Appendixes

Appendix A:

The Soviet Salyut Space Program: Space Station, Spacecraft, Support and Training Facilities

Material provided to OTA by Dr. Balayan, Vice Chairman of the Intercosmos Council of the U.S.S.R. Academy of Sciences.

The Salyut Orbital Scientific Station

The creation of the Salyut orbital stations is an important stage in the development of Soviet cosmonautics, intended to increase the length of both manned and unmanned flights.

The total mass of the orbiting scientific complex, including two transport ships, is 32,500 kilograms (kg); the mass of the space station in orbit is 18,900 kg, the mass of the transport ship in orbit is 6,800 kg. * The dimensions are as follows: 1) total length docked with two transport ships 29 meters (m), 2) station length 15 m, 3) maximum station diameter 4.15 m, and 4) maximum transverse station dimension with solar panels open 17 m.

More than 20 portholes are provided for the conduct of scientific experiments, visual observation, and still and motion picture photography from the compartments of the station.

Hatches in the docking units are used to allow the crew to move between the transport ship and the station. After docking, the crew can work and rest both in the compartments of the station and in the transport ships, moving through these hatches.

Terrestrial conditions are maintained in the sections of the station in orbit—the same gas composition, atmospheric temperature and pressure, providing the necessary conditions for the cosmonauts' activities.

Composition and Arrangement of Orbital Station

The station consists of five compartments: transit, operations, scientific apparatus, intermediate, and equipment compartments.

During powered flight the external elements of the transit section and parts of the small-diameter operations section are protected from aerodynamic forces by fairings which are later jettisoned.

*These masses appear to be related to Salyut 6 and Soyuz craft

The scientific equipment installed in the scientific apparatus section is protected during powered flight by a scientific apparatus cover which is also jettisoned after orbital insertion.

The transit section is bounded by conical and cylindrical (2 m diameter) sealed envelopes.

The passive portion of the docking unit—the "cone" —is installed at the conical end of the section (the active "rod" docking unit is installed on the spacecraft), while the cylindrical portion of the section adjoins the operations section of the orbital unit.

There is a hatch in the conical envelope of the transit section to allow servicing of the station on Earth and to allow the crew to exit into space. The outer surface of the transit section carries:

- antenna of the approach and docking unit;
- optical lamps for orientation during manual docking of spacecraft;
- external television cameras;
- panels with temperature regulation units;
- gas storage cylinders of the life-support system containing air;
- ionic and solar sensors of the station's orientation system;
- handles and restrainers for cosmonauts in spacesuits performing space walks; and
- panels for the study of micrometeorites, contamination of optical surfaces, and properties of rubber and biologic polymers.

The outside of the transit section and the apparatus installed on it are covered with a vacuum-shield thermal insulation to maintain the required temperature conditions.

Within the transit section, which is used as a lock, are spacesuits, panels, equipment and attachment devices to support space walks.

There are seven portholes in the transit section. Some carry instruments for astro-orientation of the station. These instruments, together with the corresponding control panels and knobs which control the orientation of the station, form two control posts (post Nos. 5 and 6).

The transit section connects to the operations section of the station through a sealed airtight hatch. The operations sections consists of two cylindrical shells (2.9 m diameter and 3.5 m length, and 4.1 m diameter and 2.7 m length) connected by a conical section (1.2 m in length).

The cylindrical shells have spherical ends. The posterior end has a hatch which connects the operations sections with the intermediate chamber.

In the operations section, equipment is arranged along the section forming a common passageway beside the equipment, with instruments and equipment located to the left and right. The instruments and equipment are installed on standard racks which form the frame of the interior,

Most of the monitoring and control systems and scientific apparatus of the station are in the operations section. The apparatus with which the station crew works directly is grouped by functional purpose in five control posts (there are two additional control posts in the transit section, as **was** mentioned earlier).

Post No. 1 is the central control post of the station, where control of the main station systems is concentrated. It is located in the lower portion of the operations section (in the small diameter area). This post has two working locations equipped with chairs (for restraint), communications equipment, control panels, a lever to control the angular position of the station in space, optical sites of the orientation system, and portholes with no equipment.

To the left and right of the control panel are the regenerator cartridges of the station's gas-mixture support system, as well as the refrigeration and drying units of the temperature control system. Near the forward end of the operations section beyond control panel No. 1 are the gyroscopic instruments of the orientation and motion control system, mounted on a rigid frame.

Post No. 2 (the astropost) is also in the lower, small diameter portion of the operations section, closer to its conical portion. This post is used for astro-orientation and astro-navigation of the station. The post is equipped with communications equipment, an orientation control panel, and astro-instruments (installed on two portholes).

Between post Nos. 1 and 2 in the small diameter end of the operations section is the area where the crew eat and rest. In this area is a table with special devices for heating food. A drinking water container is attached to the table. Along the right side in this area is the system which regenerates water from atmospheric moisture condensate, The cosmonauts obtain hot and cold water from this system. Behind the interior panels on the left side is the onboard computer apparatus. The cosmonauts can perform minor preventive repair of equipment on the table in this area, for which they have a special onboard toolkit available.

Post No. 3 is intended to control the apparatus located in the scientific equipment section. This post is located in the large diameter portion of the operations section in its lower part near the rear end. Control panels, communications equipment, and retainers are installed here,

The instrument zone comtains the onboard radio system, radio telemetry system, and power supply system control apparatus. Near the aft end of the operations section on the left and right sides are the crew's bunks, and in the instrument arc a there are food storage containers.

In the upper portion Of the operations section (near the aft end) are two locks for jettisoning the crew's wastes into space. Wastes are collected in special containers and, after they are ejected from the lock chamber, burn up in the atmosphere.

On the aft end of the operations section is the head. It is separated from the remaining portion of the operations section and has forced ventilation. Beside it is a vacuum cleaner, dust filters, storage for water, linens, and other life-support system consumables.

In the forward, larger-diameter portion of the operations section is a system allowing the crew to shower periodically.

