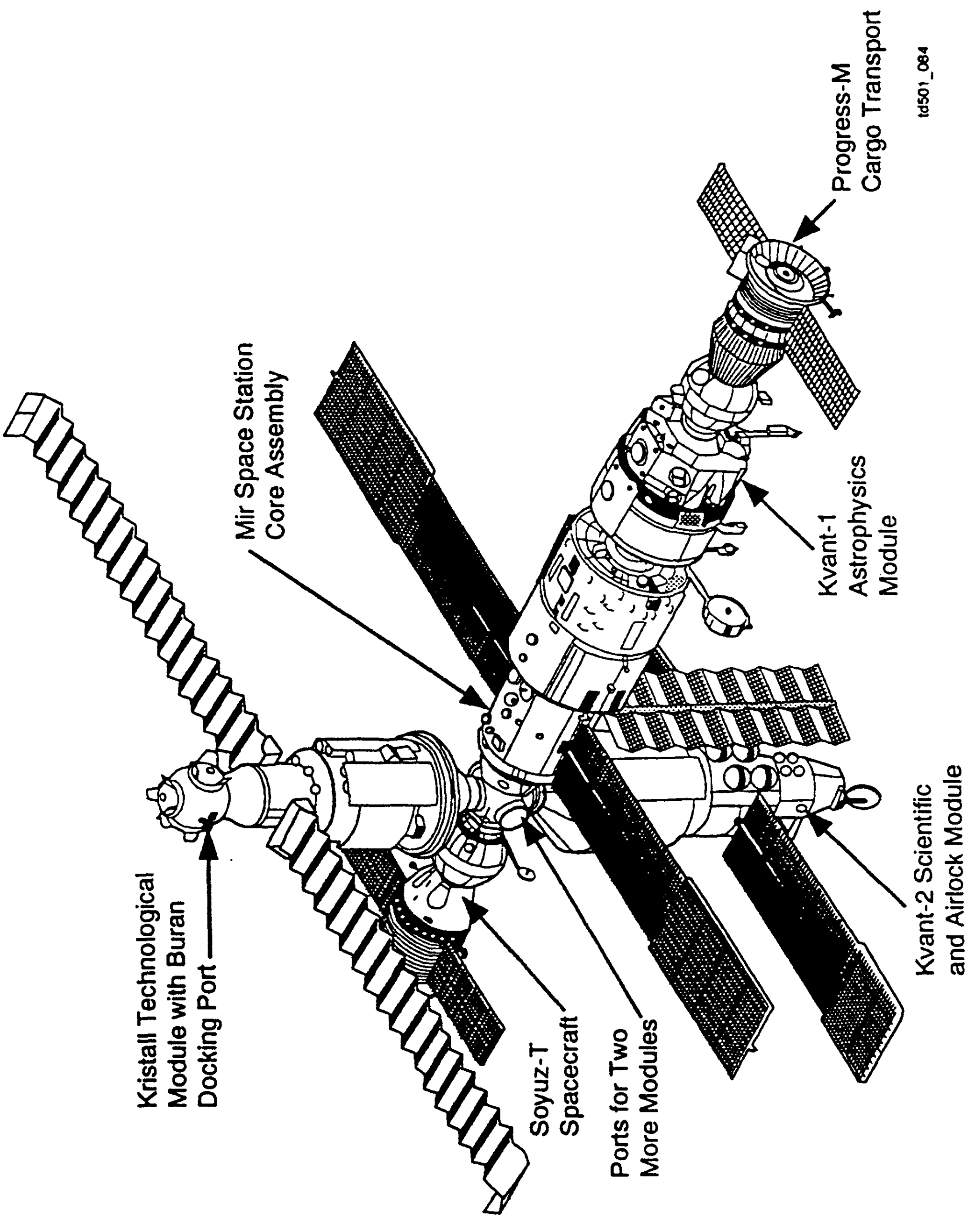
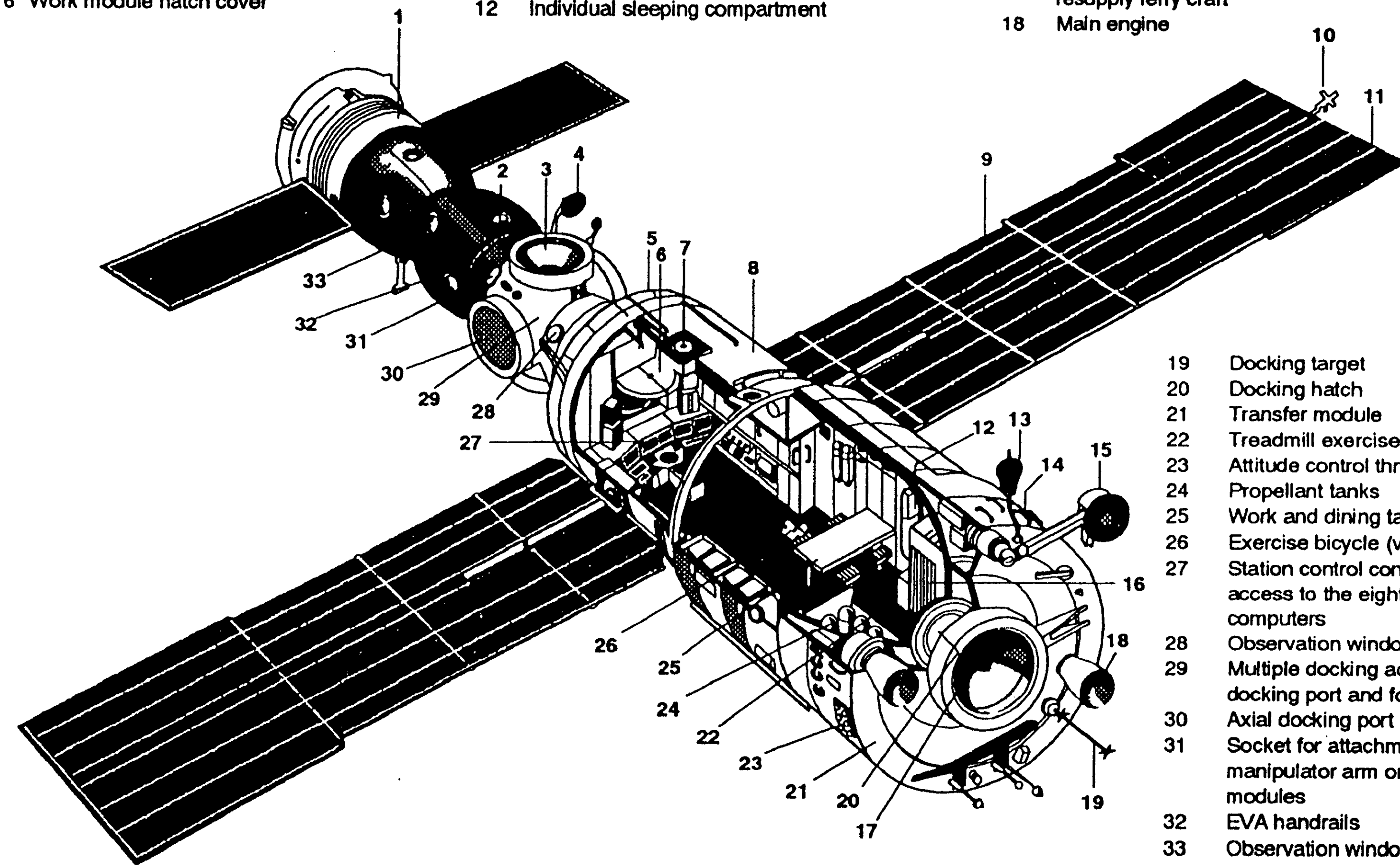


Figure E–1. Mir Complex

Mir Complex

1 Soyuz-TM craft
2 Interlock
3 Axial docking port
4 Approach and rendezvous system (Igla) antenna
5 EVA handrails
6 Work module hatch cover
7 Connection for possible auxiliary solar array
8 Mir work module
9 Solar panels, probably made of gallium arsenide (span, 29.73m; generating 9-10 kW).
10 Rendezvous antenna
11 Telemetry antenna
12 Individual sleeping compartment
13 Approach and rendezvous sytem (Igla) antenna
14 Transfer module
15 Luch relay satellite communications antenna (11/14 GHz)
16 Toliet and washing area
17 Aft docking port, primarily for Progress resupply ferry craft
18 Main engine



19 Docking target
20 Docking hatch
21 Transfer module
22 Treadmill exerciser
23 Attitude control thrusters (32)
24 Propellant tanks
25 Work and dining table
26 Exercise bicycle (veloergometer)
27 Station control consoles, provide access to the eight control computers
28 Observation window
29 Multiple docking adapter, one aft docking port and four axial ports
30 Axial docking port
31 Socket for attachment of remote manipulator arm on docking modules
32 EVA handrails
33 Observation window

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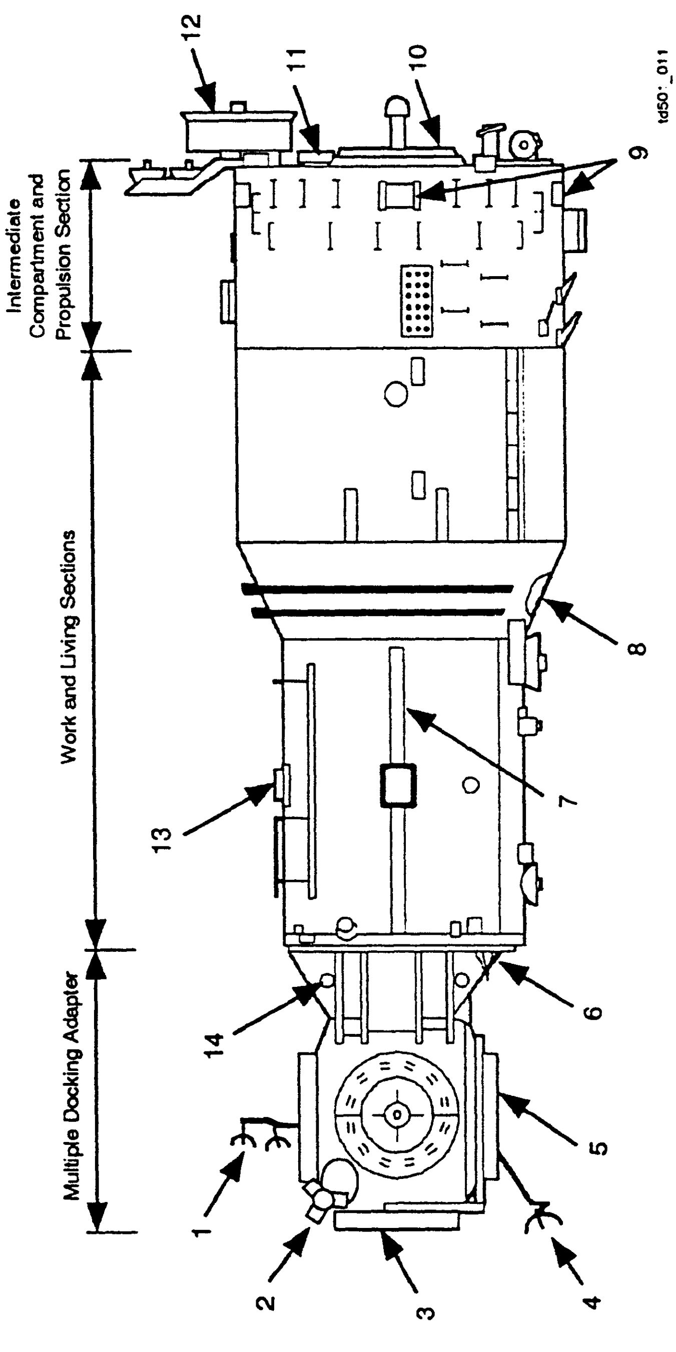
Figure E–2. Mir Complex



