==

Yu.A. Gagarin Cosmonaut's Training Center

Soyuz Crew Operations Manual (SoyCOM)
(ROP-19)
(Final)

_______________ B.Ostroumov

RSA Deputy Director General

______________ Yu.Glazkov

GCTC First Deputy Chief

June, 1999

<table>
<tr><td>GCTC</td><td>E. Zhuk</td><td>I.Milukov</td><td>N. Zubov</td><td>Yu. Glazkov</td></tr>
<tr><td></td><td>A. Malikov</td><td></td><td></td><td></td></tr>
<tr><td>NASA</td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td>Prepared by</td><td>Translation verified</td><td>Working Group Chief</td><td>Technical Director</td></tr>
<tr><td colspan="4" rowspan="2">Document title:
Soyuz Crew Operations Manual (SoyCOM)
(Final)</td><td>Document
№ 0004AE4b
(ROP-19)</td></tr>
<tr><td>Number of sheets</td></tr>
</table>

CONTENTS

1. FOREWORD

1.1. Purpose of the Document

The Soyuz Crew Operations Manual (ROP-19) ("SoyCOM") is a document that contains familiarization data on all the Soyuz spacecraft systems and flight operations. The SoyCOM Manual is a reference document for all the Soyuz crew members. It includes a general description of all Soyuz systems, the systems' operational limits and characteristics, a review of flight data file, an outline of nominal and emergency procedures, flight trajectory events and crew/MCC (ЦУП) joint operations.
Annexed to the Manual are the spacecraft control/display panel appearance and a glossary of abbreviations and acronyms most frequently used during Soyuz training.
The Manual is to be used by cosmonauts and astronauts in accordance with their assignments for preliminary familiarization training in Soyuz onboard systems, flight data file and flight operations.
The Manual is not for substantial study of the spacecraft systems but rather for preliminary familiarization with Soyuz spacecraft.
The SoyCOM reference Manual has been developed by Gagarin Cosmonaut Training Center (GCTC).

1.2. Sphere of Application

The Soyuz Crew Operations Manual (ROP-19) (SoyCOM) will make a part of the curriculum for Soyuz training. This document applies to Soyuz crew training within the Mir and the International Space Station (ISS) programs.

1.3. Update Procedure

This document will be updated by RSA as agreed by NASA.

1.4. Documents Used

When compiling the present Manual the following documents were used:

- Technical Description of the Soyuz-TM Spacecraft ("Energia", June 1994)
- Soyuz TM Spacecraft Flight Data File (of October 31, 1997)
- Shuttle Crew Operations Manual (SCOM 1.0, November, 1991)
- Plan for the ISS Russian Segment Training (NAS 15-10110/ROP-17) (NASA/RSA, 1996)
- Soyuz Training Plan (NAS 15-10110/ROP-18) (NASA/RSA, 1997)
- Ops Protocols of Technical Interchange Meetings (TIM).

2. SOYUZ SPACECRAFT GENERAL DESCRIPTION

2.1. History of Soyuz Spacecraft Development and Modifications

Development of Soyuz spacecraft started at S.P. Korolev's design bureau in 1962. It was originally supposed to be used for development tests of both equipment for spacecraft rendezvous and docking in orbit and spacecraft design and systems that would ensure a flight around the Moon and safe return to the Earth.
As the space program changed the Soyuz spacecraft design criteria were revised accordingly and from that time on its development was aimed at a second generation multipurpose orbital vehicle with a launch weight of up to 6560 kg. It was to be designed for executing a wide scope of tasks in the near space including development tests of procedures for autonomous guidance and navigation, automatic and manual rendezvous, berthing and docking, verification of principles for using manned space vehicles for science/technology experiments in space.
On the 28th of November, 1966 the first Soyuz spacecraft was launched unmanned from Baykonur cosmodrome and flew 34 orbital revolutions (Cosmos-133).
The second launch of unmanned Soyuz in December, 1966 was aborted due to the launch vehicle failure at the launch pad.
The third unmanned spacecraft made an orbital flight and landed on the Aral Sea surface in February 1967 (Cosmos-140).
The first manned flight of Soyuz-1 spacecraft was made by cosmonaut V.M. Komarov on the 26th of November, 1967. However the flight ended in a catastrophe because of the parachute system failure during descent and the cosmonaut died.
After a number of corrections and unmanned spacecraft flights the Soyuz-2 piloted by cosmonaut G. T. Beregovoy was launched in October 26, 1968.
In February 16, 1969 the first experimental space station weighing 12924 kgs was formed of two manned Soyuz-4 and Soyuz-5 spacecraft. Two cosmonauts in space suits made a transfer from one spacecraft to the other.
In June, 1970 the first long duration space flight (17.7 days) was executed onboard Soyuz-9 by cosmonauts A.G. Nikolayev and V.I. Sevastianov.
In June 1971 Soyuz spacecraft was modified and turned into a crew transfer vehicle to deliver crews to orbital stations.
During a later service period Soyuz spacecraft was several times modified substantially.
The first modification was connected with corrections that had to be made after the death of Soyuz-11 crew (cosmonauts G.T. Dobrovolsky, V.N. Volkov and V.I. Patsayev) because of the Descent Module depressurization during the descent phase.
A set of survival aids in case of depressurization during descent was introduced, including space suits, which dictated a reduction of the crew down to two persons.
The second modification was made for international "Apollo-Soyuz Test Project".
Compatible equipment for rendezvous and docking, improved assemblies of life support system and of radio/TV system were installed onboard the spacecraft.
Later on a number of the spacecraft of this modification series were used to support the long duration service of Salyut orbital stations and the "Intercosmos" international space program.
The next important modification resulted in installing onboard Soyuz spacecraft a principally new motion control system based on the onboard computer complex and a new propulsion system with unified fuel supply subsystem for all the thrusters. Many onboard instruments were replaced for improved ones. The crew was also increased up to three persons and the spacecraft orbital service life extended.
The first manned flight of so modified spacecraft - Soyuz T-2 was made in June 5 - 9, 1980 with docking to Salyut-6 station (cosmonauts Yu.V. Malyshev and V.V. Aksenov). In November, 1980 a three man spacecraft, Soyuz T-3 was launched (cosmonauts L.D. Kizim, O.G. Makarov, G.M. Strekalov).
Manned spacecraft of Soyuz T type were repeatedly flown to Salyut-6, Salyut-7 and Mir orbital stations until 1986. Cosmonauts V.A. Dzhanibekov and V.P. Savinykh successfully approached and docked their Soyuz T-13 manually to Salyut-7 station the station being out of control. In 1986 the last spacecraft of that modification, Soyuz T-15, executed interorbit flights from Mir to Salyut-7 and back (cosmonauts L.D. Kizim and V.A. Solovyov).
The next modification - Soyuz TM spacecraft equipped with a modernized rendezvous radar system "Kurs", improved motion control system and radio-communication system as well as propulsion system with sectionized propellant and gas stocks entered into service in May 21, 1986 when Soyuz TM-1 was launched in unmanned version to Mir station.

The first manned flight of the modified Soyuz TM-2 was made in February 6, 1987 with docking to Mir station (cosmonauts Yu. V. Romanenko and F.I. Laveikin).

Since the Soyuz TM-9 flight in February, 1990 until now the spacecraft is equipped with a special cupola/window to enable the crew to execute a manual approach in case of the “Kurs” rendezvous radar system failure.
In January 24, 1993 Soyuz TM-16 was launched with the Androgynous Peripheral Docking Assembly APDA-89 (cosmonauts G.M. Manakov and A.F. Polishchuk). The crew docked manually to the identical docking assembly of the KRISTALL Module. That was the operational test of the androgynous docking system to be later used for Space Shuttle dockings to Mir orbital station.
Some minor corrections and improvements were also introduced into later flown spacecraft of that modification. They were mostly associated with the motion control system modernization and small changes in the spacecraft structure.
On the basis of the Soyuz crew transfer vehicle the Progress cargo vehicle was developed. Its first flight to Salyut-6 orbital station was made in January 20, 1978. Its modification, the Progress-M that followed on the basis of Soyuz TM was launched for the first time in August 23, 1989 to Mir station and nowadays is still in service.

2.2. Purpose and Task Versions of Soyuz Spacecraft

The purpose of the spacecraft standard version is to deliver a three-man crew and a load onboard the Mir orbital complex, to fly jointly for up to 180 days and to bring the crew and the load to the Earth. And the spacecraft calculated autonomous flight life is 4.2 days.
This time period includes rendezvous/docking operations (2.2 days) and undocking, pre-landing operations and time reserve.(2 days).
Apart from its main purpose the spacecraft may be also used as a rescue vehicle, unmanned or piloted by only the commander, or as an unmanned cargo vehicle capable to deliver 250 kg of load from the orbit.
The spacecraft is injected into orbit by the “Soyuz” three stage launch vehicle having launch weight of up to 310 metric tons (payload weight inclusive) and total length of 51.3 m.
During the launch and injection the spacecraft is covered by the nose aerodynamic cap in the upper part of which the launch escape system propulsion unit is installed that is capable in case of contingency while on the launch pad or in low take-off altitudes to inject the upper part of the spacecraft including the descent module to the safe altitude clearance for the nominal parachute system reliable operation.
During the orbital flight the spacecraft is protected from overheat/overcooling by covering all the outer surface of its modules with multi-layer vacuum shield thermal insulation except the operation surfaces of the sensors, antennae, windows, docking assembly, and the thermal control system radiator.
While in the second revolution of the orbital flight tests are conducted for the radar rendezvous, communication, TV, and motion control systems.
During Soyuz manned flights to Mir station a two-day rendezvous schedule is mostly used.
The autonomous approach procedure starts at the range of less than 400 km in the automatic mode by means of “Kurs” radar rendezvous system. When the range of 150 m is reached the spacecraft transfers to the station keeping mode while over the ground tracking/communication sites. At this range the berthing (final approach) procedure is started and monitored by the Mission Control Center via telemetry data, TV and crew reports.
The docking starts at the moment of the spacecraft rod contact with the station-receiving cone and is over when the rod is fully retracted and the electric and hydraulic interfaces of the two vehicles are matched. When the retraction mode is completed the docking interface pressurization is tested and after that the transfer hatches are opened. Then the crew performs the spacecraft systems preservation and gets down to operations onboard the orbital station.
A few days before the return the crew conducts the motion control system test while still being docked to the station.
After the operation program onboard the station is over the crew transfers to the spacecraft, shuts the transfer hatch doors, dons the space suits, tests the hatch pressurization and performs the spacecraft/station undocking. After the undocking the spacecraft attitude for the retrofire is automatically configured and the engine is fired at the second revolution of the day. When the retrofire impulse is complete the spacecraft modules are separated and the descent module goes down along the descent trajectory to the nominal landing area. The Search/Rescue Service evacuates the crew from the landing site. After a medical inspection at the landing area the crew is transported to the Gagarin Cosmonaut Training Center where the post-flight rehabilitation procedure is carried out within three weeks.

2.3. Spacecraft Composition

Soyuz spacecraft in its crew transfer (TK) version consists of five modules (Fig. 2-1). There are three pressurized modules: Бытовой Отсек (БО) (the Habitable Module, the Crew Resting Module), Спускаемый Аппарат (СА) (the Descent Module) and Приборный Отсек (ПО) (the Instrument Module) and two unpressurized modules: Переходный Отсек (ПхО) (the Adapter Module) and Агрегатный Отсек

(АО) (the Assembly Module). The Instrument, Adapter and Assembly Modules (ПО+ПхО+АО) make up Приборно-Агрегатный Отсек (ПАО) (the Instrument/Assembly Module). A general view of the Soyuz crew transfer spacecraft is given in Fig. 2-2.