Post No. 4 is in the lower central portion of the operations section near the conical shell. Here is the equipment used for most of the medical experiments, still and motion picture cameras, and the scientific apparatus control panel. This post has cosmonaut restrainers and communications equipment.

Near post No. 4 is the system used to prevent ill effects of weightlessness on the cosmonauts. It includes:

- a treadmill and other devices for physical exercise;
- a bicycle ergometer;
- a pneumatic vacuum suit to create low pressure on the lower portion of the body; and
- a muscle tissue stimulation apparatus,

One of the two portholes at post No. 4 carries an MKF-6M multiple-zone survey camera manufactured by Karl Zeis Jena of East Germany with electronics and control panel.

On the left and right sides near post No. 4 are the refrigeration and drying units of the temperature control system, the onboarc radio apparatus, electronic units of the orientation system, and station movement control system.

Post No. 7 works in cooperation with the scientific equipment control post and water regeneration system control, This post is located in the central portion of the small diameter operations section.

Control panels are mounted on the interior to the left and right; the cosmonaut who works here is restrained in a reinforced seat.

All control panels and cosmonaut working locations are equipped with internal loudspeaker communications devices and daylight lamps. Other lamps are used to create general illumination in the living space. During still and motion picture photography and television reports, the cosmonauts turn on additional lights to provide the necessary illumination for the cameras.

Most of the outer surface of the small diameter operations section is covered with the temperature control system's radiator. On the left and right sides and in the upper portions of the section are three solar battery panels. Special drives rotate the panels toward the Sun at all times. In the forward portion of the operations section are the solar battery orientation system sensors, which determine the position of the Sun in the forward hemisphere as the station moves. Outside the lower portion of the small diameter operations section are the automatic station orientation instruments (an infrared vertical, solar sensor, television orientation device, etc.), Outside the conical portion of the operations section is a special repeating action cover with electric drive to maintain the temperature of the porthole through which the MKF-6M camera operates.

On the outside of the large diameter operations section are the onboard radio system and telemetry system antennas.

To maintain the proper temperature the body of the operations section is covered on the outside with mats of vacuum shield heat insulation, while the large diameter portion of the section is also covered with a fiberglas cover for protection from aerodynamic heating during powered flight. On the sides of the station are panels with sensors to study the flux of micrometeorites.

The unsealed cylindrical equipment section (4.15 m diameter, 2.2 m length) contains:

- the combined motor installation, including correcting motors and a system of low thrust motors which creates controlled torque to orient the station in space; and
- tanks of fuel.

On the outer surface of the equipment section are:

- the approach and docking radio antennas;
- optical lamps for orientation during manual docking of spacecraft with the station;
- the solar battery orientation system sensors, which determine the position of the Sun in the aft hemisphere (with respect to station flight);
- the onboard radio system antennas; and
- a television camera to monitor docking of transport spacecraft.

The equipment section is thermostatted in flight and has external heat insulation similar to the insulation of the operations section. The equipment section is connected to the end of the operations section; its aft end is connected to the booster rocket.

The scientific apparatus section is in the large diameter cylindrical portion of the operations section. It is a combination of conical and cylindrical shells (maximum 2.2 m diameter). The end of the section is oriented toward outer space and is equipped with a cover.

The intermediate chamber of the station is a sealed section consisting of cylindrical and conical shells 2 m in diameter with a total length 1.3 m. The second docking unit of the orbital station is mounted through the conical section on the intermediate chamber.

The intermediate chamber is used to carry equipment delivered by the transport spacecraft. An air line is laid through it to supply air from the operations section to the transport ship to create a common atmosphere. The intermediate section has two portholes used for visual observation, still and motion picture photography and television reporting.

Systems of the Orbital Station, Their Purpose, and Main Operating Modes

1. Onboard Equipment Control **System** (SUBK).–The SUBK controls the onboard systems:

- automatically (by a programed timer);
- on radioed command from the Earth; and
- on command of the cosmonauts at the control panels.

The SUBK switches the electric power supply system and protects the power supplies from short circuits, controls the pyrotechnic cartridges which open and deploy external elements of the structure, etc., and outputs information on the results of operations to the cosmonauts' panels and to Earth.

2. Orientation **and Motion Control System (SOLD).**—The SOUD is intended to orient and control the motion of the space station in automatic and manual modes.

The SOUD includes:

- a sensor apparatus (sensing elements);
  - — solar sensor;
  - — infrared vertical device (IKV);
  - — gyroscopic angular motion sensors;
  - — an ionic sensor;
  - — free three-way gyroscope; and
  - — velocity increment integrator.
- manual instruments:
  - — a wide-angle orienting site;
  - — optical orientors;
  - — an electronic-optical converter; and
  - — an astro-orientor.

- the "Kaskad" apparatus to maintain long-term orbital and inertial orientation;
- the approach electronic apparatus;
- lamps and targets for manual approach and docking; and
- automatic equipment and electronic units.

3. **Combined Motor Installation (ODU).–The** ODU is intended to create controlled torque around the center of mass of the station by means of low-thrust motors, and to generate power to move the station by means of the high-thrust motors.

The combined motor installation includes:

- correcting motors (two); and
- orientation motors.

The motors are supplied with fuel from two groups of collectors, each of which supplies the motors through three station control panels—pitch, yaw and roll.

4. **Command Radio Link.—The** system is intended to transmit control commands and settings from the Earth to orbit, trajectory measurements, two-way telephone communications between Earth and the station, and television and telemetry information from the station to Earth.

The system includes receivers, transmitters, antenna-feeder device, a programed timer (PVU), decoder, and other electronics and automation equipment.

5. **Television Communications** System.—The television system is used to transmit color and monochrome images from the onboard television cameras to Earth and to the onboard television screen (VKU).

The system includes:

- external stationary television cameras (monochrome images);
- the reporting television camera (color);
- the reserve reporting camera (monochrome);
- video monitors (VKU);
- the antenna-feeder devices;
- special lamps; and
- automation and electronic equipment.