1. Kurs rendezvous antenna
2. Manipulator grapple
3. Front docking port
4. Kurs rendezvous antenna
5. Bottom docking port
6. Docking target
7. Solar array
8. Solar array
9. Attitude control thrusters
10. Aft docking port
11. Main engine
12. SDRN antenna
13. Solar array attach port
14. Port hole

Figure E-3. Mir Complex

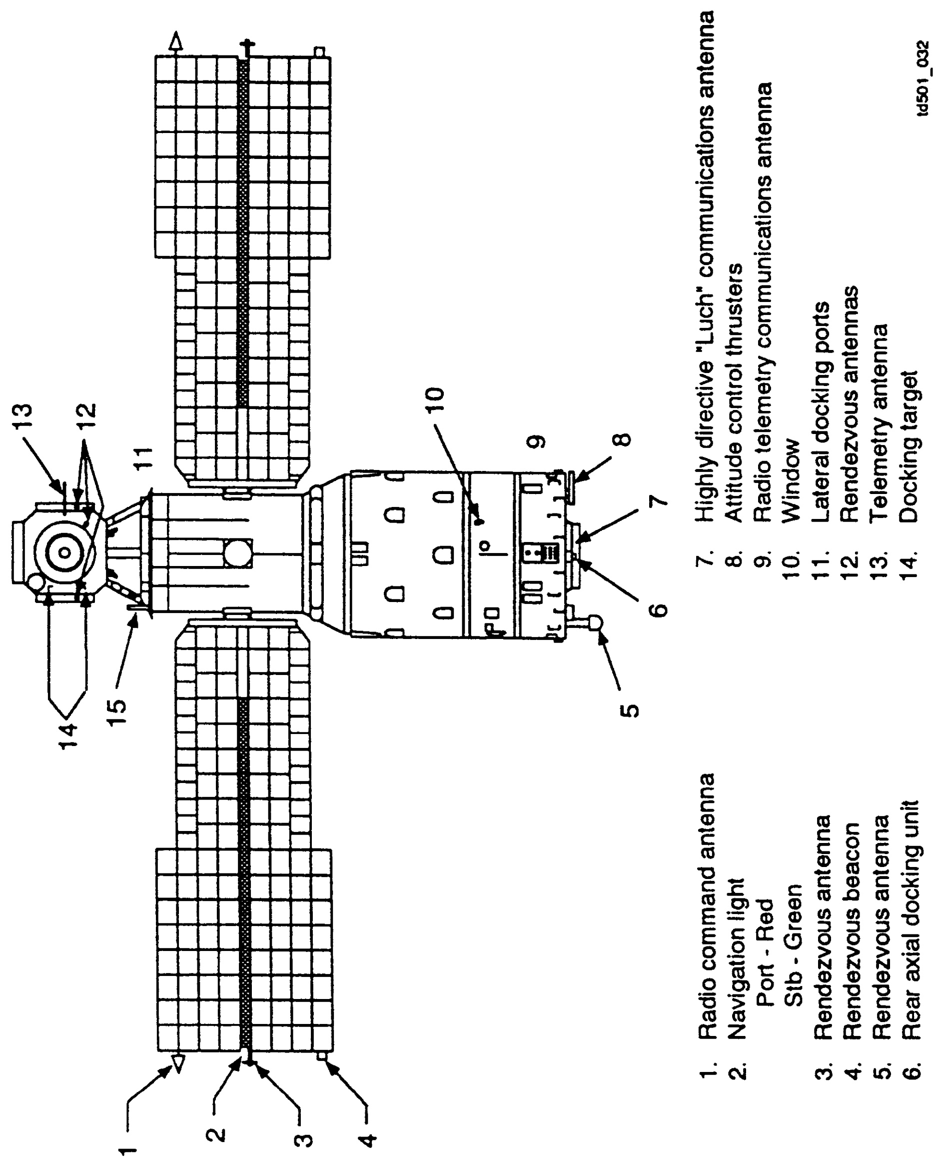
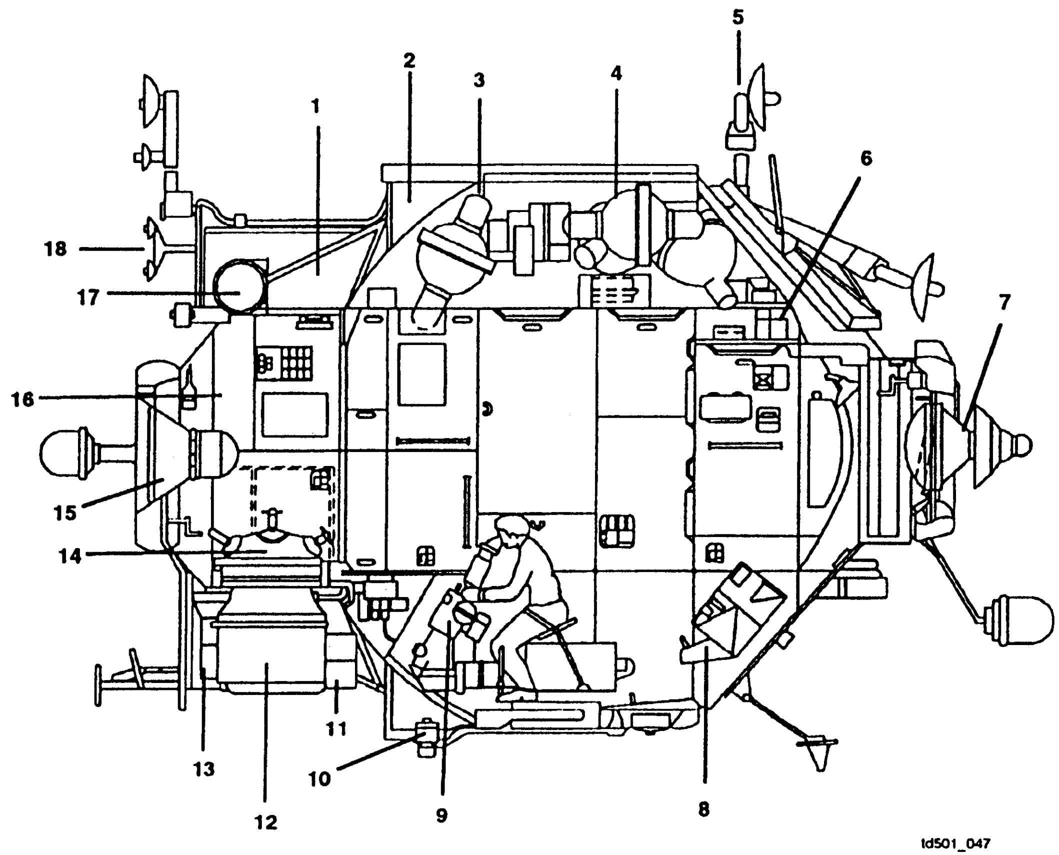


Figure E–4. Mir antenna locations



1 Compartment of scientific tools
2 Adapter of laboratory module
3 Equipment of movement module
4 Gyrodynes
5 "Igla" radiotechnical mating system
6 Onboard complex control system unit
7 Active mating assembly
8 Control station
9 Photomeasuring device
10 Optical unit of infrared vertical
11 Unit of "Pulsar" sensors
12 "Glazar" telescope
13 "Siren" spectrometer
14 Sluice chamber
15 Passive mating assembly
16 Transfer chamber
17 Magnetometer
18 "Kurs" radiotechnical mating system

Figure E–5. Kvant astrophysical module

1 Active docking unit
2 Engine installation
3 Power stabilizers of liquid fuel by hydrogenation
4 Optical star transmitter
5 Tank systems RODNIK
6 Exit outlet
7 Control post
8 Hygiene cabin
9 Water regeneration systems
10 Portable plumbing unit
11 Motion control system
12 Energy supply system
13 Food containers (or supply containers)
14 Payload container
15 Multi-zonal photo-camera
16 VIKOD equipment
17 Cosmonaut motion equipment
18 Space suit