БО

The БО is designed to accommodate the apparatus and equipment of various spacecraft systems: Life Support, Rendezvous and Docking, On-Board Complex Control, Measurement, TV etc. and also to provide for the crew resting and for the crew transfer from the spacecraft to the station.
The БО has the shape of a sphere at the top of which the docking assembly is mounted with the hatch of 800 mm in diameter for the crew transfer to the station. On the upper semisphere the cupola/window is installed to provide for the manual approach monitoring. On the lower semisphere there is another hatch of 660 mm in diameter for the crew pre-launch ingress and also the Module depressurization valve zero-torque outlet and the pressure-sealed lead-throughs of the electrical connections with the other spacecraft modules. Also mounted on the БО outside are antennae of the “Kurs” Rendezvous Radar System and the “Klest M” TV System as well as the exteriore TV-camera and the floodlight.
The БО is attached to the CA by means of pyro-locks with spring pushers of the Module Separation System.
Inside the БО Module there are “сервант” (a “cupboard”) and “диван” (a “sofa”) where various equipment is located.

CA

The CA is the principal workstation Module of the spacecraft where the crew stays during the orbit injection phase, orbital maneuvers (attitude control, orbit correction, rendezvous, docking etc.) as well as during the descent phase.
Inside the CA Module cockpit the crew main spacecraft control station - Пульт Космонавта (ПК) (Cosmonaut Panel, Crew Display/Control Panel) is installed. The CA can also be used as a floating means in case of water splash landing and as a shelter in adverse weather condition at the landing site.
The CA is equipped with the systems ensuring both its autonomous orbital flight control and safe landing within the specified area. The following is located in the CA:

- the spacecraft and CA motion control apparatus;
- equipment for the crew Life Support System and for its survival in case of the cockpit depressurization;
- Thermal Control System units;
- displays/controls of various systems: TV, radio-communications, power supply, telemetry;
- Post-Landing Survival Kit;
- payload container.

There are three shock absorbing seats inside the CA to provide for the crew’s favorable G-load tolerance during injection and descent phases. Directly in front of the seated crew there are the spacecraft system controls , spacecraft orbital attitude and motion hand controllers, the optical sight for attitude or docking monitoring.
In pressurized containers inside CA the main and back-up Parachute Systems are stowed. There are two windows in the CA structure. On the structure descent reaction control thrusters are mounted and also the detachable pressure sealed feed through plate connecting the CA with the other modules, soft landing thrusters and post-landing deployed radio-communications antennae. The hatch on top of the CA structure is for the crew transfer to the БО and for post-landing crew egress.
The CA structure is shaped as an aerodynamic “headlight” The exterior of the Module structure is covered with the heat-protective shroud of which the bottom shield is ejected before landing.

ПхО

The ПхО Module is a truss structure which is designed to link the CA with the ПО Module. In all the CA/ПхО linkage points pyro-locks and pushers of the Module Separation System are installed. In the ПхО the Atmosphere Revitalization System oxygen pressure tanks are mounted. Outside the ПхО Module there are some spacecraft attitude control/berthing thrusters, radio system antennae and ground interface electrical connectors.

ПО

The ПО is designed for accommodation of the orbital flight control electronic equipment. The ПО Module structure is cylinder shaped. The Module interior is filled with a neutral gas. Inside on a special rack instruments are mounted of various systems: Motion and On-Board Complex Control, Command Radio Link, Telemetry, Power Supply, Thermal Control etc. Mounted outside the ПО are the spacecraft Infra-Red Vertical and Solar Attitude Control sensors, electrical pressure-sealed lead-throughs and the Solar Panel attachment supports.

ÀO

The AO is designed for housing the Propulsion System main units with the propellant stock, a part of the berthing/attitude control thrusters, the accu batteries and the Thermal Control System assemblies. The AO Module body is cylinder shaped and has a thermal protective cover at one end for the main engine. Outside of the AO there are: the exterior radiator for waste heat dumping into space, the Infra-Red Vertical second sensor, thermal sensor for the Module Separation System, the Radio-Communications System antennae and the Solar Panel attachment aids.

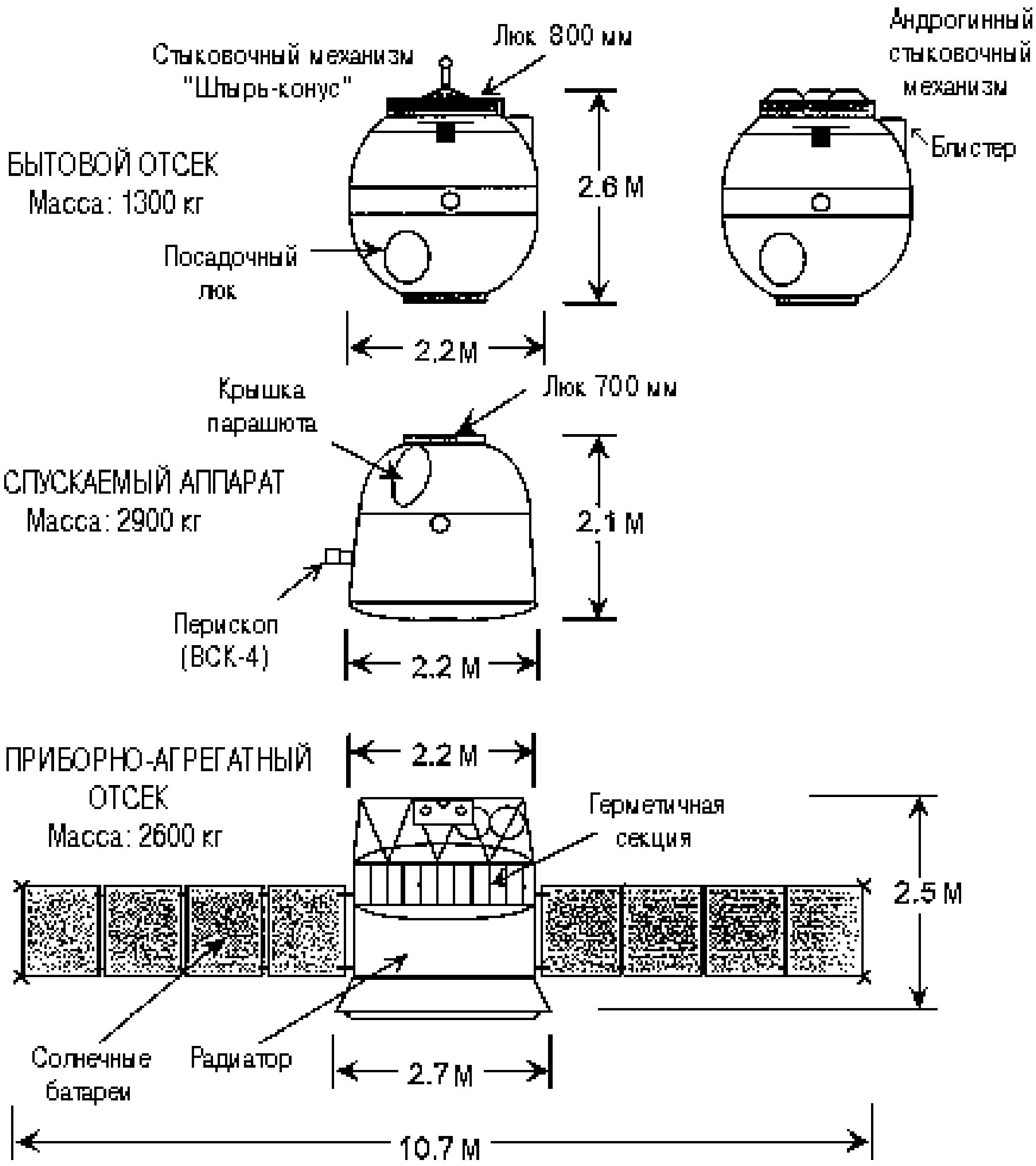


Рис. 2-1: Состав транспортного корабля "Союз ТМ"

Fig. 2-1: Soyuz Spacecraft Composition

1. БО (Habitable Module, Crew Resting Module), Weight: 1300 kg. 2. Rod/Cone Docking Mechanism. 3. Hatch 800 mm. 4. Androgynous Docking Mechanism. 5. Cupola. 6. Ingress Hatch. 7. Parachute cover. 8. Hatch 700 mm. 9. ВСК-4 Periscopic Sight. 10. СА (Descent Module), Weight: 2900 kg. 11. ПАО (Instrument/Assembly Module), Weight: 2600 kg. 12. Pressurized Section. 13. Radiator. 14. Solar Batteries.

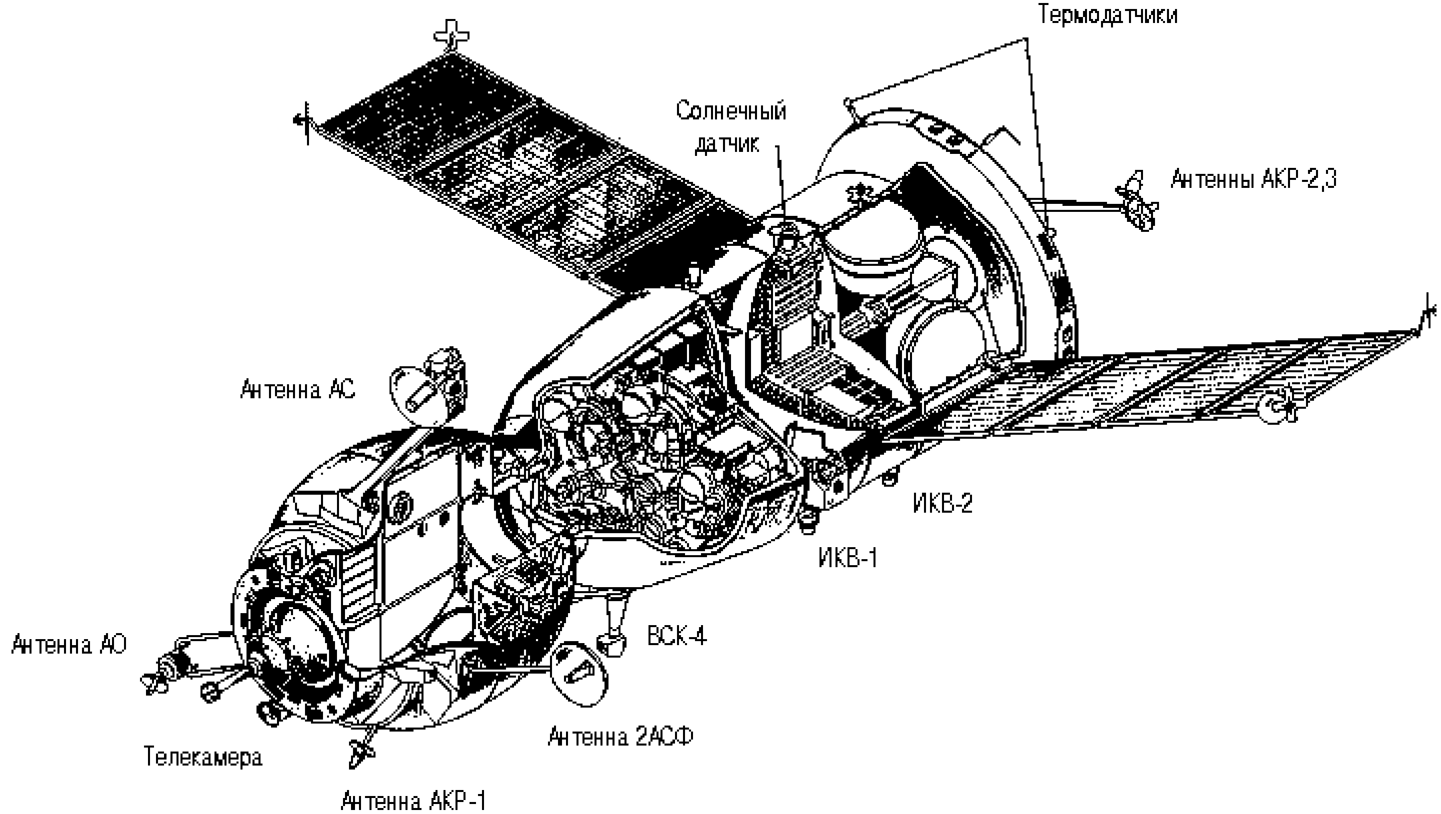


Рис. 2-2 : Внешний вид транспортного корабля "Союз ТМ"

Fig. 2-2: Soyuz Spacecraft Appearance

1. All-Around Antenna. 2. Auto-Following Antenna. 3. Solar Sensor (now not installed). 4. Thermal Sensors. 5. АКР - 2, -3 Antennae. 6. “ИКВ-2” Infra-Red Vertical Sensor. 7. “ИКВ-1” Infra-Red Vertical Sensor. 8. ВСК-4 Periscopic Sight 9. 2 АСФ Antenna. 10. АКР-1 Antenna. 11. TV-camera.