6. Telephone Communications System.—The "Zarya" radiotelephone communications system is intended to provide two-way Earth-station and station-spacecraft communications in the ultra-short wave (USW) and short wave (SW) bands. The system includes USW receivers and transmitters, SW receivers and transmitters, and antenna-feeder devices.

To provide loudspeaker communications within the sealed station sections, there are loudspeakers, microphones, and amplifiers at the control posts and working locations.

The transmission of text (alphanumeric) information from Earth to the station utilizes an apparatus with a printer.

7. **Radiotelemetry Communications system (RTS).** –The radiotelemetry system is designed to collect information and transmit it from the spacecraft to Earth. The station carries two RTS systems; one system is used for service information, the other for information from the scientific and experimental apparatus.

Independent magnetic recorders (MIR) with magnetic tape cassettes are used to record scientific measurements with high sampling frequency. The magnetic tapes are returned to Earth on transport spacecraft.

8. **Orbital Control Radio System, Which Performs Trajectory Measurements.**

9. **Power Supply System.—The power supply system** (SEP) provides electric power for all onboard systems of the station, and also charges the buffer batteries (BB) and supplies power to transport spacecraft docked to the orbital unit.

The system includes:

- solar batteries (SB); three solar battery panels are installed on three planes of the station;
- the main buffer battery (BB);
- the reserve buffer battery; and
- the power supply test unit (BKIP).

The SB panels are oriented toward the Sun by means of the solar battery orientation system (SOSB). When a minimal voltage is reached, all consumers are automatically disconnected except for the duty systems, and a switch is made to the reserve BBO. After spacecraft dock, the orbital unit SEP charges the BB and supplies the transport spacecraft as long as they remain docked.

10. **Life-support system** (SOZh).—The SOZh is intended to provide conditions which will support the life of the crew; proper pressure and gas composition of the atmosphere, food and water, sanitary-hygienic conditions, and space-walk support.

The gas composition support system (SOGS) is intended to liberate oxygen (O_2) and absorb carbon dioxide (CO_2) and other impurities.

The system includes:

- chemical O^2 regenerators;
- chemical $C0_2$ absorbers:
- gas analyzers;
- harmful impurity filters (FVPS);
- dust filters (PFs); and
- gas stored in cylinders.

Additional regenerators, absorbers, FVPs, and gas are delivered by transport and cargo ships to replenish the supplies and allow continued operations of the system.

The system can maintain the parameters of the atmosphere within assigned limits ($C0_2$=0.9 mm mercury (Hg) O_2 = 160-280 mmHg, total gas pressure 760-960 mmHg) by manual connection and disconnection of regenerators and absorbers according to the readings of the gas analyzers.

The crew is supplied with water by regeneration of water from atmospheric moisture condensate and by reserves of stored water.

The water is stored in special containers.

Food is stored onboard the station as daily pacs in boxes. The food supply is supplemented by delivering it on transport and cargo spacecraft.

Sanitary-hygienic conditions are maintained onboard the spacecraft by means of a sanitary installation (ASU) [head —Tr.], shower, sets of linen, personal hygiene washcloths, and two lock chambers (ShK) with containers for waste ejection. Liquid wastes are collected in the sanitary device and ejected through the locks. Solid wastes (ASU, food, etc.) are collected in packets, then placed in special rigid containers designed for ejection through the locks.

Two spacesuits are used to allow two cosmonauts to perform space walks simultaneously. The transit section is used as a lock for this purpose.

11. Medical Monitoring and Prophylaxis Equipment. —This equipment is designed to allow regular medical monitoring of the cosmonaut~ health and prevent harmful effects of spaceflight factors.

The system includes medical testing apparatus, an "Aelita" combined medical examination apparatus, a treadmill, bicycle ergometer, pneumatic vacuum suit, units for testing and indicating parameters of the crew's condition upon orbital insertion, and a pharmacy.

These devices are used for:

- regular medical testing, the information from which is transmitted to Earth through the telemetry channels;
- periodic medical examination with the "Aelita" apparatus, the data from which are recorded onboard the spacecraft and transmitted to Earth; and
- regular crew training (with a treadmill, bicycle ergometer, and pneumatic vacuum suit).

12. Temperature Regulation System (STR).—The STR is intended to support the proper temperature of structures, units, and apparatus of the orbital station and docked transport spacecraft, and to create comfortable temperature conditions within the habitation sections.

13. Docking **and Internal Transfer System (SSVP).** —The SSVP is intended to perform mechanical, electrical, and hydraulic docking of the orbital station with transport and cargo spacecraft, and to support internal transfer of cosmonauts from spacecraft into the station without passage through open space.

The docking unit is based on the rod (active portion) and cone (passive portion) principle.

The Soyuz T Transport Spacecraft

The Soyuz T spacecraft is an improved manned transport spacecraft for the delivery of the crew to Salyut orbital stations and return of the crew to Earth, as well as transportation of cargo.

The experience gained in the development of flights of Soviet spacecraft and stations was used extensively in designing the Soyuz T spacecraft.

The Soyuz T spacecraft is placed in orbit by a Soyuz booster rocket, which determined the size and mass of the new spacecraft. The well-proved Soyuz spacecraft, including the descent module, orbital (habitation) section, and instrument-equipment section, was used as the basis for arrangement of the new spacecraft.

However, the Soyuz T spacecraft differs in a number of details from the earlier craft, has improved characteristics and, particularly, increased effectiveness as a transportation vehicle for orbital space stations, plus improved reliability and crew safety.

The spacecraft is designed to carry up to three crew members in space suits. In addition to the special onboard systems, the spacesuits protect the crew in case of a loss of seal in the living spaces. If necessary, depending on the mission of each specific flight, the spacecraft crew may be reduced in number with no changes in spacecraft design. The free spaces are then used to carry special cargo containers, allowing, in combination with Progress spacecraft, the problem of delivering cargo to the station and returning cargo from the station to be solved.