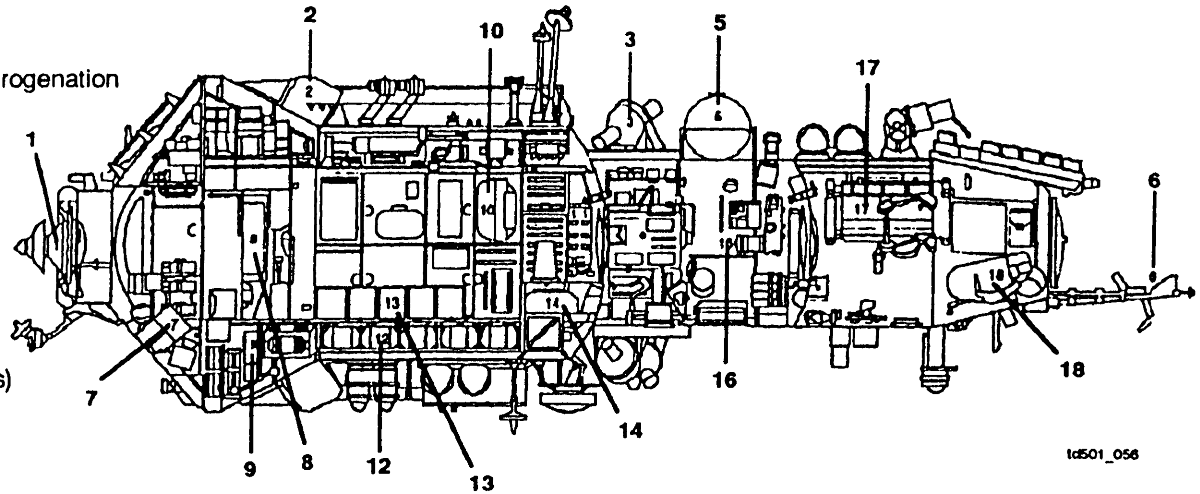


Figure E–6. Kvant–2 module

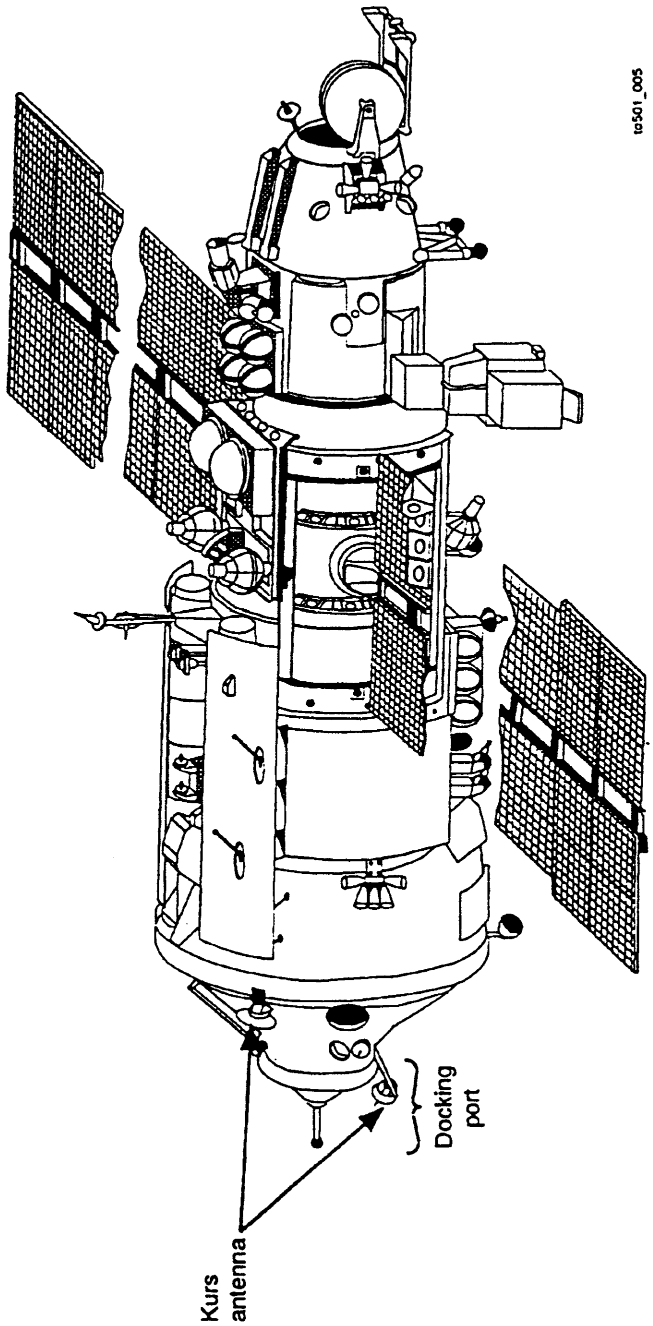
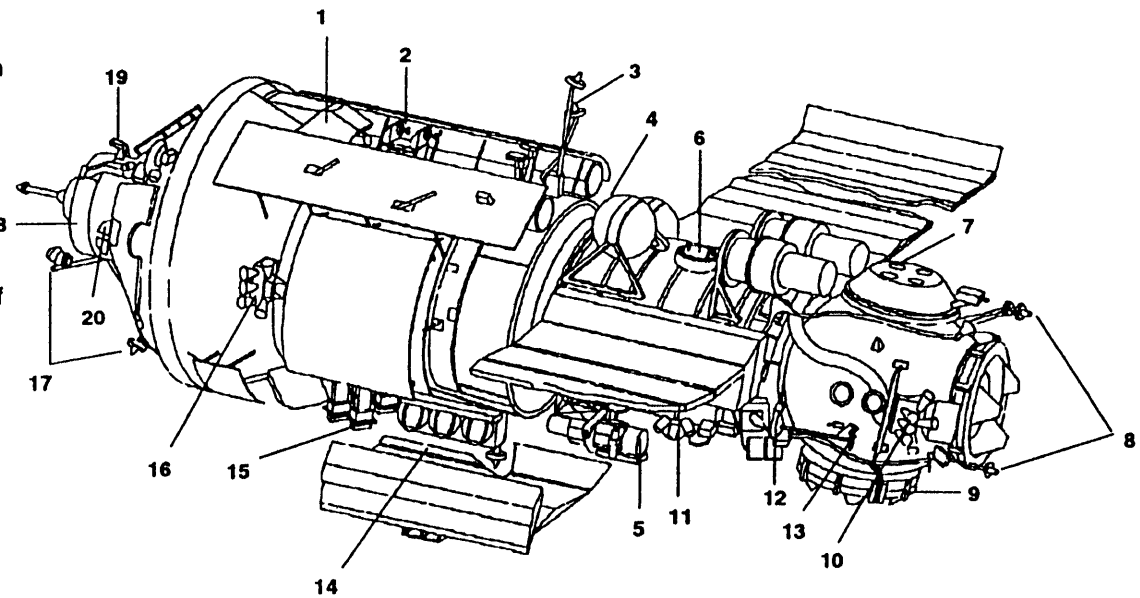


Figure E–7. Kvant–2 module

1 Correction and stabilization engine
2 Instrument of orientation to the Sun
3 Command radio line antenna
4 Tank with water of the "Rodnik" system
5 "Glazar" telescope unit
6 Freezer loading cover
7 Photo compartment
8 "Kurs" mating system antennas
9 Androgine peripherical assembly of mating
10 Mooring and stabilization engines
11 "Kseniya" equipment
12 "Marina" equipment
13 Bench mark device of mating and hovering
14 Solar battery
15 Instrument of orientation to the Earth
16 Accurate stabilization engines
17 "Kurs" mating system antennas
18 Mating assembly
19 Manipulator
20 Sensor of orientation to the Sun



Start - June 1, 1990
Mating with "Mir" orbital station - June 10, 1990

Figure E–8. Kristall technological module

1 Active docking unit
2 Engine installation
3 Telescope GLAZAR 2
4 Tank system RODNIK
5 Instrumentation MIRINA
6 Androgenous-peripheral docking assembly
7 Control post
8 ONIKS panel for the KRATER V installation
9 Running track
10 Motion control system
11 Energy supply system
12 SVET arrangement
13 RODNIK system panel armature
14 Freezer
15 KSENIA device
16 Reusable solar battery drive
17 Kristallizer ChSK-1
18 PRIRODA-5 equipment

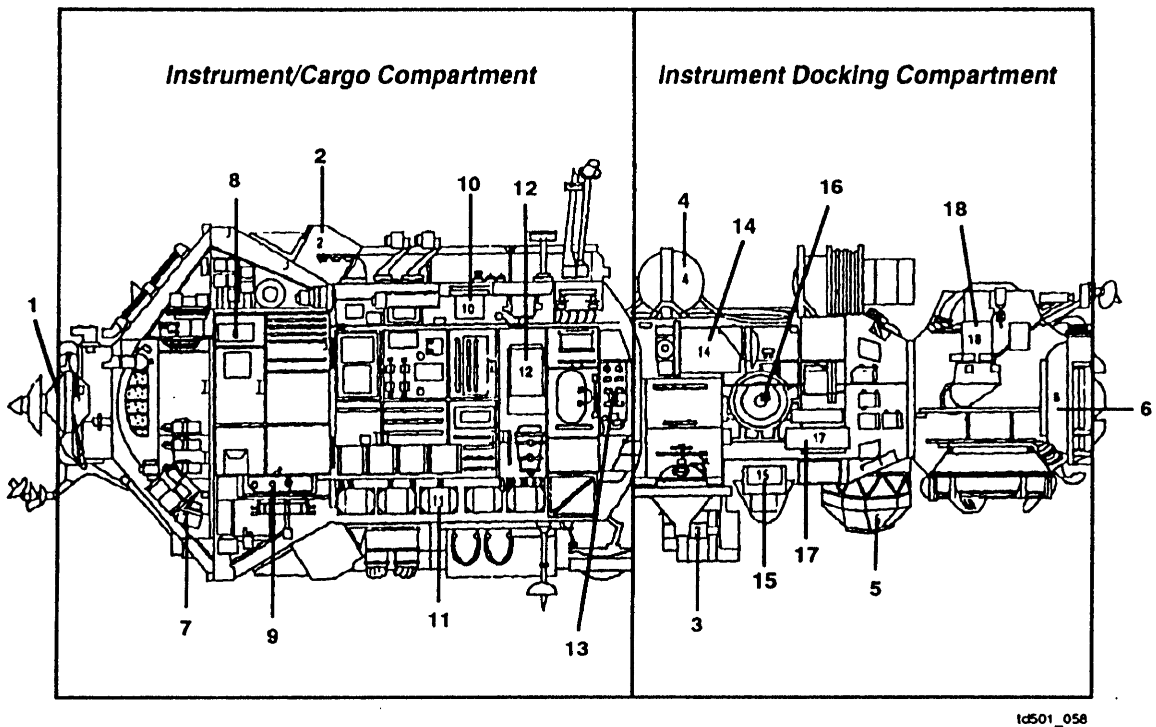


Figure E–9. Kristall module

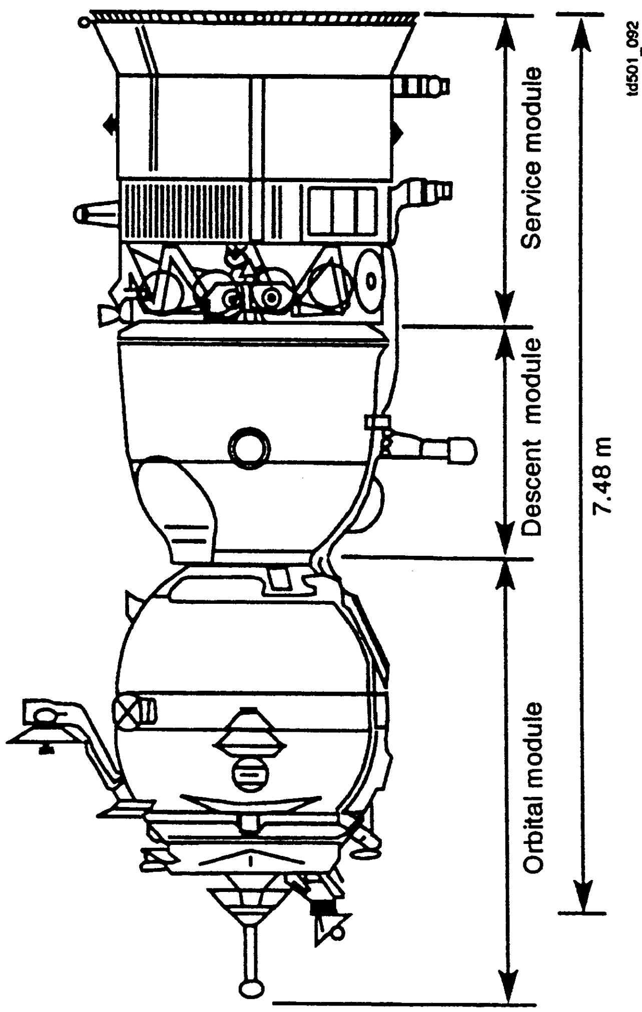


Figure E-10. Orbit, Descent, and Service modules

Soyuz-T

The New Soyuz-T space station ferry was identified by the Soviets at the end of 1979 and first flew with men the following year. Although it retains the basic Soyuz design, it has been greatly modified.