3. SYSTEMS

3.1. КОНСТРУКЦИЯ И КОМПОНОВКА (КиК) (DESIGN & CONFIGURATION)

GENERAL INFORMATION ON THE SYSTEM

The Soyuz spacecraft standard version is designed for:
- delivery of a three man crew and a payload onboard the orbital station;
- joint fly with the station for up to 180 days;
- bringing the crew and the payload to the Earth.

The Soyuz spacecraft calculated autonomous flight life is 4,2 days. This time period includes rendezvous/docking operations (2,2 days) and undocking and pre-landing operations and time reserve (2 days).
Apart from its main purpose the spacecraft may be also used as a rescue vehicle, unmanned or piloted by only the commander, or as an unmanned cargo vehicle capable to deliver 250 kg of payload from the orbit.

SYSTEM COMPOSITION

The Soyuz crew transfer vehicle consists of three pressurized modules:
- the БО (Habitable Module, Crew Resting Module);
- the СА (Descent Module);
- the ПО (Instrument Module);

and two unpressurized modules:
- the ПхО (Adapter Module);
- the АО (Assembly Module).

The ПО (Instrument), ПхО (Adapter) and АО (Assembly) Modules make up the ПАО (Instrument/Assembly) Module (Fig. 1).

БО

The БО is designed to accommodate the apparatus and equipment of various spacecraft systems: Life Support, Rendezvous and Docking, On-Board Complex Control, Measurement, TV etc. and also to provide for the crew resting and for the crew transfer from the spacecraft to the station.
The БО body has the shape of a sphere at the top of which the docking assembly is mounted with the hatch of 800 mm in diameter for the crew transfer to the station. On the upper semisphere the cupola/window is installed to provide for the manual approach monitoring. On the lower semisphere there is another hatch of 660 mm in diameter for the crew pre-launch ingress and also the Module depressurization valve zero-torque outlet and the pressure-sealed lead-throughs of the electrical connections with the other spacecraft modules.
Also mounted on the outside of the БО are antennae of the “Kurs”Rendezvous Radar System and the “Klest M” TV System as well as the outside TV-camera and the floodlight (Fig. 3).
The БО is attached to the СА by means of pyro-locks with spring pushers of the Module Separation System. The БО Module body is made of an Aluminium/Magnesium alloy.
Inside the Module there are “сервант” (a “cupboard”) and “диван” (a “sofa”) which comprise the “interieur furniture” and where apparatus and equipment as well as various system controls are located (Fig. 4, 5, 6, 7).

СА

The СА is a pressurized habitable module where the crew stays during the orbit injection phase, orbital maneuvers (attitude control, orbit correction, rendezvous, docking etc.) as well as during the return to the Earth phase.
Inside the СА Module cockpit the crew main spacecraft control station is installed. The СА can also be used as a floating means in case of a water splash landing and as a shelter in case of adverse weather condition at the landing site.
The СА is equipped with the systems ensuring both its autonomous orbital flight control and safe landing within the specified area. (Fig. 8).
The following is located in the СА:
- the spacecraft and СА motion control apparatus;
- equipment for the crew Life Support System and for its survival in case of the cockpit depressurization;
- Thermal Control System units;
- controls/displays of various systems: TV, radio-communications and direction finding, power supply, telemetry;

- Post-Landing Survival Kit;
- payload container.

The CA body is made of an Aluminium alloy and shaped as an aerodynamic "headlight". The exterior of the CA Module structure is covered with the heat-protective shroud.

ПхО

The ПхО Module is a truss structure which is designed to link the CA with the ПО Module. In all the CA/ПхО linkage points pyro-locks and pushers of the Module Separation System are installed. In the ПхО the Atmosphere Revitalization System oxygen pressure tanks are mounted. Outside the Module there are some spacecraft attitude control/berthing thrusters, radio system antennae and ground interface electrical connectors (Fig. 9).

ПО

The ПО Module is designed for accommodation of the orbital flight control electronic equipment. The Module body is cylinder shaped with spherical bottoms and is made of Aluminium alloy (Fig. 10).The body interior is filled with a neutral gas. Inside on the instrument rack instruments are mounted of various systems: Motion and Onboard Complex Control, Command Radio Link, Telemetry, Power Supply, Thermal Control etc.

АО

The АО Module is designed for housing the main engine with the fuel stock, a part of the berthing/attitude control thrusters, the accu batteries and assemblies of the Thermal Control System. The Module unpressurized body is shaped as a cylinder with a conical bottom and has a thermal protective cover at one end for the main engine. Outside the АО Module the exterior radiator for waste heat dumping into space is mounted (Fig. 11).

SOYUZ SPACECRAFT SELECTED ONBOARD SYSTEMS

"CHAYKA-3" СИСТЕМА УПРАВЛЕНИЯ ДВИЖЕНИЕМ (СУД) (MOTION CONTROL SYSTEM)

The СУД is built on the basic principle of using a strapdown inertial navigation system and implementing all the control procedures by means of the Onboard Digital Computer Complex. The inertial system of such a type makes use of the spacecraft attitude rate and acceleration data derived from digital attitude rate sensors and string accelerometers.

СИСТЕМА УПРАВЛЕНИЯ БОРТОВЫМ КОМПЛЕКСОМ (СУБК) (ONBOARD COMPLEX CONTROL SYSTEM)

The СУБК System is designed to control the spacecraft systems and units during pre-flight and flight phases in response to commands issued by the ground, from the ПК СА (Crew Display/Control panel), by the Program Timing Device and by other spacecraft systems (Interactive Multisystem Control Commands).

КОМБИНИРОВАННАЯ ДВИГАТЕЛЬНАЯ УСТАНОВКА (КДУ) (COMBINED PROPULSION SYSTEM)

The КДУ (Combined Propulsion System) provides thrust impulses for the spacecraft correction and retrograde maneuvers, the spacecraft attitude hold (stabilization) during the Orbital Maneuver Engine burns: in pitch and yaw (by gimballing the Engine camera) and in roll (by means of microthrusters) and the spacecraft attitude control by means of the microthrusters in the modes of attitude configuration(establishment), attitude hold, attitude maneuver and injection to passive thermal control (barbecue maneuver).In case of the Engine failure the retrofire impulse is provided by the simultaneous burn of four primary berthing/attitude control thrusters.

СИСТЕМА ЭЛЕКТРОПИТАНИЯ (СЭП) (POWER SUPPLY SYSTEM)

The СЭП (Power Supply System) is designed to provide all the spacecraft equipment with 27 V dc power and comprises the current generating Solar Batteries, buffer and back-up accu batteries, CA battery, БО battery and automatic power supply control equipment.

СИСТЕМА ОБЕСПЕЧЕНИЯ ТЕПЛОВОГО РЕЖИМА (СОТР) (THERMAL CONDITION CONTROL SYSTEM)

The СОТР (Thermal Condition Control System) is designed to maintain conditions of normal temperature (18 - 25^{o} C) and humidity (20 - 80 %) in habitable modules and the specified thermal conditions (0 - 40 ^{o} C) for instruments, units and spacecraft structure.

КОМПЛЕКС СРЕДСТВ ОБЕСПЕЧЕНИЯ ЖИЗНЕДЕЯТЕЛЬНОСТИ (КСОЖ) (COMPLEX OF LIFE SUPPORT ARTICLES)

The КСОЖ (Complex of Life Support Articles) is designed to provide conditions in the spacecraft modules ensuring the crew comfort and capacity for work in space flight.

The КСОЖ Complex includes:
- Средства обеспечения газового состава (СОГС) (Atmosphere Revitalization System);
- Комплекс средств спасения (КСС) (Survival Aid Complex);
- Средства подачи газовой смеси (СПГС) (Gas Mixture Supply System);
- Средства водообеспечения (СВО) (Water Supply System);
- Система питания (СП) (Food Rations);
- Средства личной гигиены (СЛГ) (Personal Hygiene Items);
- Underwear, Garments;
- Medicinal/Prophylactic Aids;
- Medical Monitoring Equipment;
- Ассенизационно-санитарная установка (АСУ) (Waste Management System);
- Носимый аварийный запас (НАЗ) (Post Landing Survival Kit).

The СОГС (Atmosphere Revitalization System) is designed to support and monitor specified atmosphere composition in the spacecraft habitable modules during 4,2 days of the autonomous flight and during 1 day in the CA after landing. It provides for the oxygen supply to the habitable modules and absorption of CO2 and injurious additives.

The КСС (Survival Aid Complex) purpose is to ensure safe crew return to the Earth in case of a habitable module depressurization.

The СПГС (Gas Mixture Supply System) is designed for the oxygen stowage and supply to the crew. The oxygen for the orbital operations is stowed in the ПхО Module and for the descent operations after the separation - in the CA Module.

The СВО (Water Stock/Supply) is to provide the crew with potable water which is stowed in the БО (20 liters) and in the CA (1,7 liters).

The СП (Food Rations) are the crew's meals in the autonomous flight. They consist of canned and sublimated food stuffs. A daily ration provides for four meals a day of 3000 kcal a day. The СП Rations are stored in the БО "сервант" ("cupboard").

The СЛГ (Personal Hygiene Items) are located in habitable modules and comprise wet and dry napkins and towels kits.

The Medical Monitoring Equipment is for the crew medical state monitoring. It consists of the Amplifier/Converter Unit and sensor harness (belts). The equipment provides for a simultaneous monitoring of three cosmonauts by taking their seismocardiograms, electrocardiograms, pneumograms and pulse rates.

The АСУ (Waste Management System) is for collecting the crew's physiological and eventual motion sickness vestibular disorder wastes and isolating them from the module atmosphere. It is located in the left part of the "сервант" ("cupboard").

The НАЗ (Post Landing Survival Kit) is provided to ensure the crew survival in extreme climate conditions. It includes visual signaling aids, medicines, weapon and ammunitions, water stock, swimming aids and clothes.

СИСТЕМА ПРИЗЕМЛЕНИЯ (СП) LANDING SYSTEM

The СП (Landing System) is to ensure the CA Module safe landing with the crew inside both when nominally returning from the orbit and in case of emergency during the launch/injection phase. The System includes:
- Primary and Back-Up Parachute Systems;
- "Kazbek" Shock Absorbing Seats.

СИСТЕМА СТЫКОВКИ И ВНУТРЕННЕГО ПЕРЕХОДА (ССВП) (DOCKING & INTERNAL TRANSFER SYSTEM)

The ССВП (Docking & Internal Transfer System) is designed for the spacecraft/station mechanical linkage, compensating for the docking impact energy, spacecraft/station alignment during structural latching procedure, rigid connection and docking interface pressurization and for undocking at any moment of the docking procedure and after termination of the joint flight. The active part of the "rod/cone" system is installed on board the spacecraft. The hatch door Open/Close and pressurization mechanisms can be operated manually.