Most of the onboard systems of the spacecraft were designed anew or modernized using systems design principles, new elements, and new production and testing technologies.

A new motion control system has been developed for the spacecraft, using an onboard digital computer. The system calculates motion parameters and automatically controls the spacecraft in the optimal mode with minimum fuel consumption, performs self-testing, and automaticall$_y$ switches if necessary to reserve programs and hardware, while outputting information to the crew via the onboard display.

The decisions implemented in the system assure higher accuracy, reliability, and flexibility of spacecraft control in both orbital flight and descent.

The crew can control the spacecraft manually not only in orbit but also during descent in the atmosphere.

The approach and correcting motor and docking and orientation micromotors operate with the same fuel components and have a common *fuel storage* and supply system, allowing more effective utilization of onboard fuel reserves. During flight the consumption of fuel is monitored b$_y$ a special measurement system.

In order to improve reliability, the landing equipment system has been modernized, and the emergency crew rescue system, used as the spacecraft is placed in orbit, has been improved.

The radio systems of the spacecraft—such as the command-program radio link and radiometry and television systems—have been improved, and solar batteries have been included in the power supply system,

The design of the spacecraft provides for duplication of important mechanisms, sealing devices, separator units, etc.

The total volume of the living spaces aboard the Soyuz T is about 10 m^3.

The Progress Automatic Transport Spacecraft

The automatic transport spacecraft is intended for delivery of the following items to the Salyut piloted orbital station:

- scientific apparatus, photographic materials, crew life-support supplies, instruments, and units in need of replacement; and
- fuel components to recharge the combined motor installation of the orbital station.

In addition, it provides for the removal of wastes and units which have completed their operating life from the space station.

The automatic cargo transport spacecraft has a launch mass of 7 tonnes and consists of three main structural units:

- the cargo section (GO) with docking unit;
- the fuel component section (OKD); and
- the instrument and equipment section (PAO), consisting of the transit, instrument, and equipment sections.

The *docking unit* of the spacecraft is based on the docking unit of the Soyuz manned spacecraft and is designed for mechanical docking of the spacecraft with the station, to assure an airtight seal, and also to connect electrical lines and automatically connect and seal the main fuel supply lines. The crew passes through the docking unit into the cargo section of the spacecraft.

The cargo section of the spacecraft is intended to carry instruments, scientific apparatus, photographic materials, food, water, and life-support system equipment, including regeneration installations, all mounted on special frames and in containers. Throughout the flight, with the docking unit hatch sealed, conditions are maintained in the cargo section as required to preserve all of the instruments and food products being delivered to the space station. The volume of the cargo section is 6.6 m^3. The cargo section has an ordinary air atmosphere (7612 mmHg). The temperature in the section is maintained between + 3° and + 30° C,

The cargo section is connected to the refueling component section. On the outer surface of the section are three antennas of the electronic approach system, two external television cameras (one aimed forward, the other toward the Earth), 103 light indices (used by the crew to monitor correct placement of the spacecraft during automatic approach and docking). Outside the section are the main lines which feed fuel components from the refueling section to the connections on the docking unit. The cargo section of the spacecraft can carry up to 1,300 kg of cargo to the orbital station.

The refueling component section structurally consists of two truncated conical shells. The section connects at one end to the cargo section, at the other end to the transit section and instrument and equipment section. At the outside of the section are two light indices which supplement the light index on the cargo section. This section is intended to carry tanks of fuel components for delivery to the orbital station, gas cylinders, and the equipment of the refueling system. The gas in the cylinders (nitrogen or air) is used to drive the fuel components during the refueling and also to fill the habitation compartments of the station if necessary.

The refueling system includes a system which tests the seal of the fuel lines, a blowing system, and sensors to monitor the temperature and pressure of the components and gas in the process of storage and refueling. During refueling, up to 1 tonne of fuel components can be transferred to the tanks of the combined motor installation of the station.

The refueling system is controlled by the crew of the orbital station, with radio signals from Earth controlling the cargo spacecraft end.

The instrument and equipment section is designed to carry all of the main service systems of the spacecraft supporting independent flight, approach and docking, flight as a part of the orbital station, and undocking.

The transit section of the instrument-equipment section is a framework which carries the fuel tanks, spherical containers, and fittings of the approach and orientation system motors. Outside the section are 10 approach and orientation motors of the system and the command radio link antenna.

The instrument and equipment sections are similar to the instrument and equipment sections of the Soyuz transport spacecraft in their design, purpose and apparatus, and equipment carried.

A Soyuz booster rocket is; used to insert the transport cargo spacecraft into orbit.

After the cargo spacecraft separates from the booster rocket, structural elements carrying the antennas of the electronic approach system and radiotelemetry system, as well as the panel carrying the light indices, are deployed from the spacecraft.

Basic Information on the Soyuz Booster Rocket

The Soyuz booster rocket has three stages.

Stage I consists of four lateral units, each of which is 19 m long, 3 m in diameter; its motor has four chambers, two of which are steering chambers, developing a total thrust in a vacuum of 102 tonnes.

Stage II is the central unit, about 28 m in length, maximum 2.95 m in diameter, its motor has four chambers, all of which are steering chambers, developing a total thrust in a vacuum of 96 tonnes.

Stage III is a unit with a length of 8 m and a diameter of 2.6 m; its motor has four chambers (with steering nozzles), developing 30 tonnes of thrust in vacuum. The launch mass of the booster rocket with a Soyuz T spacecraft aboard is over 300 tonnes.

When the booster rocket is launched, the motors of the first and second stages are ignited simultaneously. The second stage continues to operate after the four lateral units [of the first stage] are jettisoned. The third stage is ignited after the second stage motor has completed operation. The booster rocket uses kerosene-oxygen fuel in all stages. The total length of the booster rocket with a Soyuz T spacecraft is 49 m. The maximum diameter at the stabilizers is 10.3 m.