1 Orbital module, which appears to be little modified from the earlier Soyuz variants.
2 A pair of solar panels, reinstated to the Soyuz ferry after not being used for 8 years.
3 Re-designed instrument module, with the forward section containing much of the electrical equipment.
4 A new unified propulsion system, which allows the attitude control engines to be operated from the same propellant supply as the new main propulsion system; it seems probable that a pair of the Soyuz-T main engines were used for the Salyut 6, Salyut 7, and Mir main propulsion systems.
5 Redesigned descent module, which allows a return to three-person crews. For the first time there is sufficient room for three people to sit in this module wearing pressure suits.

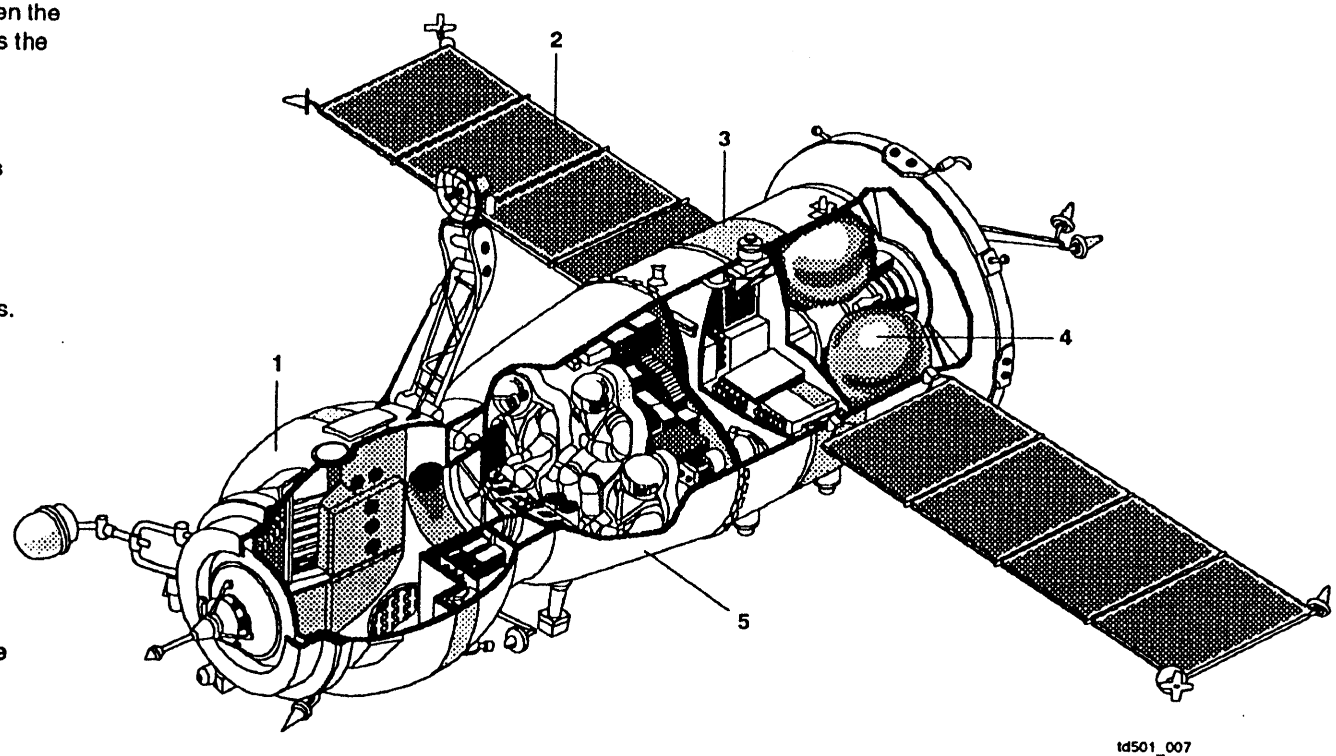


Figure E–11. Soyuz–T

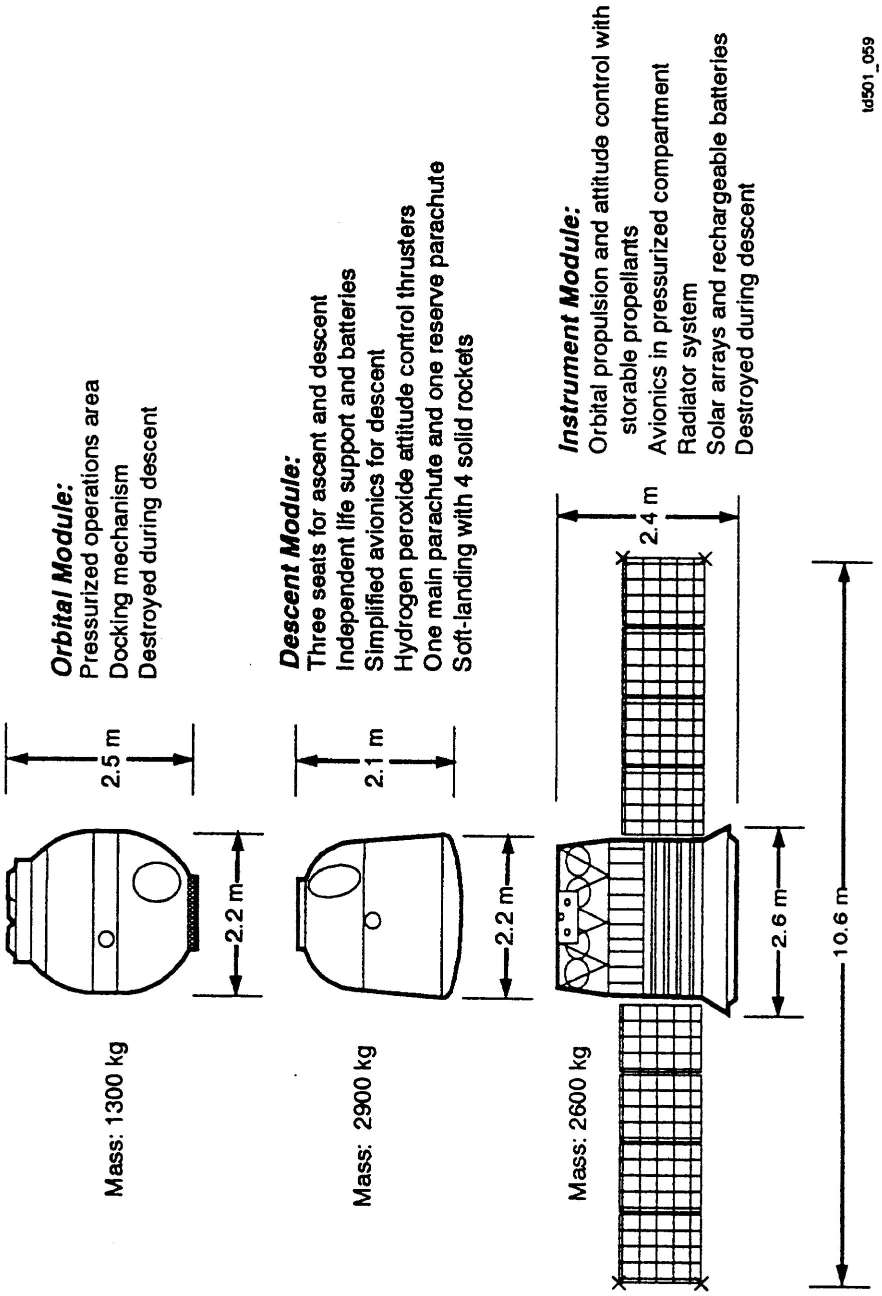


Figure E–12. Soyuz spacecraft modules

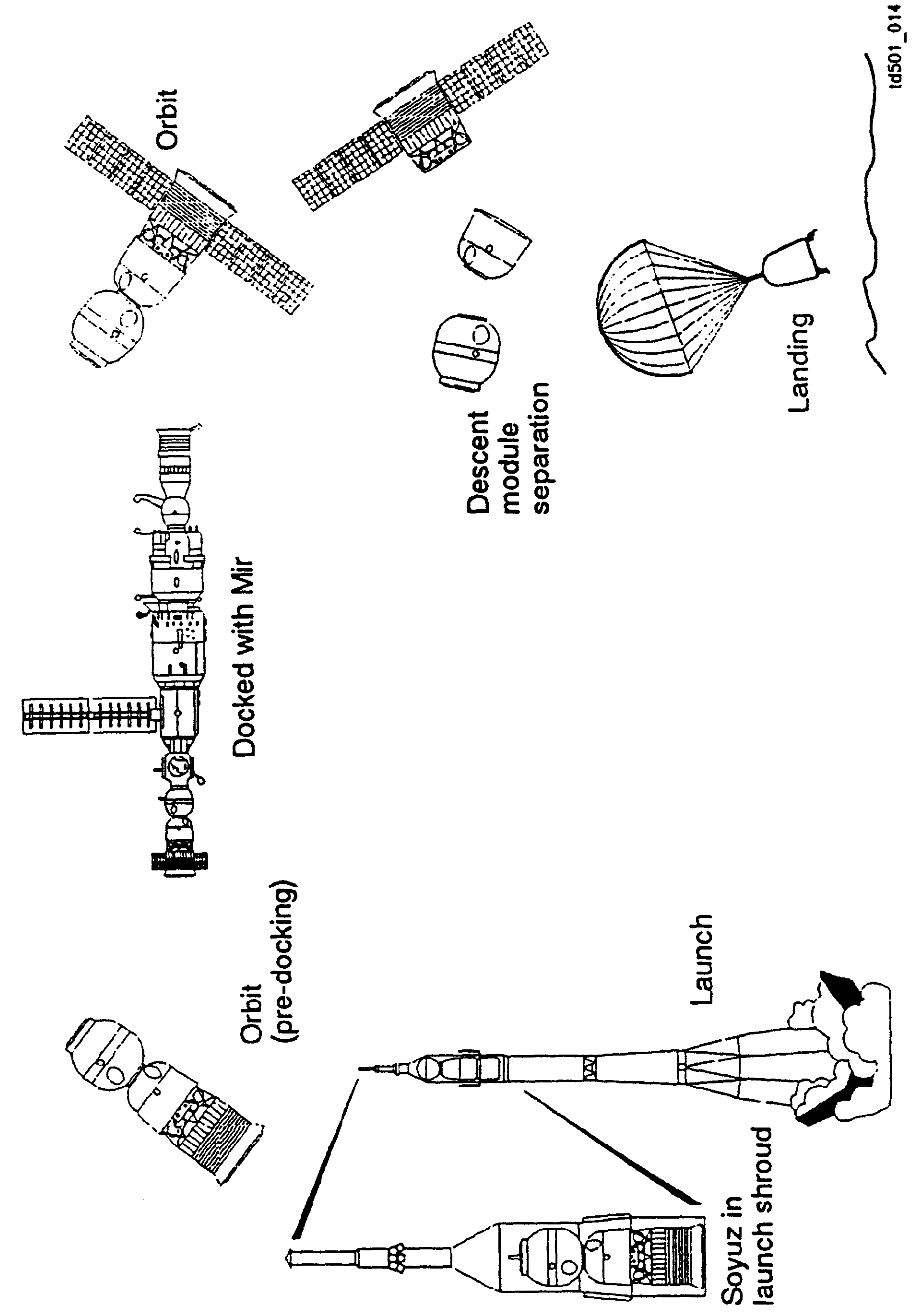


Figure E–13. Soyuz launch through landing

Progress

This cutaway of the Progress resupply craft clearly shows its Soyuz derivation.