СИСТЕМА КОНТРОЛЯ ГЕРМЕТИЧНОСТИ СТЫКА (СКГС) (INTERFACE PRESSURIZATION CONTROL SYSTEM)

The СКГС (Interface Pressurization Control System) enables the crew to monitor the docking interface pressurization and to equalize pressure between the spacecraft and the station, also to monitor pressurization of the transfer hatches, dump pressure out of the docking node and to monitor the pressurization of the spacecraft habitable modules. There are manual valves and the Vacuum Pressure Gauge installed in the БО to provide for the System control by the crew.

"RASSVET" СИСТЕМА РАДИОСВЯЗИ (СРС) (RADIO COMMUNICATIONS SYSTEM)

The СРС (Radio Communications System) is mainly used for crew/ground voice and telegraph communication. It operates in SW and VHF bands for two-way crew communication with the ground sites. It provides voice crew intercom in all spacecraft and station modules as well as voice data recording and playing by means of the Onboard Tape Recorder.

"KLEST-M" ТЕЛЕВИЗИОННАЯ СИСТЕМА (ТВС) (TELEVISION SYSTEM)

The ТВС (Television System) provides for:

- TV image transmission from the CA to the ground accompanied by voice data both at the launch pad and in all flight phases;
- Rendezvous and docking TV monitoring;
- Onboard systems operational status display;
- TV data transmission to the ground via the "Kvant-B" Command Radio Link transmitters.

СИСТЕМА БОРТОВЫХ ИЗМЕРЕНИЙ (СБИ) (ONBOARD MEASUREMENT SYSTEM)

The СБИ (Onboard Measurement System) is designed to sample, memorize and transmit data from the spacecraft sensor equipment. It is a time division multichannel pulse coding frequency modulation system. It is absolutely automatic and does not require any crew activities.

"KVANT-B" COMMAND RADIO LINK SYSTEM

The Command Radio Link System is designed for the ground/spacecraft two way multi-function radio communication and for the spacecraft control during active portions of its orbital flight. The "Kvant-B" System supported by ground facilities ensures execution of the following tasks:

- Measurement of the slant range to the spacecraft and its velocity radial component;
- Spacecraft onboard systems control by means of functional commands;
- Digital data exchange with the spacecraft Onboard Computer Complex and Program-Timing Control Equipment, these data receiving/transmitting via up and down radio links;
- TV and telemetry data downlinking;
- Onboard-to-Ground time synchronization.

The system is completely automated and does not require any crew activities.

The antennae layout on Soyuz spacecraft is shown in Fig. 12.

THE SYSTEM OPERATIONAL LIMITS AND CHARACTERISTICS

Soyuz Crew Transfer spacecraft technical characteristics:

- body length 7 m
- maximal diameter 2,7 m
- CA full volume 4 m^3
- БО full volume 6 m^3
- autonomous flight service life 4,2 days
- joint flight (as a part of the Mir Station (ISS)) service life 180 days

The Soyuz principal dimensions are shown in Fig. 13.

CREW OPERATIONS WITH THE SYSTEM

The crew operations with the System are assumed to be those of mounting/dismounting the easy-mount instrument/assembly access panels in the БО and opening/closing the CA/БО hatch door. The hatch door open position is 85 degrees. In the ground operations conditions the brake mechanism should be used. The door open position is monitored by the indicator light illumination on the Electroluminescent Indicator Display of the ПК (Crew Display/control Panel) in the CA.

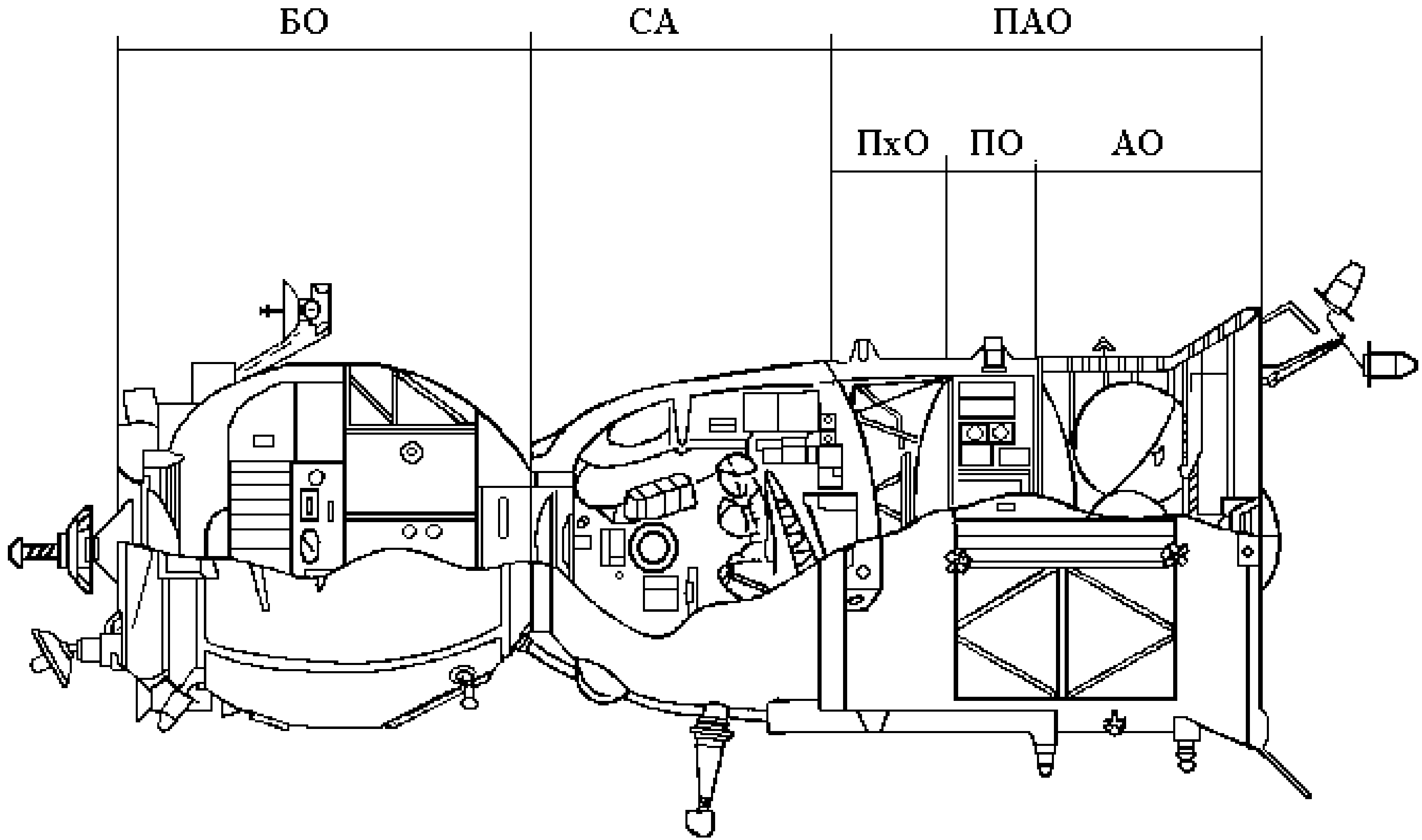


Fig.1. Soyuz Spacecraft Modules

1. БО (Habitable, Crew Resting Module). 2. СА (Descent Module). 3. ПАО (Instrument/Assembly Module). 4. ПхО (Adapter Module). 5. ПО (Instrument Module). 6. АО (Assembly Module).

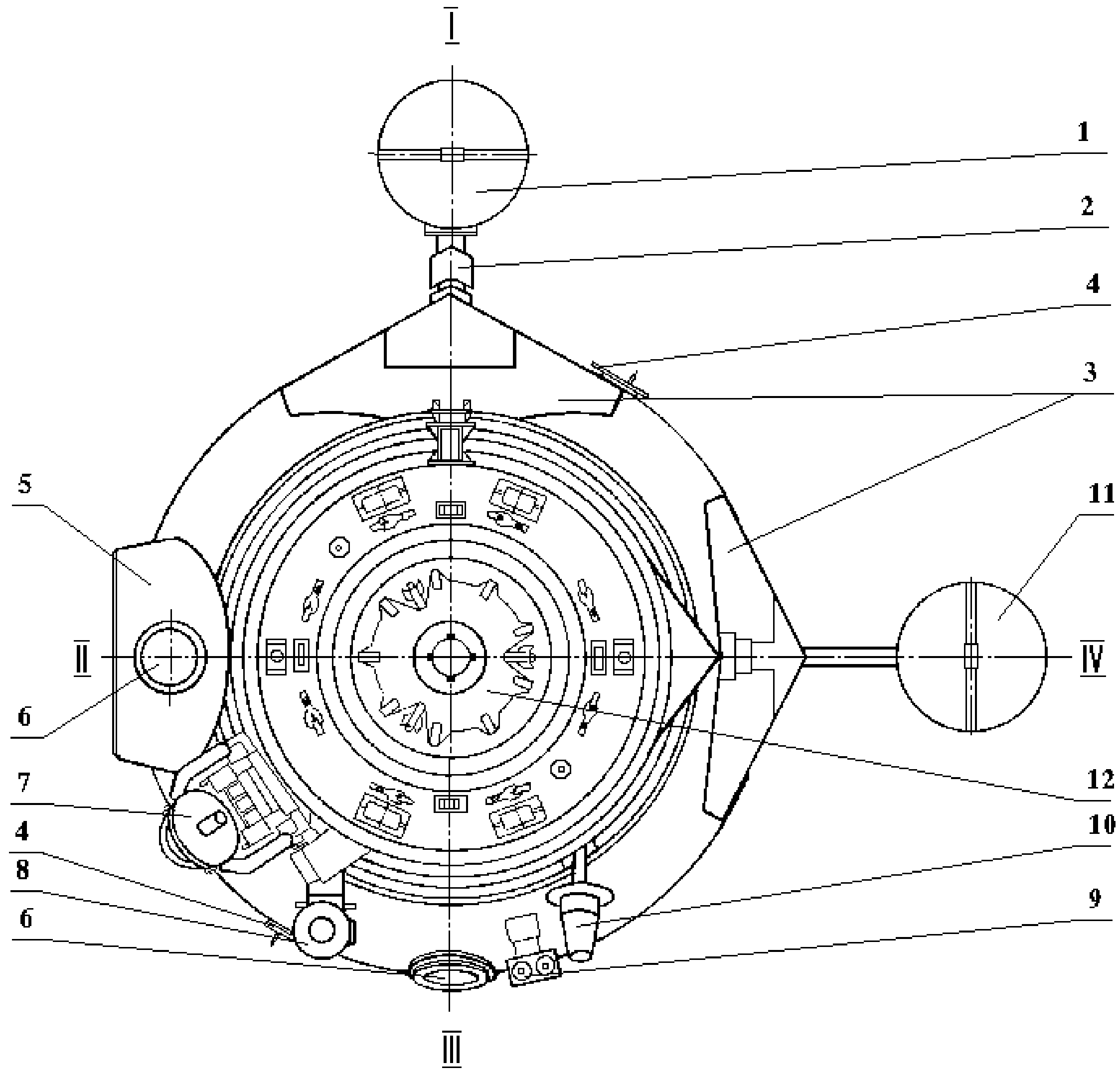


Fig.2. БО Exterior Layout

1. АС-ВКА Antenna. 2. Boom. 3. Radar shield. 4. АБД-24 Antenna. 5. Cupola. 6. Window. 7. 2АО-ВКА Antenna. 8. КЛ-101-02 TV Camera. 9. СМИ4 Small Dimension Light Emitter. 10. АКР-1 Antenna. 11. 2АСФ1-М-ВКА Antenna. 12. Docking Mechanism.