Controlling the Flight of the Salyut Orbital Scientific Station

Organization of Flight Control

Flight control of the Salyut orbital scientific station, transport and cargo spacecraft is provided by:

- the flight control center near Moscow;
- a network of tracking stations;
- a system of modeling devices including a mathematical model of the station and a physical model of the spacecraft; and
- a communications system with Earth and satellite-information transmission channels.

Flight Control Center

The flight control center performs the following tasks:

- operational administration and coordination of the operation of the entire system;
- collection, processing, and display of telemetry, trajectory, and television information arriving from the station and from transport and cargo spacecraft; and
- interaction with the launch and search and rescue systems, trainers and modeling equipment, and various organizations participating in flight support.

The flight leader and flight control personnel are located at the center. The flight control center is equipped with a computer system; devices for collection, processing, and display of information; internal communications and television; remote-command output; communications with the crew; and transmission of telegraph messages to the Salyut station. The control center is in communications with the Moscow television technical center at Ostankino.

The flight control center has been significantly improved. It now has a second control room to control the flight of the transport and cargo spacecraft and a modernized computer system which now allows the problem of controlling several spacecraft simultaneously to be solved. At the same time the number of communications channels between the center and tracking stations has been increased to support simultaneous transmission of telephone, telemetry, and television information to the center from three spacecraft over surface channels and through Molniya communications satellites.

The modernized computer system of the center and the improved communications system allow transmission, processing, and display of information from all telemetry sensors of the Salyut station and from Soyuz spacecraft simultaneously for the control personnel.

The flight control personnel operating with the Salyut and Soyuz spacecraft systems are a carefully selected trained team consisting of specialists of various profiles. They include specialists on the flight program and flight control organization specialists, onboard systems developers, designers of the station and transport spacecraft, scientists, ballisticians, physicians, communications specialists, as well as specialists on the control and maintenance of the tracking stations, flight control central hardware, communications system hardware, plus representatives of scientific organizations of our country and other socialist countries.

Most of the control personnel are located at the flight control center–this is the chief operational flight control group. Some of the personnel are located at tracking stations and on ships of the U.S.S.R. Academy of Sciences, the Priroda state scientific research and production center, and the center for medical and biological research. The total number of personnel is about 100. Successful performance of the flight mission and completion of scientific research and crew safety depend on precise operations by every man.

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The organizational structure of the flight control center personnel was developed by specialists with experience in the organization of manned spacecraft and station flight control, is recorded in special organizational documentation, and has been repeatedly tested in training exercises and in controlling the flights of previous stations and manned spacecraft.

The flight leader heads the control personnel.

Flight control is performed from two rooms: the main station flight control room and the transport and cargo spacecraft control room.

The personnel in the rooms work under the control of shift flight leaders.

Each room contains: the shift flight leader; specialists responsible for the main onboard systems; persons responsible for the operation of tracking stations; persons responsible for planning the flight program and for complete analysis of the operation of onboard systems; a cosmonaut operator in communication with the crew; representatives of the organizations which develop the station and spacecraft; a ballistics expert; a physician responsible for medical monitoring of the crew; the shift center leader; and specialists responsible for the main system at the center (communications, computer system, display systems, etc.).

All specialists work at positions with individual display and communications equipment.

The personnel work in four shifts. Shift changes occur during flight with no delay in flight operations.

Since the flight control center, tracking stations, and communications equipment are all the same for the station and the transport spacecraft, priority had to be assigned for their use. During orbital insertion, approach, and docking of the transport spacecraft with the station, the transport spacecraft control room has priority for use of equipment.

After docking and movement of the crew into the station, priority is transferred to the main control room. Priority transfer occurs at the moment the transfer hatches between the spacecraft and station are opened.

Organization of Work in Control Room

Control of the station or transport spacecraft is transferred to the control center from the launch complex immediately after separation of the last booster rocket stage.

Up to this point the personnel in the control rooms monitor the operation of onboard systems by telemetry, observe the crew by television, and listen to the conversations between the crew and the launch team.

A central screen shows the course of the booster rocket's flight over the entire insertion trajectory. After separation of the spacecraft from the booster the personnel in the control room monitor the opening of the antennas by telemetry, make contact with the crew, and begin testing onboard systems.

Work in the room is organized as follows: When the spacecraft enters the zone of visibility of ground tracking stations (the movement of the spacecraft is displayed on the central screen in the main hall) commands are transmitted to the spacecraft in accordance with the flight program. The personnel in the room monitor the transmission of commands and their reception by the spacecraft. The necessary onboard systems are switched on by commands from Earth or by the crew. The tracking stations begin to receive and transmit to the control center the telemetry, trajectory information, and television images received from the spacecraft. As the telemetry and trajectory data are received they are automatically processed by the control center's computers and transmitted to the display devices in the control room.

Telemetry information is analyzed in detail by systems specialists who generate conclusions concerning the status and operation of each onboard system for the responsible personnel.

Those responsible for individual systems are in communications with the support personnel outside the control center and can, if necessary, consult with them or obtain additional information on the operation of the systems.

In case of abnormal operation of spacecraft systems, the specialist responsible for overall analysis determines the effect of any system failures on the operation of individual systems, prepares suggestions for elimination of defects and correction of onboard system-operating modes, ard then reports these suggestions to the shift flight leader.

The physician responsible for medical monitoring performs detailed analysis of biotelemetry data, estimating the condition of the crew and reporting it to the shift flight leader.

As trajectory information is processed and orbital parameters are determined, the ballistic data are automatically transmitted to the control room displays.

The communications operator carries on planned radio conversations with the crew. The person responsible for the tracking stations monitors their operation and, if there is any deviation from the planned program, informs the shift flight leader and takes steps to eliminate deviations.

The onboard computer specialist monitors operation of the computer and, if necessary, prepares changes to the computer program which are then transmitted to the spacecraft.

The center shift leader monitors the operation of all services at the center and, if there are deviations in any operations, informs the shift flight leader and takes steps to eliminate them.