1 Short range radar transponder
2 Modified Soyuz orbital module with cargo for the Salyut crew
3 Long range radar transponder
4 Antenna
5 Soyuz Instrument module
6 Soyuz KTDU-35 propulsion system
7 Equipment for the automatic control of Progress
8 Tanks for the propellant to be transferred to Salyut and nitrogen pressurant gas
9 Docking probe

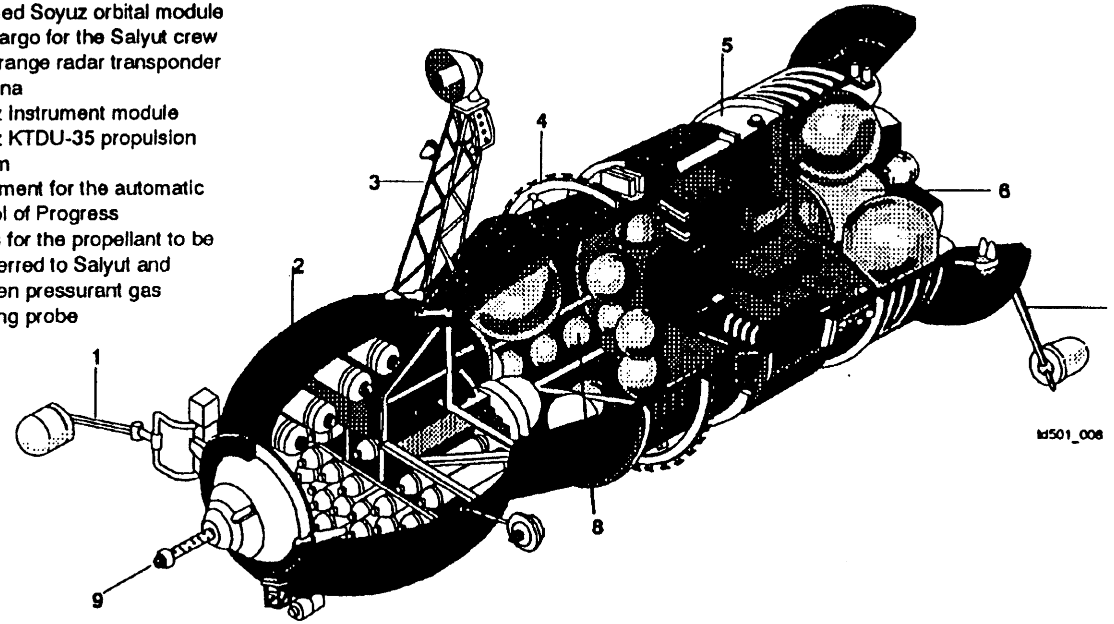


Figure E–5. 14. Progress

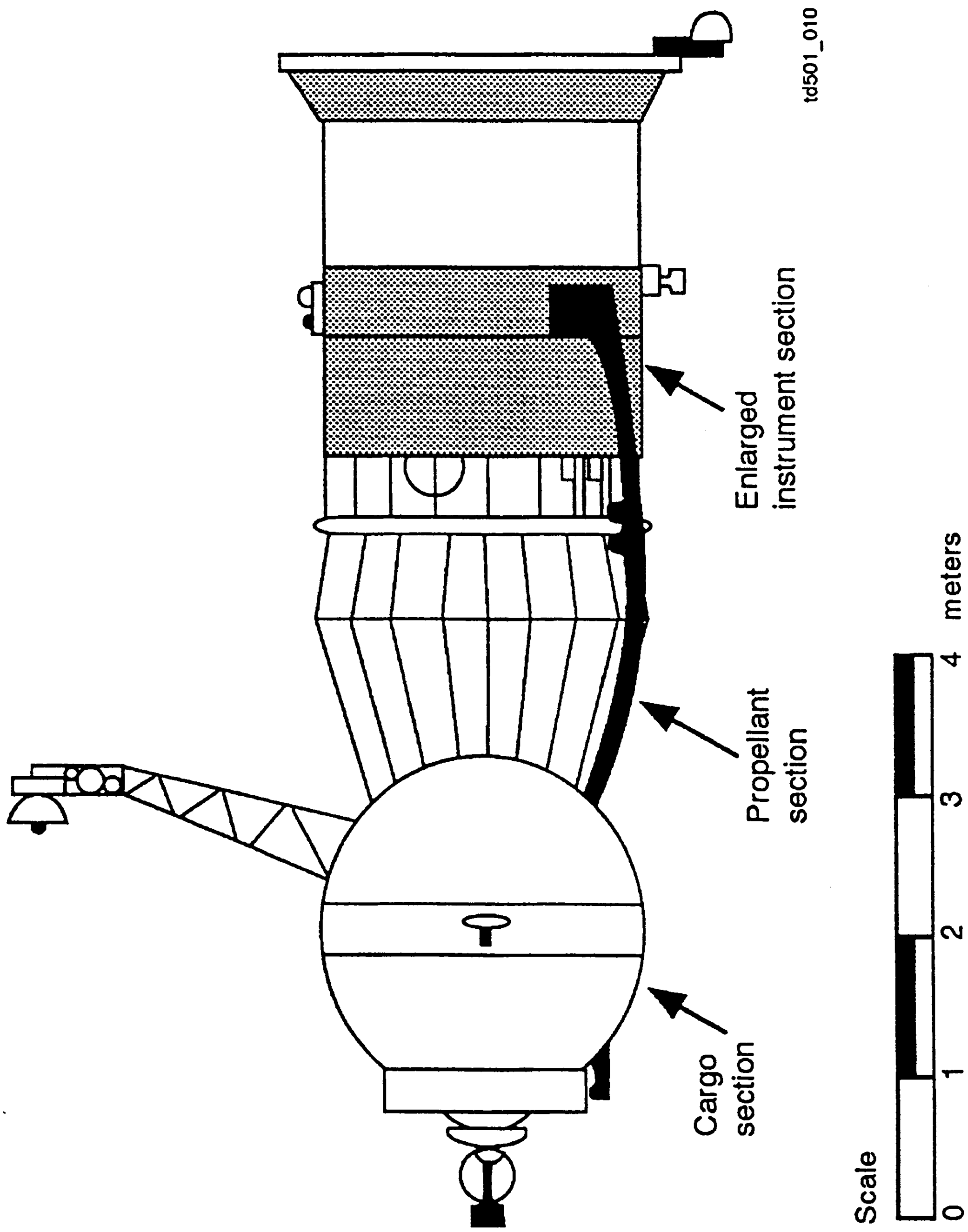


Figure E–15. Progress

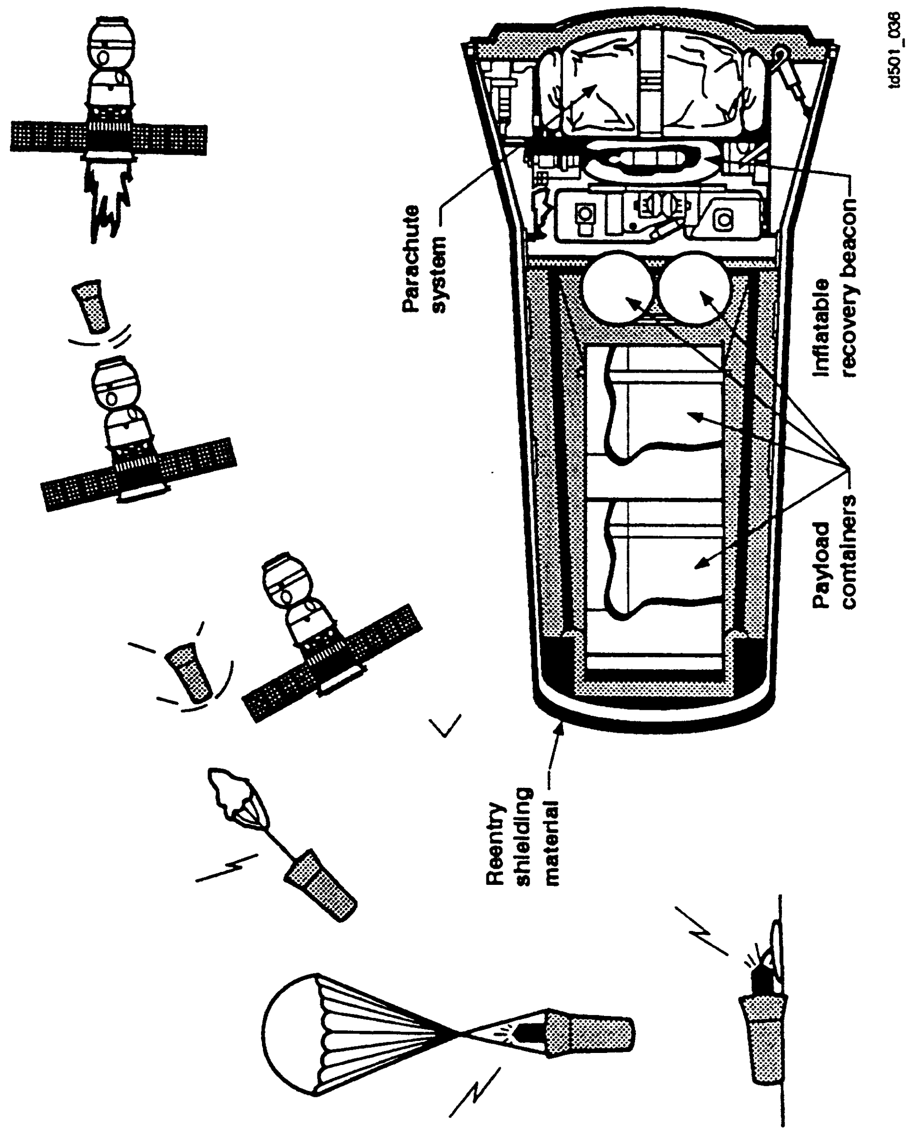
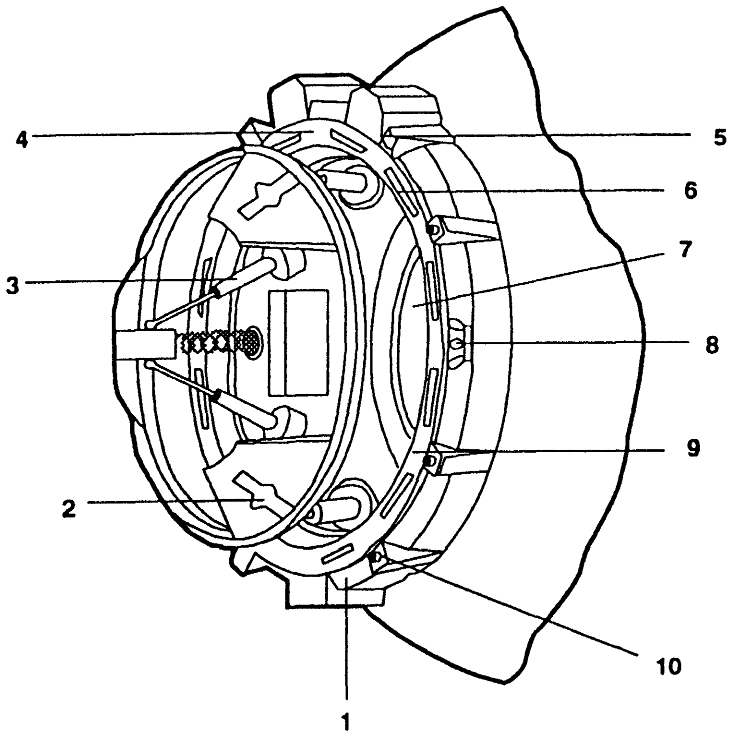