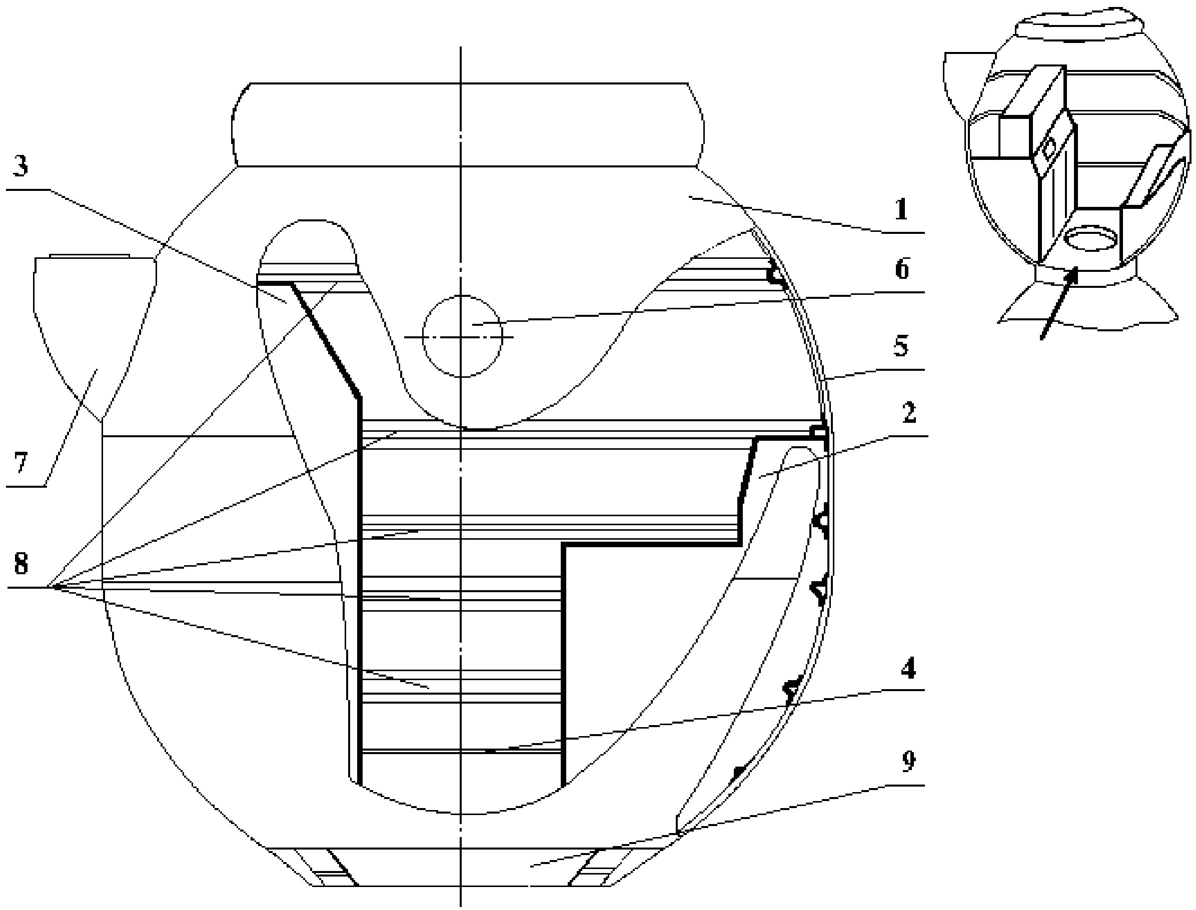


Fig. 3. БО Main Structural Elements

1. Body. 2. Port Side (the “Диван” - “Sofa”). 3. Starboard (the “Сервант” - “Cupboard”). 4. Floor. 5. Interior decor trim. 6. Window. 7. Cupola. 8. Frame Ring. 9. Flange.

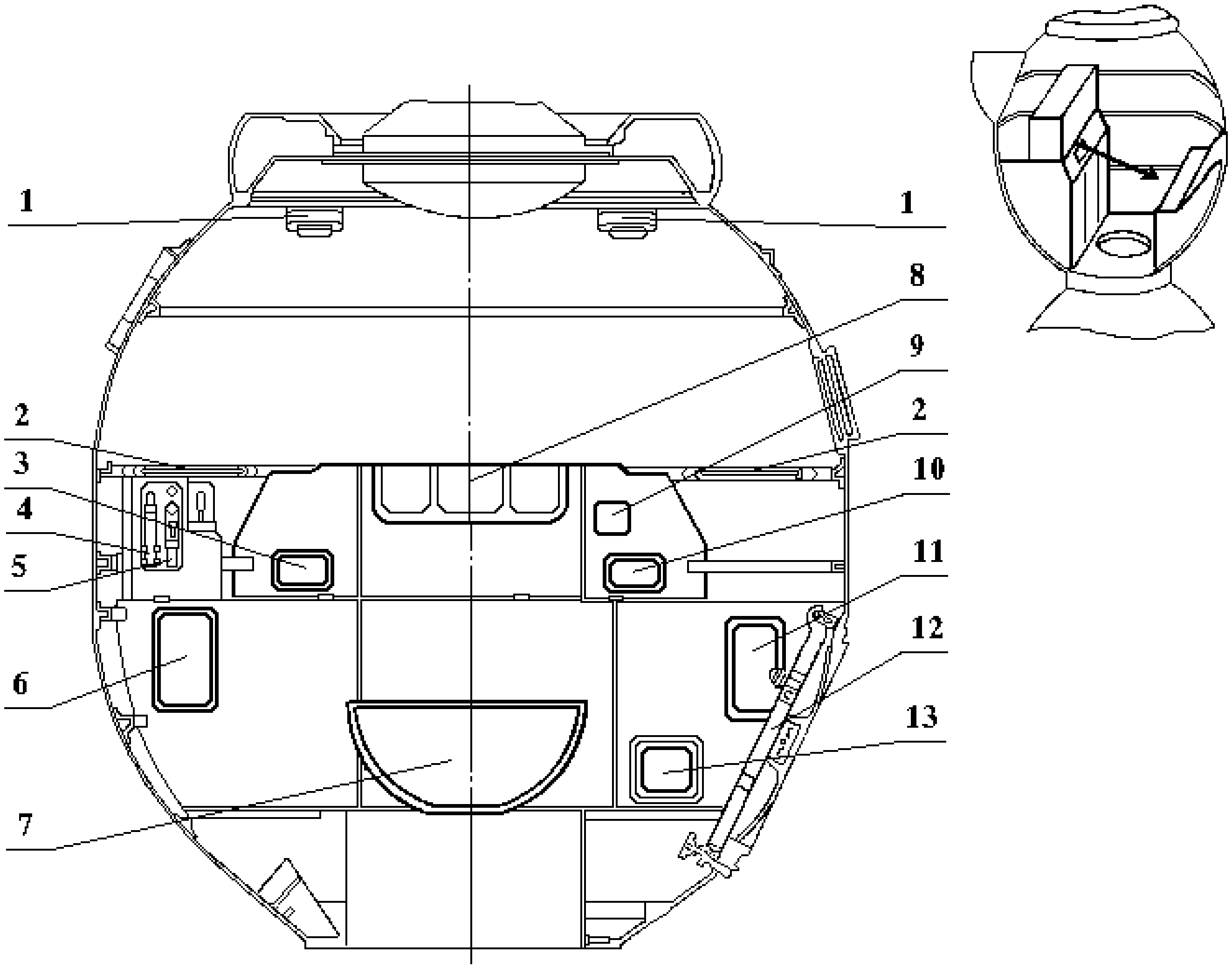


Fig. 4. View on the “Диван” (“Sofa”) (Panels Mounted)

1. СД1-6 Luminary. 2. Handhold. 3. The РБС-У-1 (Universal Onboard Network Outlet) Access Panel. 4. АСУ (WMS) Receptacle. 5. Circuit breaker Unit. 6. Water Container Access Panel. 7. Protective Grid. 8. Ventilation Grid. 9. Medical Equipment Connectors. 10. The РБС-20 (Onboard Network Outlet) Access Panel. 11. Auxiliary Connector Plate Access Cover. 12. Ingress Hatch Door. 13. КСД-БО Pressure Relief Valve Access Cover.

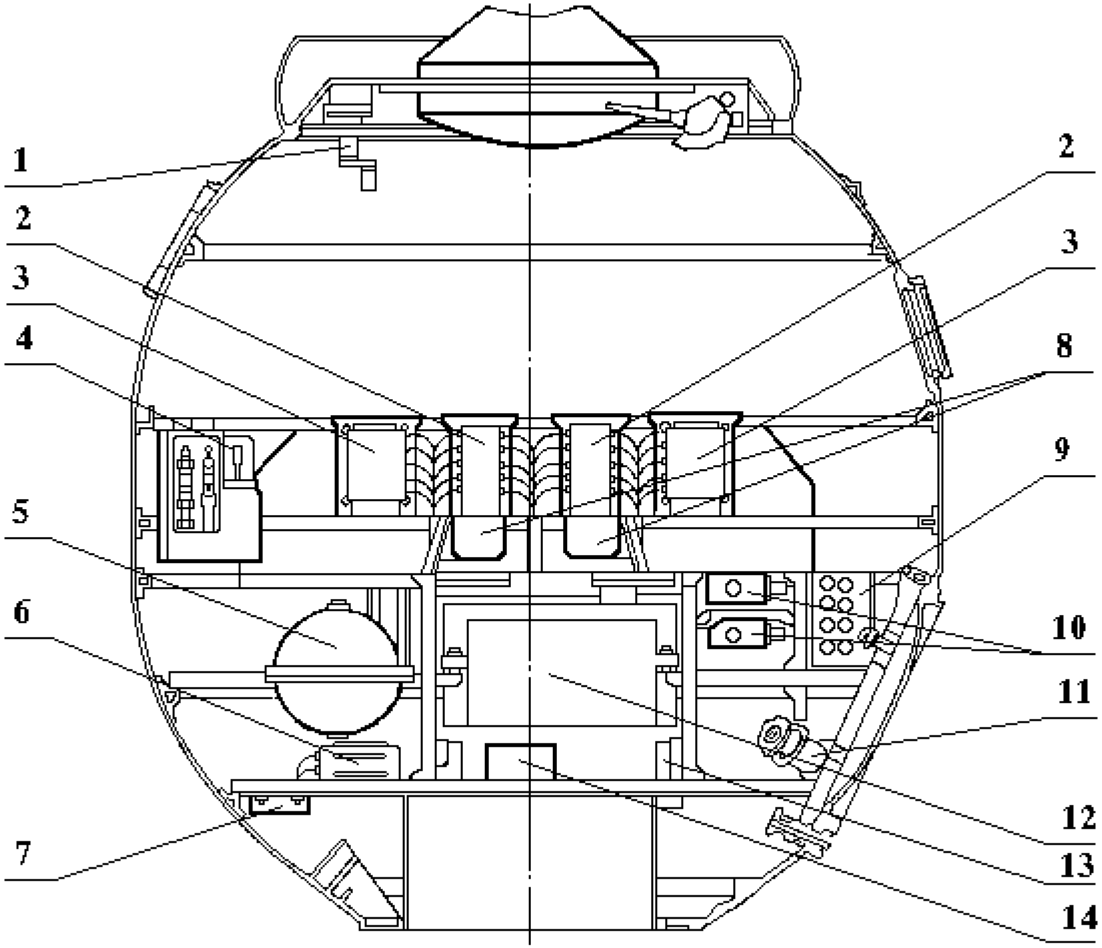


Fig. 5. View on the “Диван” (“Sofa”) (Panels Dismounted)

1. Transfer Hatch Opening Handle. 2. TA-601 Telephone Distributor Unit. 3. TA-203 Local Commutator . 4. Manual Pump. 5. Container. 6. CAC (Launch Escape System) БАС-1 Automatic Control Unit. 7. ВКБ Dismountable Commutation Unit. 8. КПБ, КПБ-1 Pyro Cartridge Commutators. 9. Auxiliary Connector Plate. 10. 907, 9071 Power Supply Units. 11. КСД-БО Pressure Relief Valve. 12. “Kurs” System 17P64 Electronic Equipment Container. 13. УДПК-24 Channel Selector. 14. ПТС-250АТ-2 Static Converter.