The shift flight leader, considering all the information which he receives, makes decisions concerning the future flight program. If there are no deviations in the operation of onboard and ground-based systems, permission is given to perform operations in accordance with the planned program.

If it is necessary to correct the program, the correction is made by the person responsible for planning the program. Correcting actions may be undertaken during a session or in subsequent sessions. If necessary in order to identify failures and test correcting actions, a mathematical model of the station or the combined spacecraft physical model may be used. Decisions are implemented by transmitting instructions by radio from the flight control center to onboard systems or by verbal transmission of instructions to the crew.

Control Room Operation Support

In addition to the major specialists in the control room, there are also support groups at the center. The specialists in these groups are located in separate rooms equipped with positions similar to those in the control rooms, The main tasks of these personnel are to provide:

- support to personnel in the control room with calculations and information which can be used to make decisions concerning the flight program;
- consultation with control room specialists and assistance to them in analyzing the operation of onboard systems;
- assurance of implementation of decisions made by the shift flight leader;
- support for the operation of the technical equipment at the center; and
- prospective flight planning.

The personnel include the following specialists:

- specialists in onboard systems preparing and transmitting to the display devices the necessary additional information to control room specialists;
- specialists in operational planning of the flight program, to prepare, if necessary, changes to the flight program;
- specialists in advanced planning of the flight program (1 week);
- specialists in coordination of tracking station opera tions;
- specialists in communications which support communications of the center with the spacecraft and tracking stations;
- specialists in ballistics, included in the main ballistic center staff and performing the necessary ballistic calculations to determine the orbit, zones of visibility, entry and exit of the spacecraft from the shadow, maneuvers, as well as data necessary for scientific experiments;
- onboard computer specialists;
- representatives of the search and rescue system, constantly ready to go to work in case of an emergency return of the spacecraft;
- the medical monitoring group, which regularly analyzes biotelemetry and maintains communications with the flight medical support center;
- a group which plans the program for the crew's day off, prepares music transmissions for the crew, radio conversations between the crew and their families, and cultural and scientific activities; and
- to provide consultations to the flight leaders during experiments sponsored by representatives of another Socialist nation, the flight control center includes a consultation group of specialists representing the sponsoring nation.

Training of Control Personnel

Before starting to work at the center, control personnel undergo a training cycle. Training is performed using the mathematical model of the Salyut space station, the physical model of transport spacecraft, and training machines. Actual tracking stations and communications devices are used in these training exercises. The crew of the Soyuz T spacecraft participate in the training as well.

Training exercises are performed under conditions as close to those of real flight as possible. The flight program is developed in real time with interactions among individual groups of control personnel, the flight control center, and the tracking stations. Nonstandard situations which may develop on board and on ground are simulated. The most difficult flight stages are run through repeatedly.

The Baykonur Kosmodrom

The Baykonur Kosmodrom is a complex organization with many branches, a combination of unique devices, automatic systems, and engineering structures serviced by specialists of many sorts.

The Baykonur Kosmodrom is located in the Kazakh SSR in a semidesert area with a continental climate (hot, dry summer and cold, dry, windy winter). It was founded in 1955.

The reasons for selecting the location of the Kosmodrom were that it is remote from large populated areas, thus allowing safe rocket launches to be assured and separation zones (i. e., areas for the landing of returning spacecraft) to be set aside, and that many days in this area are cloudless.

Launches are performed from the Baykonur Kosmodrom in accordance with the national space research and utilization program of the U. S. S. R., in cooperation with other socialist nations in the "Interkosmos" program, and also in accordance with agreements for joint operations concluded with the United States, France, and other nations.

The world's first artificial Earth satellite was launched from the Baykonur Kosmodrom, the first cosmonaut Yu. A. Gagarin, and the first woman V. V, Tereshkova started from Baykonur; the Luna, Venera, Mars, and Zond automatic interplanetary stations were launched here, as were space stations and artificial Earth satellites of various types (Kosmos, Elektron, Polet), and the Molniya series of satellites used to relay television programs and to provide long-distance telephone and telegraph communications.

Manned Soyuz T spacecraft and Salyut orbital stations are regularly launched from the Baykonur Kosmodrom.

The Kosmodrom is used for assembly, testing, and launching of booster rockets with spacecraft, as well as for final prelaunch preparation of the cosmonauts.

The main component parts of the Kosmodrom are:

- the booster rocket assembly and testing building;
- the spacecraft assembly and testing building;
- the launch areas; and
- observation, command, and telemetry points.

The residential area of the Kosmodrom is located some tens of kilometers from the launch area and technical buildings, Here we find the cosmonaut training complex (classrooms for technical and scientific training of crews, the sports complex with swimming pool, laboratories to prepare the cosmonauts for flight, and the medical complex), as well as the institute, technical school, schools, club, stadium, television center, etc.

The Kosmodrom is connected to other points in the nation by air, highway, and rail. The territory of the Kosmodrom also has a well-developed network of highways and railroads.

The operations of assembly, testing, and joining of booster rockets and spacecraft are performed at the technical positions in the installation and testing buildings of the Kosmodrom, which are equipped with the necessary testing and measurement equipment and tools.

A number of launch and technical positions have been constructed at the Kosmodrom. One of the most important is the position from which three-stage booster rockets carrying the Vostok, Voskhod, Soyuz, and now Soyuz T spacecraft are launched,

The launch structure for this booster rocket includes a launch system with releasable supporting beams. The rocket is "suspended" in the launch system by the supporting units. The rocket system is delivered to the launch position from the assembly and testing building of this technical position, where it is assembled in the horizontal position.

The launch complex of the system, equipment, and engineering structures used to transport the rocket system to the launch position, set it in the launch structure, and perform prelaunch testing includes:

- the transporter and erector;
- the launch structures;
- the launch system (supporting frames and restraining devices; cables, hoses, and cable towers);
- the servicing devices (servicing frames and cabin); and
- the fuel and oxidizer supply systems.