Figure E-16. Progress recovery capsule



Androgynous peripheral docking unit   APAS-89

1	Frame; Hull	6	Latches; Bolts
2	Ring latches	7	Hatch cover
3	Shock absorbers	8	Latches on frame
4	Docking frame	9	Joint compress/tightener
5	Hydraulic section	10	Electrical section

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Figure E–17. Androgynous peripheral docking unit

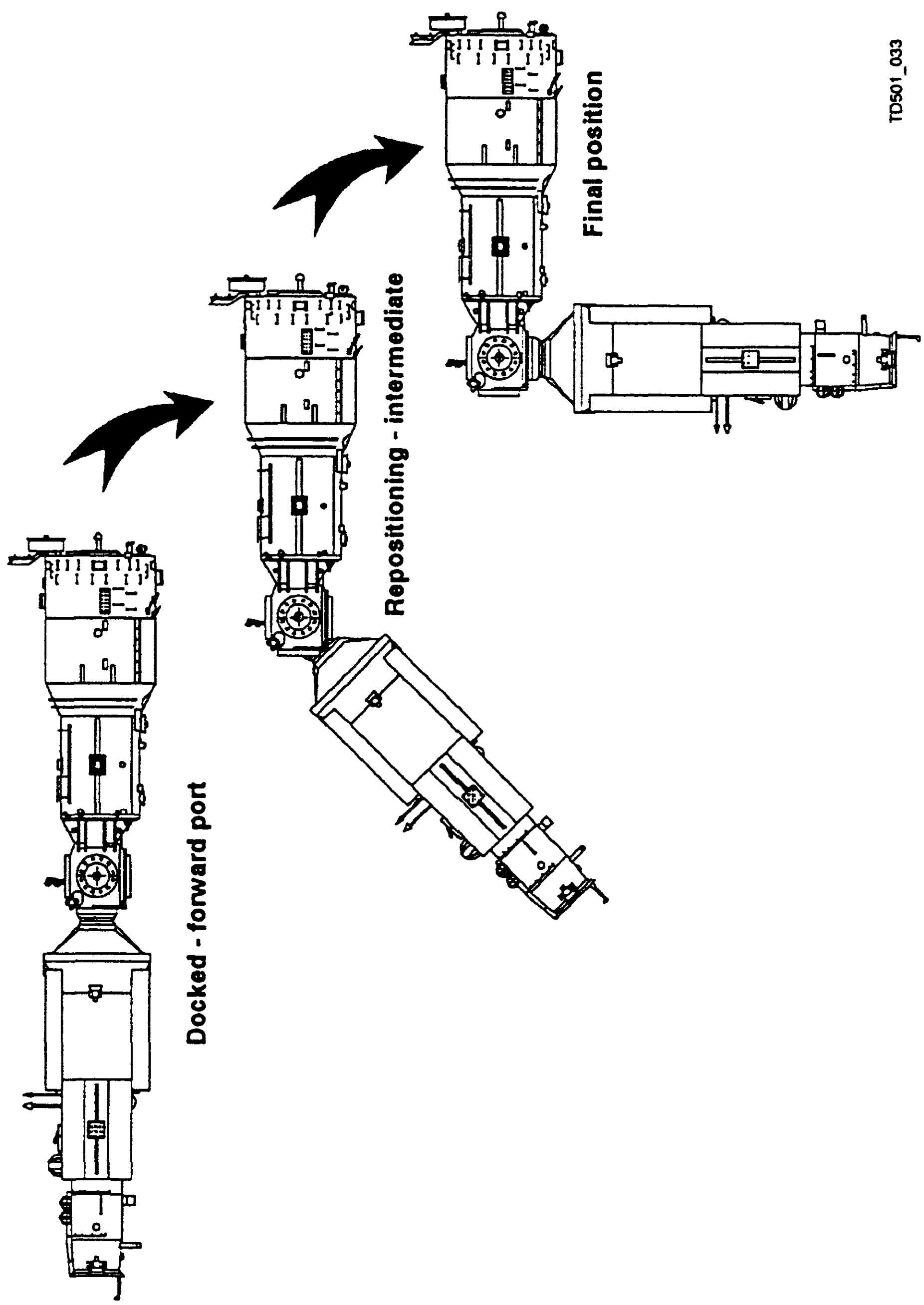


Figure E–18. Expansion module repositioning

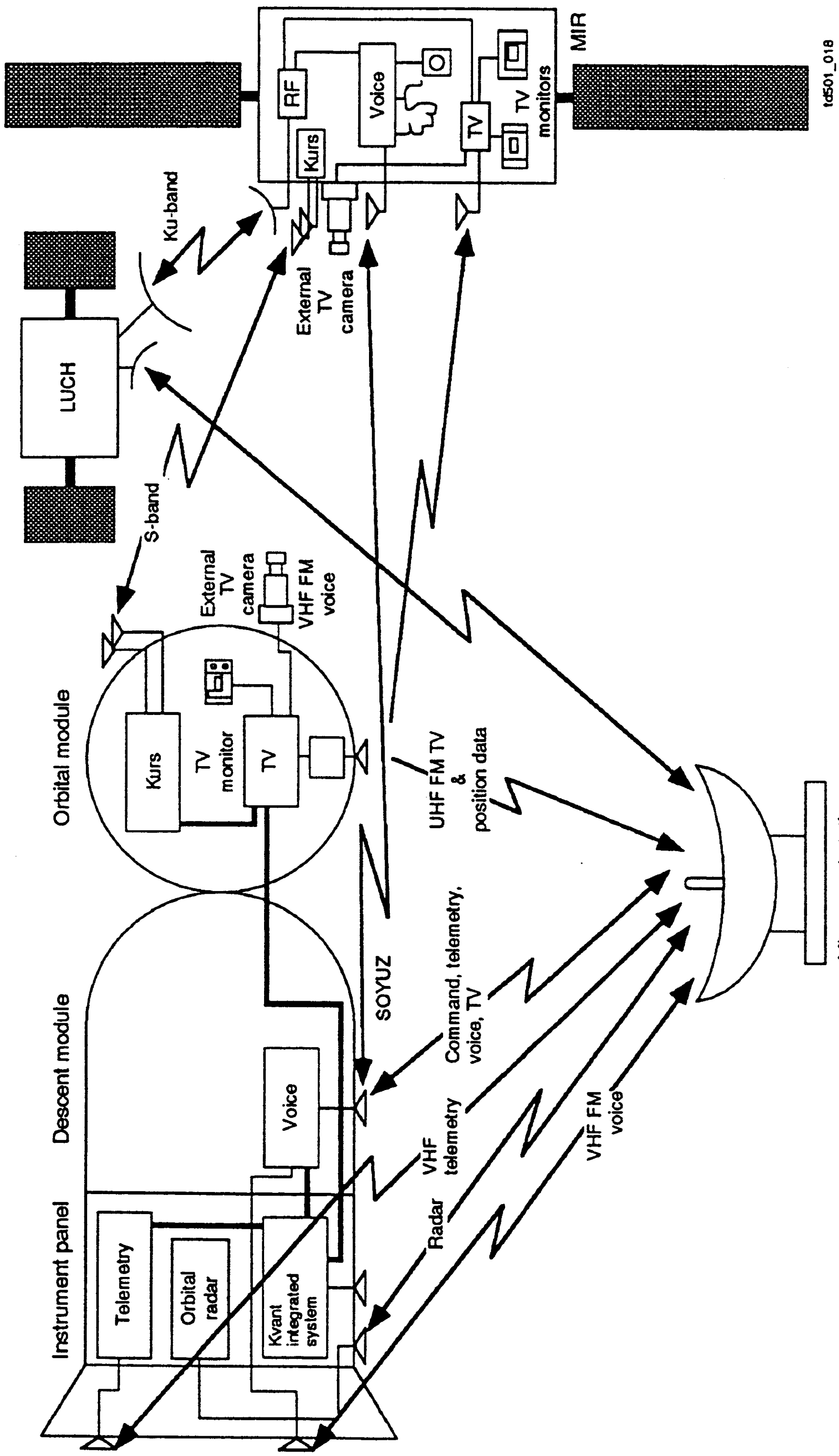


Figure E–19. C&T between Soyuz and ground station

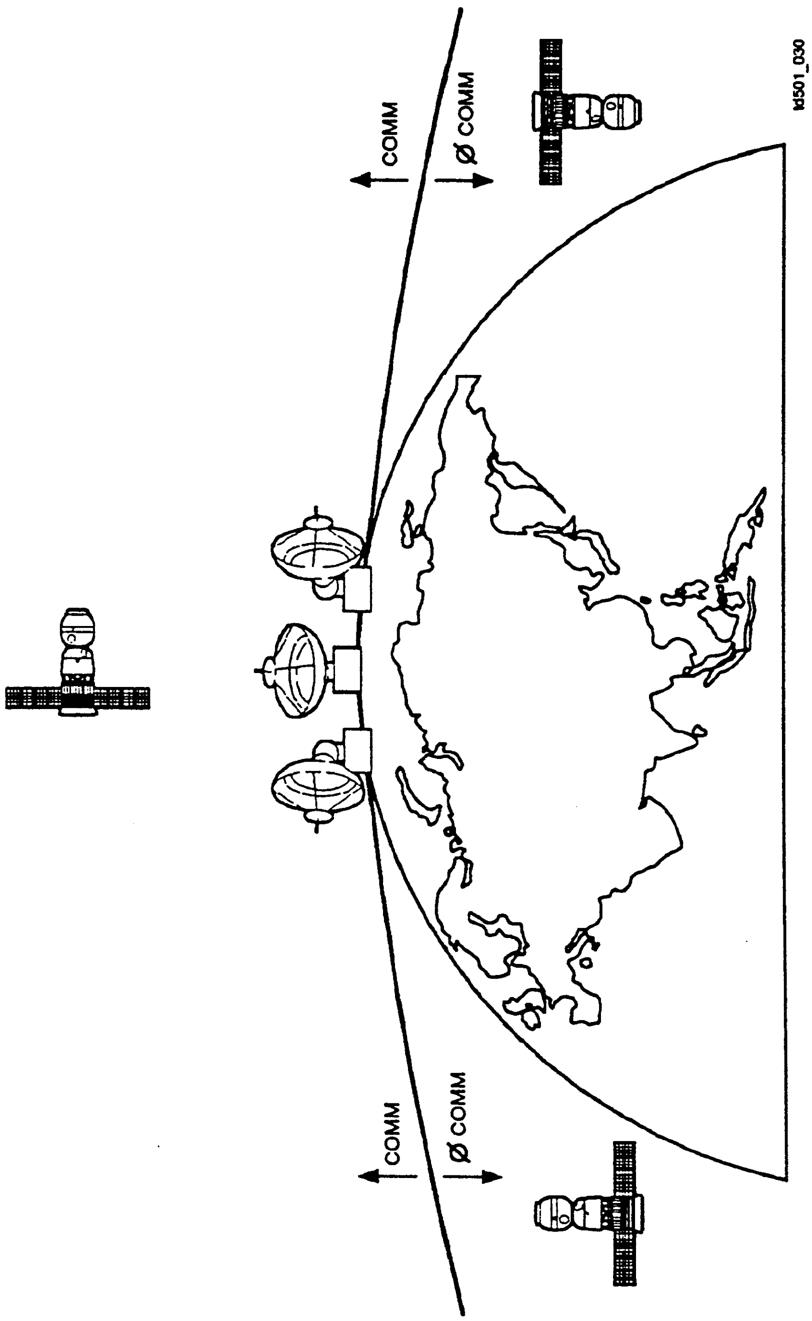


Figure E–20. Line of sight limitation

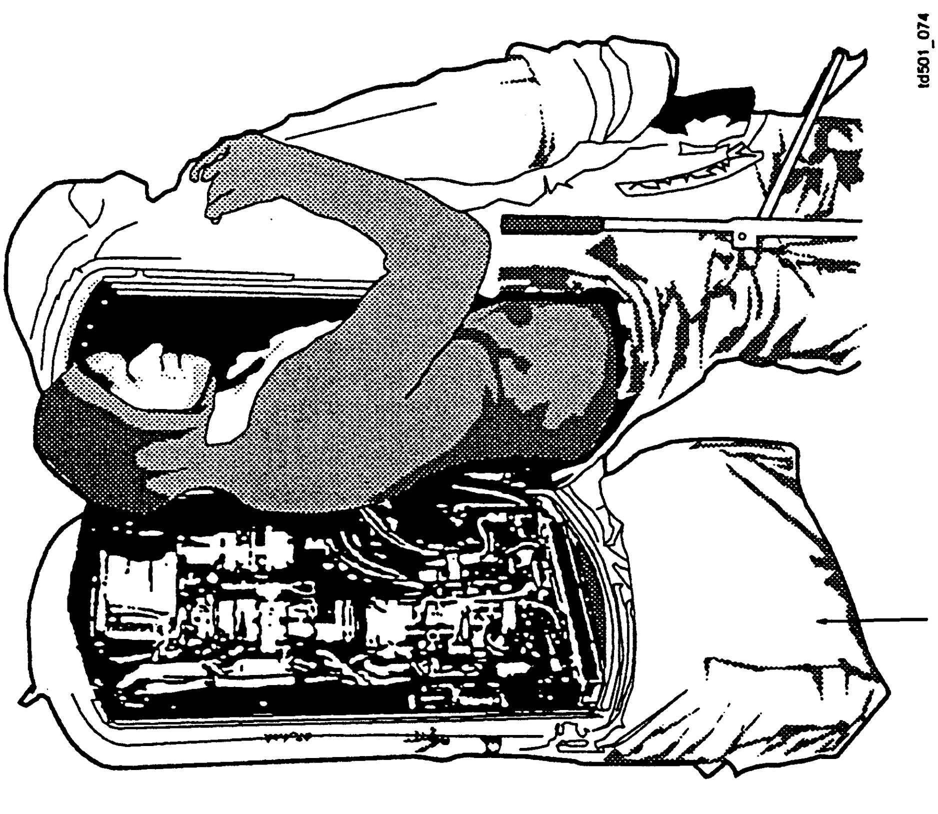
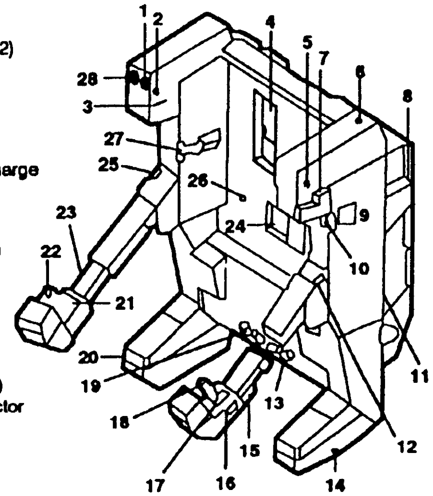
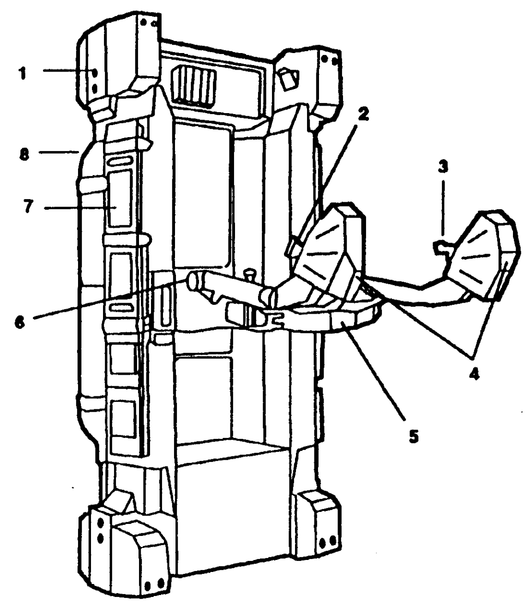


Figure E–21. PLSS of the Mir Complex EVA suit



1 Main power Switch (2)
2 GN_2 Pressure Guage (2)
3 Thruster Cue (2)
4 Battery (2)
5 Locator Light Switch
6 Thrusters (24)
7 GN_2 Cross Feed/Recharge Valve (2)
8 GN_2 Tanks (2)