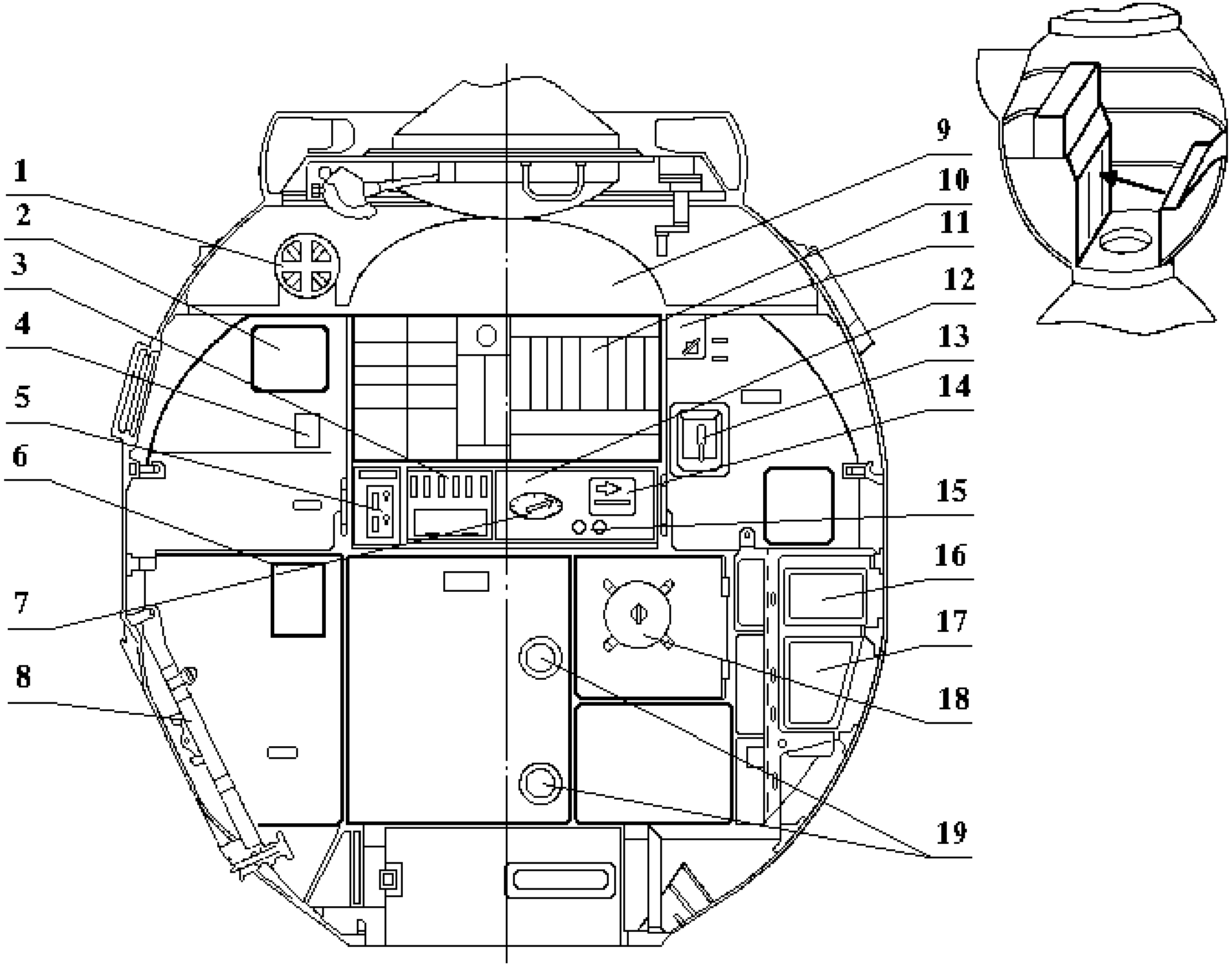


Fig. 6. View on the "Сервант" ("Cupboard") (Panels Mounted)

1.Comfort Fan. 2. Container. 3. БРУБ (БО Manual Control Unit). 4. 3C Unit. 5. ППС (Space Suit Power Supply Panel). 6.Access Cover to the Urine Receptacle with Wring Out. 7. MB Absolute (Vacuum) Pressure Gauge. 8. Ingress Hatch. 9. Cupola.10 Container № 1. 11. 2B Manual Cock. 12. СКГС (Docking Interface Pressurization)Control Panel. 13. Manual Pump. 14. Valve Set. 15. Pressure Sensors. 16. Container №5. 17. Container № 6. 18. Deflector. 19. Ventilation holes.

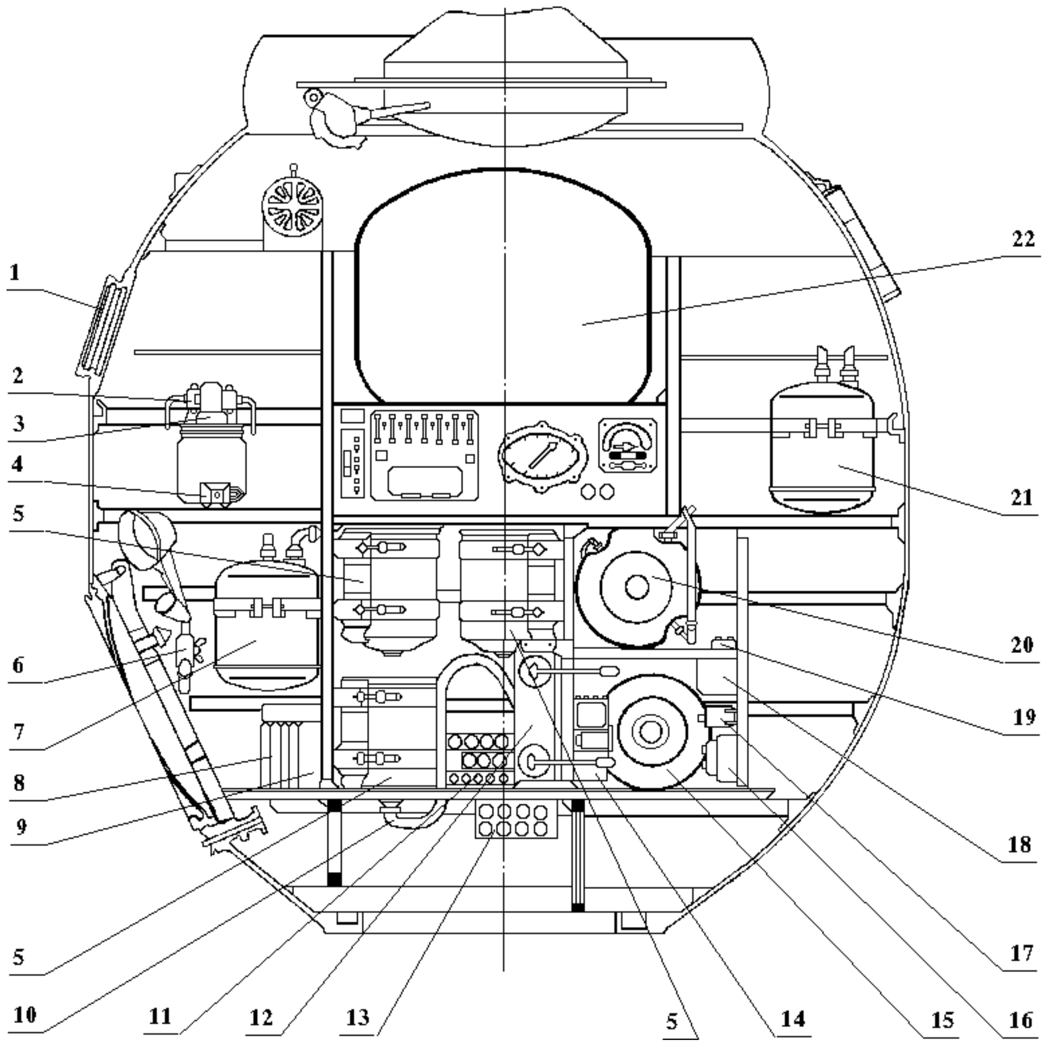


Fig. 7. View on the "Сервант" ("Cupboard") (Panels Dismounted)

1. Window. 2. Radio Interference Filter. 3. Unit II. 4. АСУ (Waste Management) Panel. 5. Air Purification Cartridge. 6.Urine Receptacle. 7. АСУ Collector. 8. Insert. 9. Renewable Ring Kit. 10. Pipeline. 11. Matrix Commutator. 12. Fan Assembly. 13. Pyro Cartridge Switchboard. 14. КЛ-108 Radio Transmitter Unit. 15. 3E Condensate Collector Container. 16. Antenna Switch. 17. КЛ-105-1.2 Commutator Unit. 18. КЛ-106 Synchronizer. 19. Sensor. 20. ХСА (Cooling/Drying Unit). 21. 2E Condensate Collector Container. 22. Cupola.

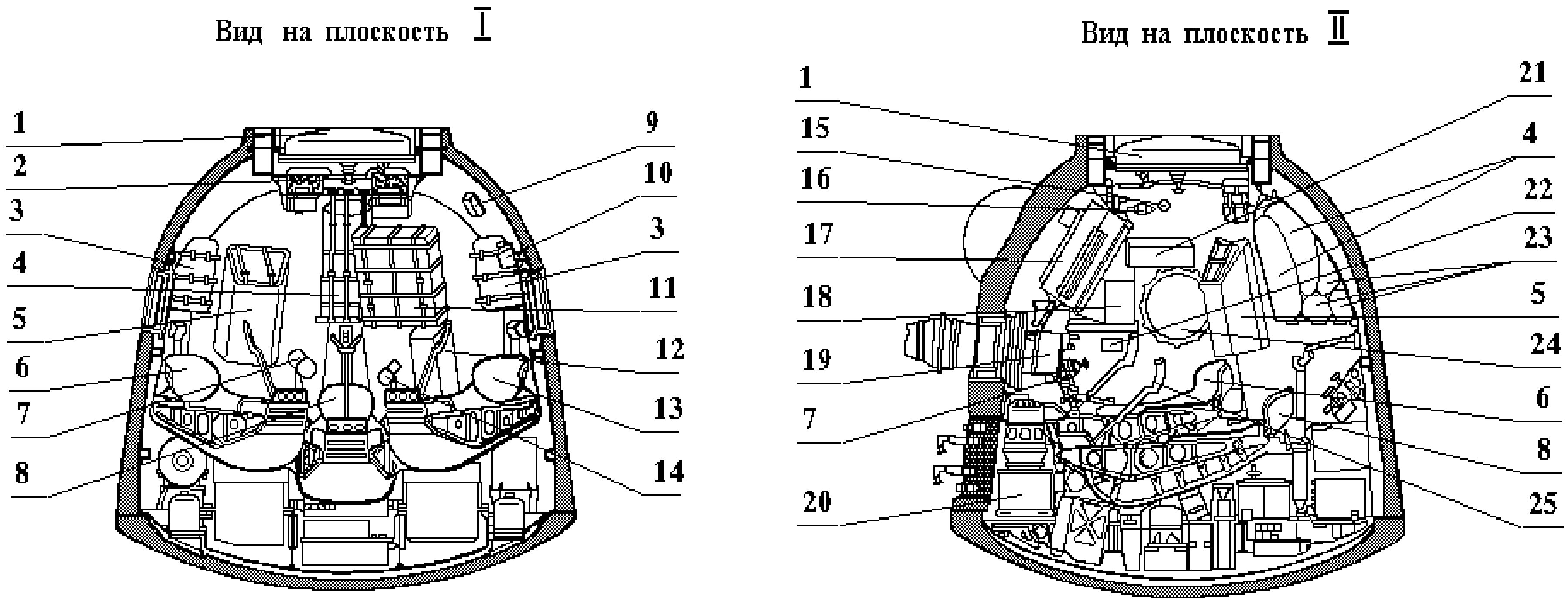


Fig. 8. CA Interior Layout

View on Plane I.