The launch and other structures also contain: systems for filling and thermostatting fuel; a compressor station; compressed-gas receiver; fuel storage tank; a system to control both the preparation of the rocket for launch and the actual launch; the command point bunker, connected by communications lines to all operational services of the Kosmodrom; observation and command-measurement points; and the flight control center.

Preparation of the booster rocket for launch begins with transportation of its stages and sections of the spacecraft in special railroad cars from the manufacturing plants. The individual stages of the booster rocket are delivered to the spacecraft assembly building, where they are automatically tested, assembled, and prepared to be joined with the spacecraft. The spacecraft is assembled and tested in the spacecraft assembly building.

The ship is filled with fuel components and compressed gases at the filling station of the Kosmodrom, to which the spacecraft is delivered in a special railroad car. After it is filled and final operations are performed, the transit section and nose fairing are attached to the spacecraft. The assembled forward unit is then attached to the booster rocket, and the entire rocket-spacecraft system is tested.

This completes the work at the technical position, and the space system is delivered to the launch position on its transporter.

To install the rocket on the supporting beams of the launch system, the transporter raises the rocket to the vertical position by means of hydraulic jacks. During this time the supporting beams are shifted from an inclined position to their operating position and accept the weight of the rocket in its central (supporting) belt. The rocket is thus suspended over the gas-deflecting trough. Its tail portion is several meters below ground level. This helps to protect equipment on the ground from the powerful high-temperature jet of the motors.

The transporter, after placing the rocket on the supporting beams, lowers its boom to the horizontal position and rolls away the launch system. The servicing booms, cable, and hose towers are brought up to the rocket. As soon as they are in their operating position the process of azimuthal guidance of the rocket and placement of the rocket in the strictly vertical position is begun. All of these operations are performed by mechanisms on command of the remote control system. The air system which controls the temperature of the spacecraft is then started up. The essence of this operation is feeding of air beneath the fairing of the booster rocket at a rate such that the apparatus and fuel components remain within a defined temperature range. The air thermostatting system continues operating almost up to the moment of launch.

After the various lines are connected (fuel, drainage, pneumatic, electrical) to the rocket and spacecraft, the next operation begins—pressure-testing, i.e., checking the tightness of seal of all connection points with compressed air. Any pressure drop indicates a leak.

The testing and launch apparatus then begins prelaunch testing of the onboard systems and units of the rocket. All onboard systems are tested to determine if they are functioning properly and their initial conditions are correctly set; individual onboard and ground-based instruments are checked (without starting the standard programs or turning on the actuating organs); the television, communications, command radio link, onboard power supply, and other systems are tested. The results of prelaunch testing are displayed on all video-monitoring devices and recorded by the telemetry systems and multichannel recording machines. If all onboard system and unit parameters are normal, permission is given to begin fueling the booster and filling its compressed-air tanks.

The transfer of liquid oxygen into the booster is a special operation. The lines and tanks are first cooled; i.e., their temperature is artificially reduced to prevent the liquid oxygen from boiling off and to reduce the pressure in the booster's tanks and lines. For this purpose a small quantity of liquid oxygen is fed in from the storage container. As it evaporates, it cools the tanks and lines then passes through the safety and drainage valves in the gaseous state. After the tanks and lines are cooled, the pumps begin to operate. The level-monitoring system (SKU) assures precise measurement of fuel components.

Control of the filling process and monitoring of the transmission of instructions are performed remotely from the launch-pad command point.

At the same time as the booster rocket and the spacecraft are fueled, their systems, instruments, and units undergo final testing, adjustment, and simulated operation, and commands are transmitted to the memory unit of the onboard control system—it is set up to perform a definite program of orbital insertion.

Since liquid oxygen evaporates it must be topped off; i.e., additional liquid oxygen is pumped in to fill the tanks to the required level. The fuel components are then drained from the filling lines, after which the filling, drainage, and pneumatic lines are disconnected, and the correct vertical position and azimuthal guidance of the rocket are tested.

Two hours and thirty minutes before the launch the cosmonauts take their places in the spacecraft. The final prelaunch and launch operation program is started. The automatic system assures a launch at the precise time with an accuracy of a few hundredths-of-a-second. Final monitoring of all rocket system before the launch is performed by telemetry.

At minus 1 minute, when it becomes clear that all systems and units of the booster rocket and spacecraft are operating properly and the cosmonauts are ready for the launch, the operator places a switch in the "launch" position. The automatic final launch-operation program is started. Operations performed are displayed on the control panel. The fuel-and oxidizer-tank drainage lines are closed at this time. The cable and hose towers swing away from the rocket. The turbine pumps begin operating. The ignition is turned on. The pyrotechnic ignition devices create flames in the chambers of the first- and second-stage motors. The motors develop thrust, operating in the preliminary, intermediate, and then main operating modes. When the motor thrust exceeds the weight of the booster rocket it begins to rise and is freed from the clamps of the launch system support beams. At this instant a contact closes and the "launch" light begins to shine on the control panel. Information on the prelaunch preparation and insertion of the spacecraft into orbit is sent to the flight control center, where it is processed and displayed on the common and individual screens in the control rooms. Control of the spacecraft is transferred from the launch complex to the flight control center immediately after separation of the third stage of the booster rocket.

Command, Measurement, and Search and Rescue Systems

The flight of the Soyuz T spacecraft is controlled through the U.S.S.R. command and measurement complex, based on seven tracking stations in the Soviet Union—Dzhusaly, Yevpatoriya, Ussurisk, Ulan-Ude, Kolpashevo, Tbilisi, Petropavlovsk-Kamchatskiy, U.S.S.R. Academy of Sciences research vessels in the Atlantic and Pacific Oceans, and the USSR Academy of Sciences computer centers, These ground-based and ocean tracking stations are located so as to provide communications with the station and transport spacecraft in all orbits of the flight.

The longest continuous communications with the crew are provided for those orbits when the spacecraft dock, the crew move out for a space walk, or the spacecraft begins its return from orbit.