9 Ancil Equipment Attach Points (3 each side)
10 Propellant Recharge Point (2)
11 GSE Attach Points (4 each side)
12 Arm Hinge and Lock (2)
13 External Power Connector
14 Locator Light
15 Arm Angle Adjustment Lever
16 Arm Length Adjustment Lever (2)
17 Control Mode and Gyro Power Switches
18 Translation Hand Controller
19 External Power Switches
20 Body Side Towers ((2) aluminum sheet metal constuction/mechanical attach)
21 CEO and ISO Valve Switches
22 Rotational Hand Controller
23 Adjustable Arm (2)
24 Circuit Breakers (8)
25 Arm Stowage Lock
26 PLSS Contact Button (4)
27 PLSS Latch (2)
28 MMU/PLSS Releasing Ring (2)

U. S. MMU



1 Thrusters (32)
2 Rotational Control Knob
3 Translation Control Stick
4 Hand Controllers (2)
5 Frame with Attachment Points for Ancilliary Equipment
6 Arm Hinge (2)
7 Battery (2)
8 Compressed Air Tanks (2)

Soviet SPK

Figure E–22. Comparison between U.S. and Russian MMUs

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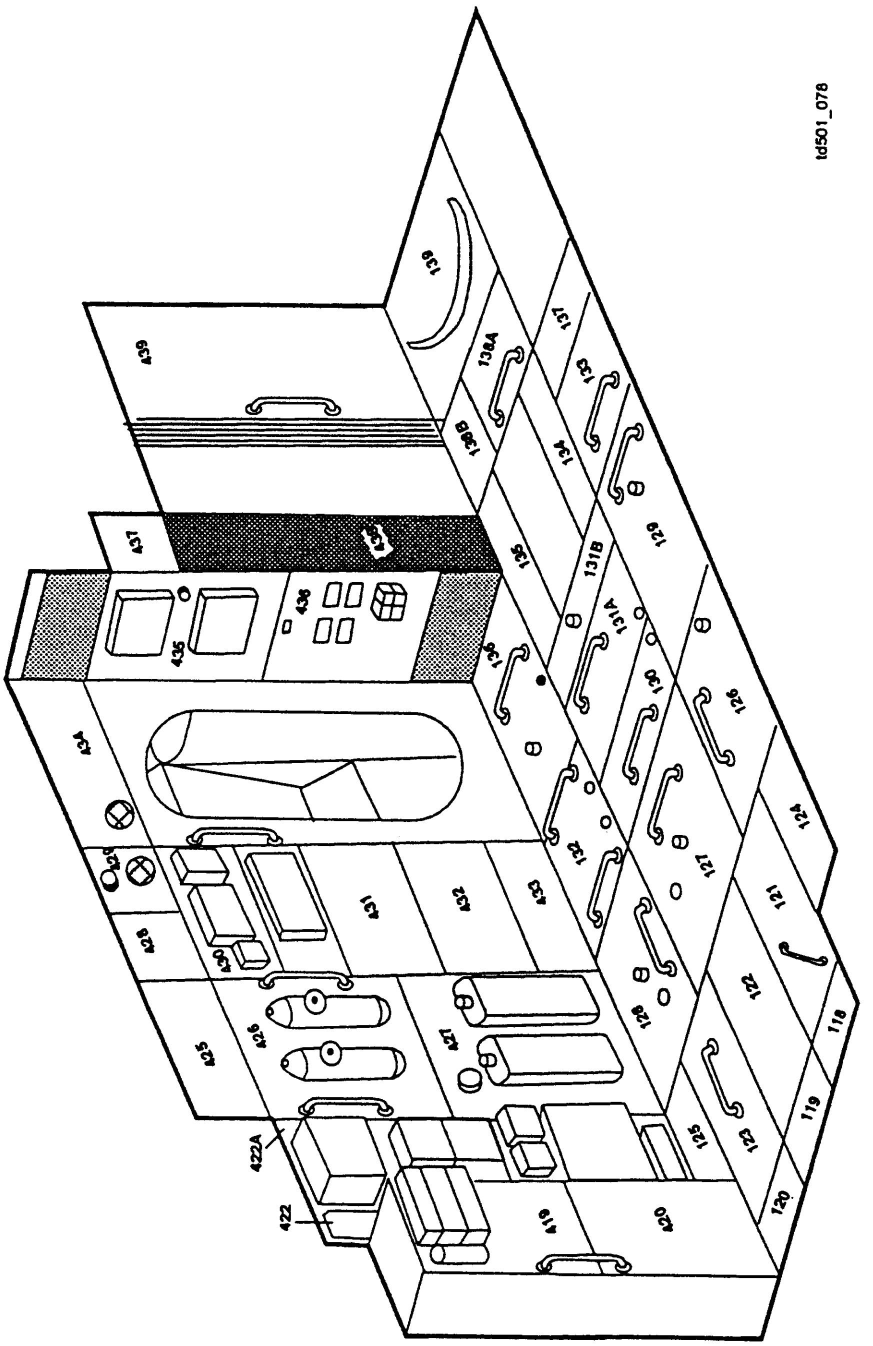