View on Plane II.

1 - СА/БО Hatch Lid;
2 - СА/БО Hatch Lock Mechanism;
3 - ПК14 Flight Garment;
4 - ТЗК (Thermal Protective Suit);
5 - Container;
6 - “Kazbek-U” Item (Right);
7 - РУО (Rotation Hand Controller);
8 - “Kazbek-U” Item (Middle);
9 - Luminary;
10 - ПЗВС (Spacesuit Fan Circuit Breaker Panel);
11 - “Forel” Hydrosuit;
12 - “Neva-KV” Set;
13 - “Kazbek-U” Item (Left);
14 - РУД (Translation Hand Controller);
15 - TV Camera;
16 - “ЗВ” Manual Cock;
17 - ПСА-1-ф732 ПК СА (Descent Module Cosmonaut Panel);
18 - Flight Data File Container ;
19 - ВСК-4 Sight;
20 - ХСА (Cooling/Drying Unit);
21 - газоанализатор (ГА) (Gas Analyser);
22 - РУО (Rotation Hand Controller) Connector;
23 - Pull-Overs;
24 - Starboard Window;
25 - Push-To-Talk Button;

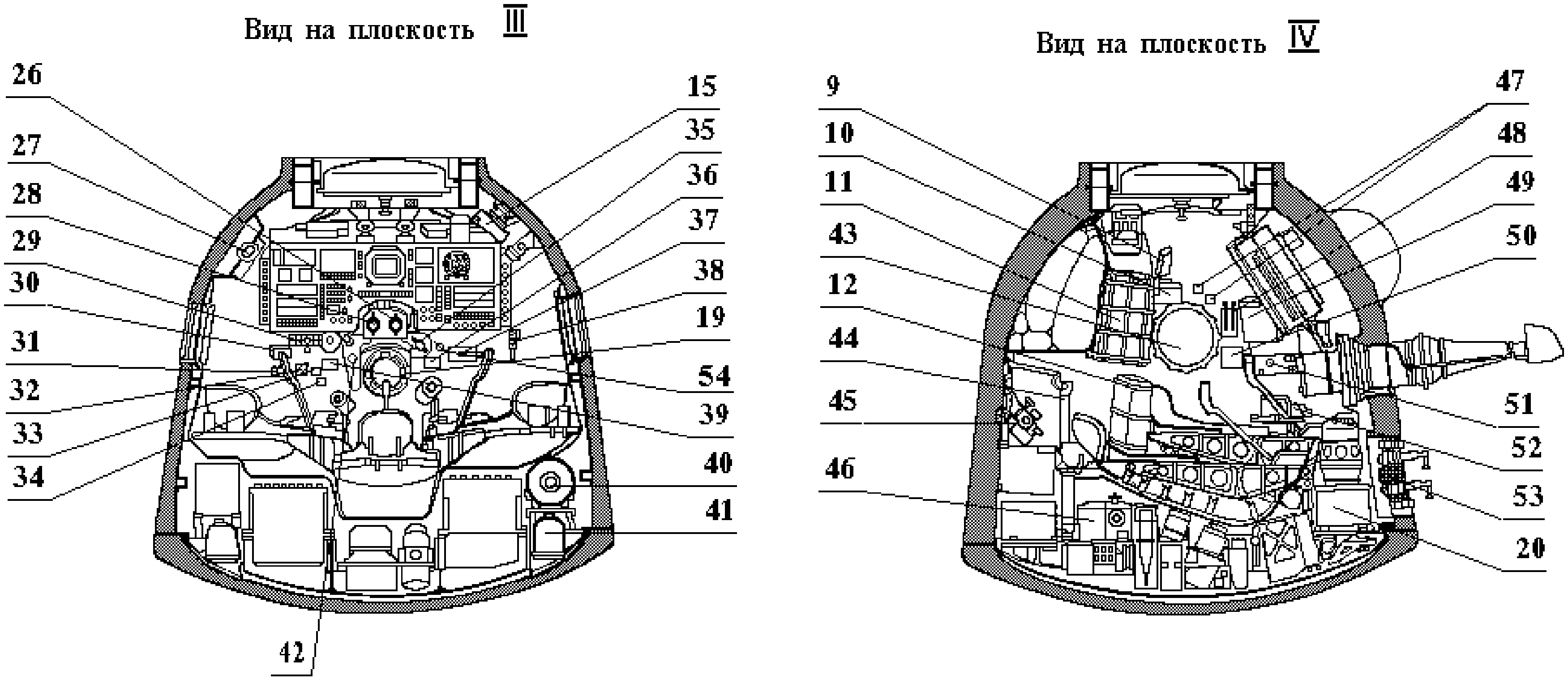


Fig. 8. CA Interior Layout (Continuation)

View on Plane III.

26 - РПВ-2 Manual Turn Valve;
27 - РАП-10 Manual Antenna Switch;
28 - РПВ-1 Manual Turn Valve;
29 - РУС (Descent Control Handle);
30 - ДСД (Pressure Caution/Warning Signal Sensor);
31 - РАП-7 Manual Antenna Switch;
32 - 1В Manual Cock;
33 - ПБК Valve Inhibit Switch;
34 - ПБК-Д Command Inhibit Switch;
35 - ЭПК-ПСА Electro-pneumatic Valve;
36 - КРУО (Rotational Hand Controller Commutator);
37 - 1НР Manual Pump;
38 - ЭПК-РД Electro-pneumatic Valve;
39 - КРУД (Translational Hand Controller Commutator);

View on Plane IV.

40 - Regenerator ;
41 - ДМП (Soft Landing Thrusters);
42 - ЭПК-П Electro-pneumatic Valve;
43 - Port Side Window ;
44 - “Kazbek-U” ItemShock Absorber;
45 - БР-1 Distribution Unit;
46 - Payload Container;
47 - БВК Separation Contact Command (KO)Issue Unit;
48 - СДВ (Ventilation Valve System) Shutter Control;
49 - БРУС (CA Manual Control) Unit;
50 - “Gnom-M” Tape Recorder;
51 - БПК Plug Cap;
52 - K1 Telegraph Key;
53 - Pressure Sealed Lead Through Plate;
54 - “4B” Manual Cock

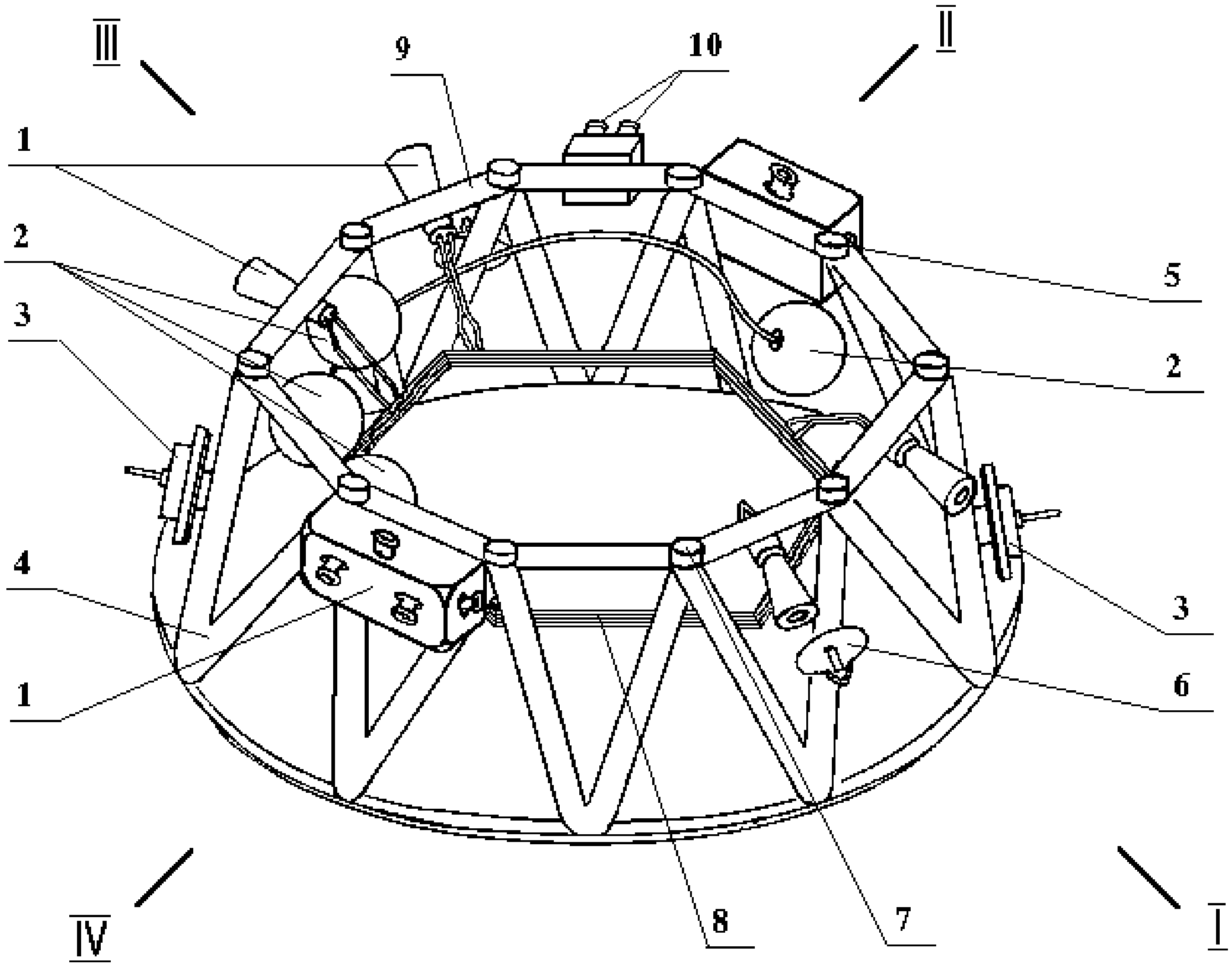


Fig. 9. ПхО Layout

1. ДПО (Berthing/Attitude Control Thruster) Unit. 2. Oxygen Pressure Bottle (4 pcs). 3. РКО (Orbit Radio Tracking) Antenna. 4. Truss. 5. Pyro Lock. 6. АБД-27 Antenna (2 pcs). 7. Spring Pusher. 8. Heat Exchange Manifold. 9. Ring. 10. Electrical Disconnects.