Command program information is transmitted from the control center to the tracking stations through automated telephone communications lines and is relayed from there to the orbital station. Telemetry and television information can also be recorded at the tracking stations for subsequent transmission to the flight control center.

The ground-based complex is a component part of the Salyut space station and Soyuz T spacecraft flight control loop. The control loop includes: the flight control center, ground-based and shipboard tracking stations, the ground and satellite communications system, and ballistic centers.

As it controls the flight, the ground-based control complex performs the following tasks:

- exchange of all types of information between the spacecraft and the flight control center;
- provision of two-way telephone and" telegraph communications between the control center and the spacecraft crew;
- measurement of the parameters of the spacecraft's motion;
- organization of communications between elements of the ground-based control system and the flight control center; and
- operational administration and coordination of operation of tracking stations and other elements of the ground-based system.

The tracking stations in the process of a flight measure the parameters of the spacecraft's motion and receive telemetry and television information from the spacecraft. All decisions related to flight control are implemented through the tracking stations by conducting conversations with the crew and transmitting radio commands to the spacecraft,

There are about 20 telephone and telegraph communications channels between the center and a typical tracking station. Most tracking stations have wideband communications channels with the center, The tracking station is equipped with a computer which can perform about 50,000 operations per second. Elimination of telemetry redundancy from the flow of telemetry information is performed by specialized apparatus. The throughput capacity of the data transmission apparatus used over the telephone channels is 2,400 bps.

Shipboard command and measurement points receive and transmit to the center the complete flow of telemetry information from the spacecraft. Molniya communications satellites ar-e used in the satellite communications system.

The tasks of the search and rescue complex include:

- search for and location of the returning spacecraft and cosmonauts,
- determination of the coordinates of their landing,
- evacuation of the cosmonauts and provision of medical aid,
- technical servicing of the spacecraft, and
- its removal from the landing area to its assigned point.

The men and equipment of the search and rescue complex are placed where the returning spacecraft will land. Helicopters and aircralt, observing the spacecraft visually and by radio, converge on their assigned locations along the landing track, using radio direction finding to approach the spacecraft and accompany it as it comes in for a landing, and maintain two-way communications with the crew.

The returning spacecraft land in a selected area of the Soviet Union. The descent apparatus is designed to land on dry land; the apparatus has special systems assuring safety of the cosmonauts should it land in water.

In the landing area the cosmonauts are met by a specially trained search group. This group includes technical specialists and physicians. The search group is provided with everything necessary to reach the landing point rapidly and to provide any needed assistance to the cosmonauts.

The search aircraft carry parachute personnel including physicians and rescue specialists who if necessary parachute to the spacecraft after it lands. Search and rescue equipment includes aircraft and helicopters, ships and all-terrain vehicles. The technical specialists and physicians included in the search group are well-trained parachute jumpers and scuba divers. The physicians of the group have available the necessary medical equipment and medications, adapted for use under any weather conditions.

After landing, the cosmonauts open the hatches of the spacecraft and prepare containers of scientific apparatus and photographic film for transportation. If necessary they can use the reserve stores onboard the spacecraft, including warm clothing, swimsuits, signaling and radio communications devices, extra water, and other necessary products. After landing and leaving the spacecraft, the cosmonauts take off their spacesuits and put on flight clothing. The containers of scientific apparatus and film are turned over to the specialists in the search group. The cosmonauts undergo post-flight physical examination at the landing point.

If the spacecraft lands in water, the cosmonauts remove their spacesuits, don special equipment, prepare to use their flotation devices, and maintain contact by radio with the search service. The search group which arrives at the landing zone helps the cosmonauts to leave the spacecraft.

The search process, location of the spacecraft, and evacuation of the cosmonauts from the spacecraft and from the landing zone are all reported from the area in which the search and rescue complex operates to the flight control center.

The Yuriy Gagarin Cosmonaut Training Center

The Yuriy Gagarin Cosmonaut Training Center (TSPK) was created in 1960 and is located outside Moscow, in Zvezdnyy Gorodok [Star Village].

The cosmonaut training center is an institution provided with modern equipment and manned by qualified specialists, capable of training crews for space and expeditions in accordance with the increasing demands of the time.

The specialists at the Center have accumulated great experience in educational, scientific, and indoctrination work. They take part in studies of the prospects of using manned spacecraft, and contribute to the improvement of spacecraft and their equipment and to the planning of future flights.

The structure of the TSPK, the mission of its main subunits, and [the composition of its] professional staff of specialists are determined by the tasks which it performs in preparing and supporting space flight.

In 1968 the Center was named in honor of Yuriy Gagarin.

In 1971, for its great services in the preparation of crews for spaceflight, its participation in the mastery of space, and in connection with the l0th anniversary of the world's first manned space flight, the center was awarded the Order of Lenin.

During the operation of the TSPK (up to June 1, 1982) 49 manned spacecraft crews were trained, including: 6 for the Vostok spacecraft, 2 for the Voskhod spacecraft, 37 for the Soyuz spacecraft, 4 for the Soyuz T spacecraft. Sixty cosmonauts had been in space, including 10 three times (Vladimir Shatalov, Aleksey Yeliseyev, Valeriy Bykovskiy, Petr Klimuk, Nikolay Rukavikhnikov, Valeriy Kubasov, Valeriy Ryumin, Viktor Gorbatko, Oleg Makarov, Vladimir Kovalenok), and 15 twice, as well as 9 cosmonauts who were citizens of other Socialist nations: Vladimir Remek (CSSR), Miroslav Germashevskiy (Poland), Zigmund Jen (GDR), Georgiy Ivanov (Bulgaria), Vertalan Farkash (Hungary), Fam Tuan (Viet Nam), A. Tamayo Mendes (Cuba), Zhugderdemidiyn Gurragcha (Mongolia), and Dumitru Prunariu (Roumania).

In 1980 the cosmonaut training center celebrated its 20th anniversary.