Figure E–23. Location coding side 4 looking aft

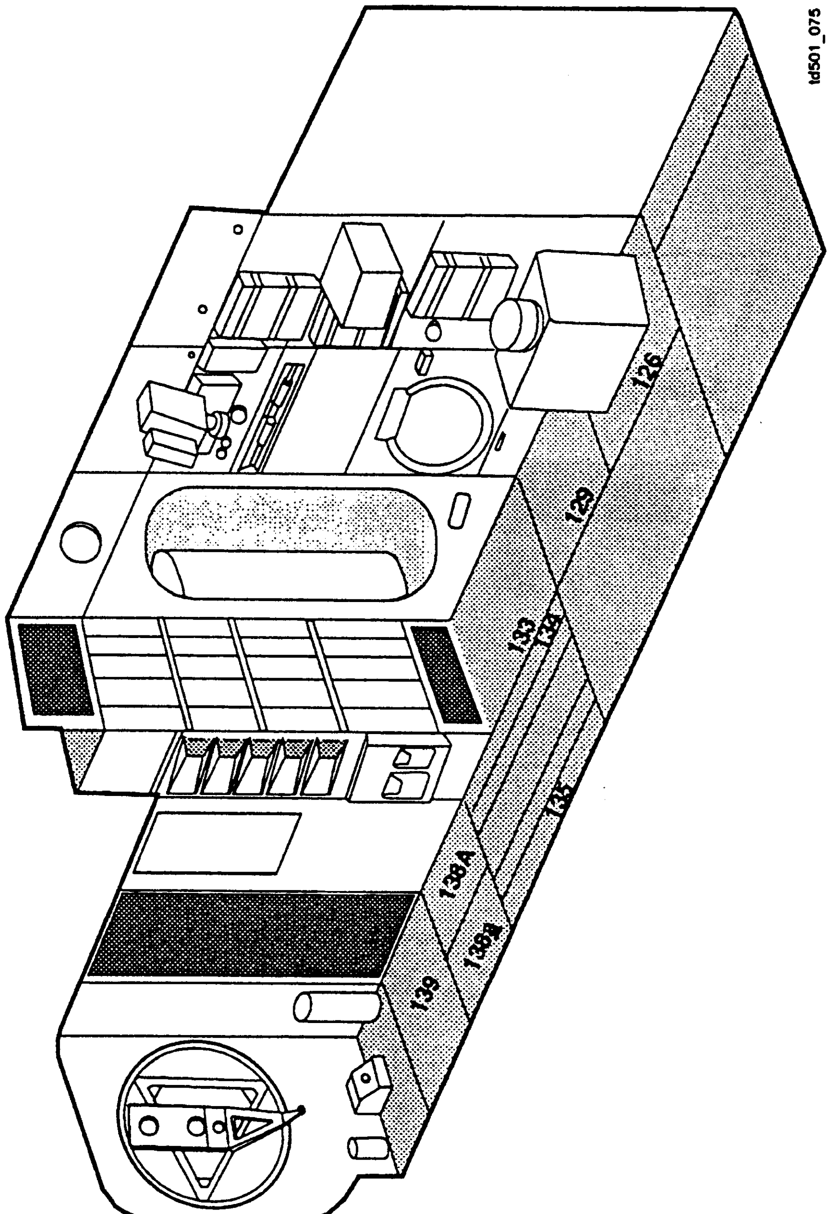

Figure E–24. Location coding side 2 looking aft

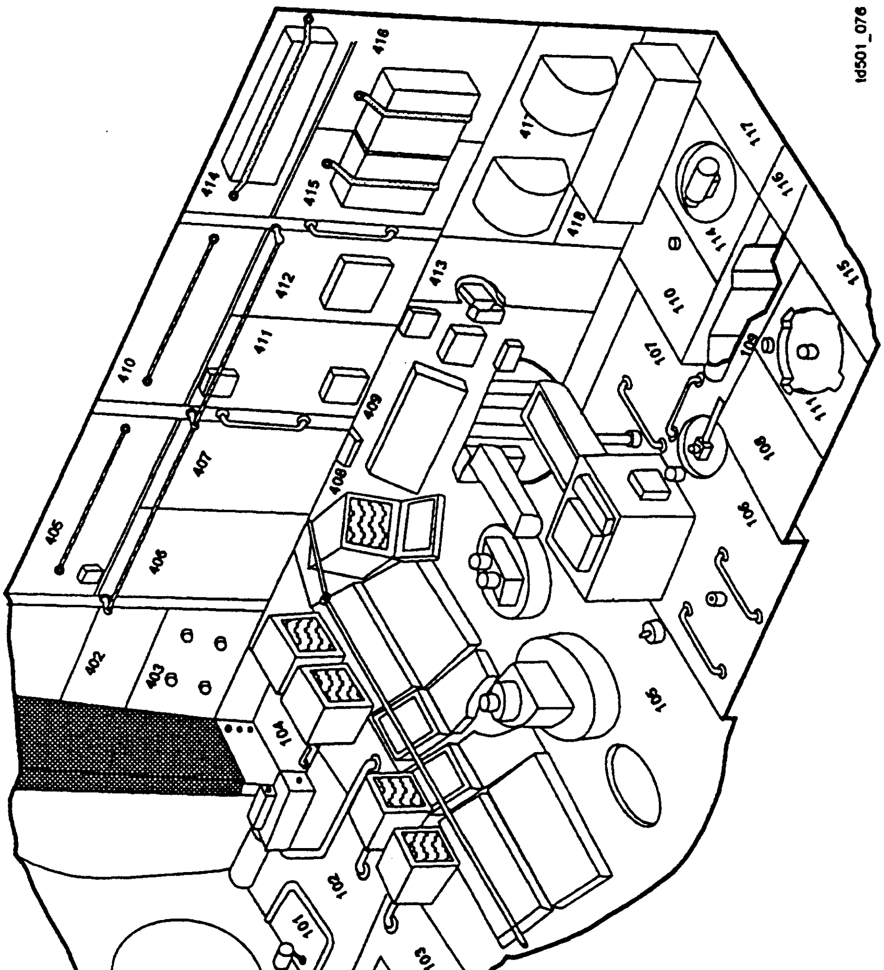

Figure E–25. Location coding side 4 looking forward

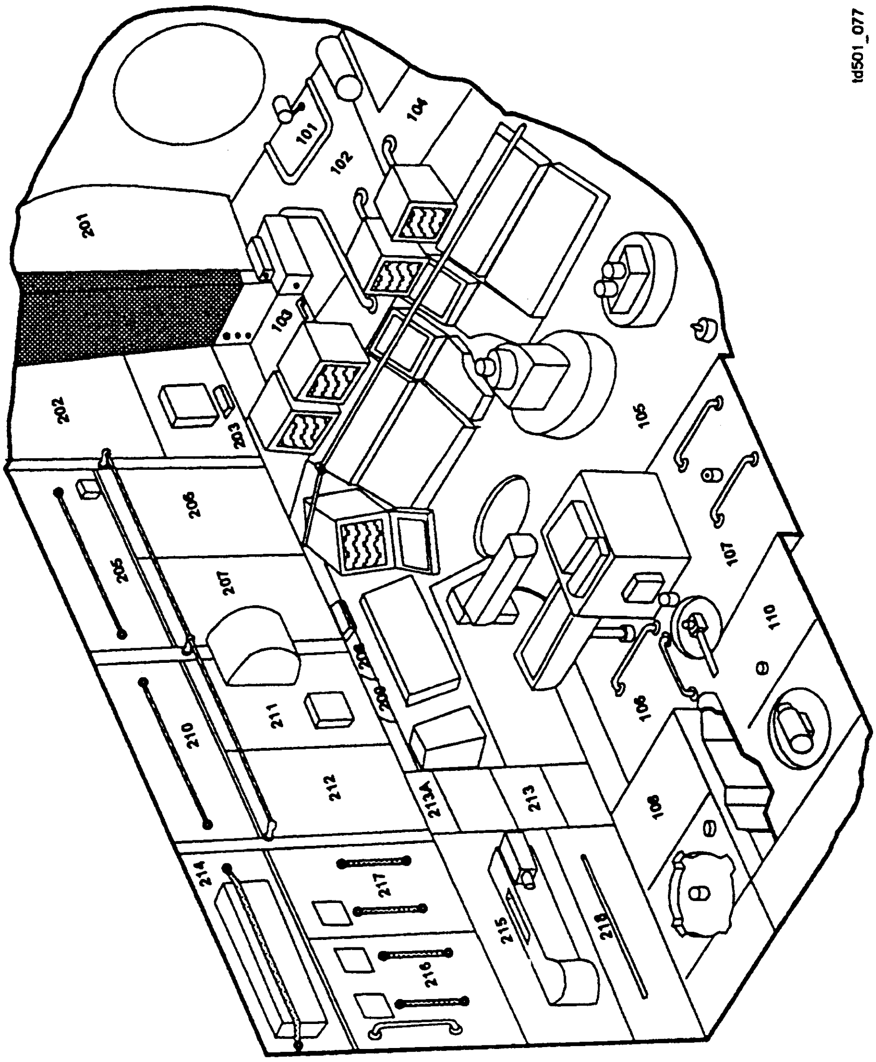

Figure E–26. Location coding side 2 looking forward