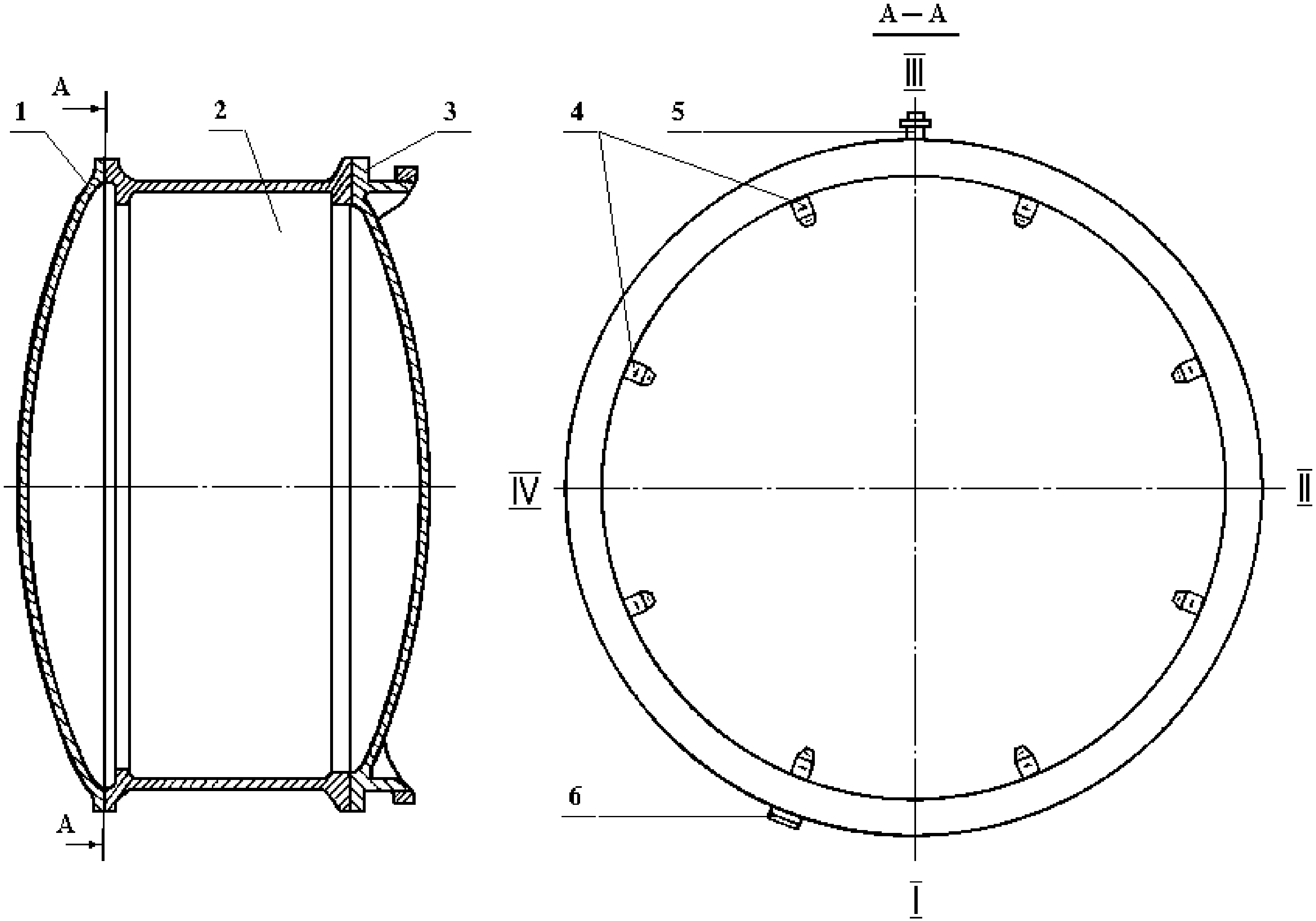


Fig. 10. ПО Body Structure

1. ПхО (Adapter Module) Spherical Bottom. 2. Cylinder Cowling. 3. AO (Assembly Module) Spherical Bottom. 4. Support. 5. Flanged Socket. 6. Socket/Sprayer.

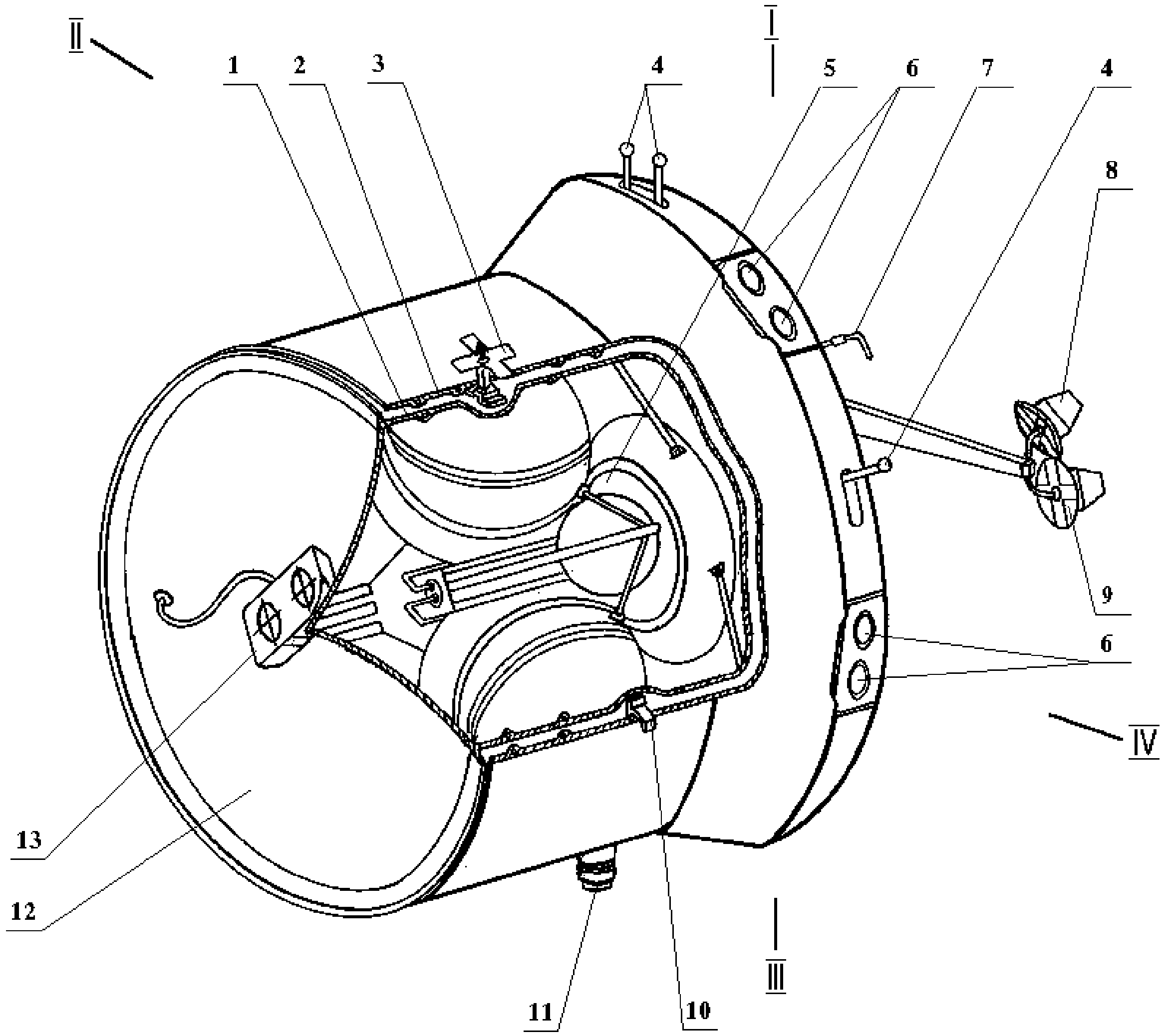
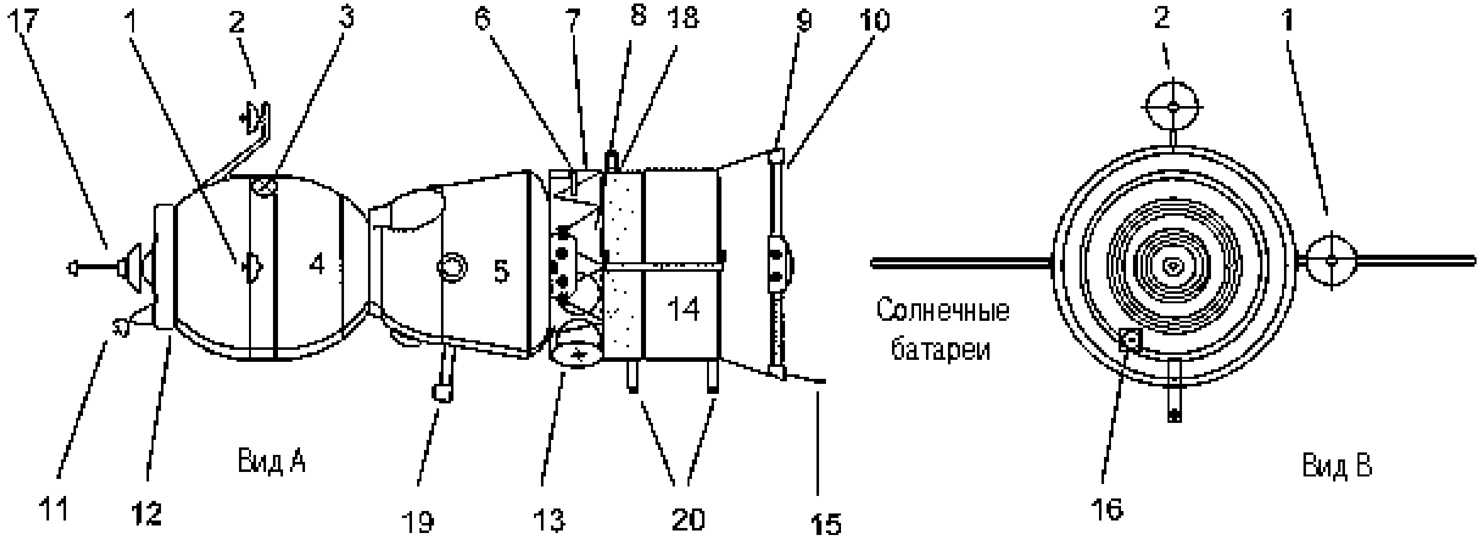


Fig. 11. AO Configuration

1. AO Body. 2. Hinged Cooling Radiator. 3. АБД-26 Antenna. 4. Thermal Sensor (6pcs). 5. КДУ (Combined Propulsion System) Basic Unit. 6. ДПО (Berthing/Attitude Control Thruster) Unit. 7. Radio Communications Antenna. 8. АКР-2 Antenna. 9. АКР-3 Antenna. 10. Solar Battery Mounting Support. 11. ИКВ (Infra-Red Vertical) Sensor. 12. Spherical Bottom. 13. ГЖА (Gas-Liquid Unit).



1 - Антенна "Курс" 2АСФ
2 - Антенна "Курс" АС
3 - Антенна ТВ
4 - Бытовой отсек
5 - Спускаемый аппарат
6 - Остронаправленная антенна КРЛ
7 - Антенна КРЛ на СБ
8 - Переходной отсек
9 - Антенна телеметрии
10 - Антенна "Курс" АКР2,3
11 - Антенна "Курс" АО
12 - Антенна "Курс" АКР1
13 - Антенна РКО
14 - Приборно-агрегатный отсек
15 - УКВ-антенна (голосовая связь)
16 - Внешняя телекамера
17 - Стыковочный механизм
18 - Солнечный датчик
19 - Перископ (ВСК-4)
20 - Датчик ИКВ1,2

Fig. 12. Soyuz Antennae Layout

1. "Kurs" System 2АСФ Antenna. 2. "Kurs" System АС Antenna. 3. TV Antenna. 4. БО Module. 5. СА Module. 6. Command Radio Link Pencil Beam Antenna. 7. Solar Panel Mounted Command Radio Link Antenna. 8. ПхО Module. 9. Telemetry Antenna. 10. "Kurs" System Antenna АКР2,3. 11. "Kurs" System АО Antenna. 12. "Kurs" System АКР1 Antenna. 13. Orbit Radio Tracking Antenna. 14. ПАО Module. 15. VHF Antenna (Voice Communications). 16. Exterior TV Camera. 17. Docking Mechanism. 18. Solar Sensor (now not installed). 19. ВСК-4 Periscope Sight. 20. ИКВ-1,2 (Infra-Red Vertical) Sensor.

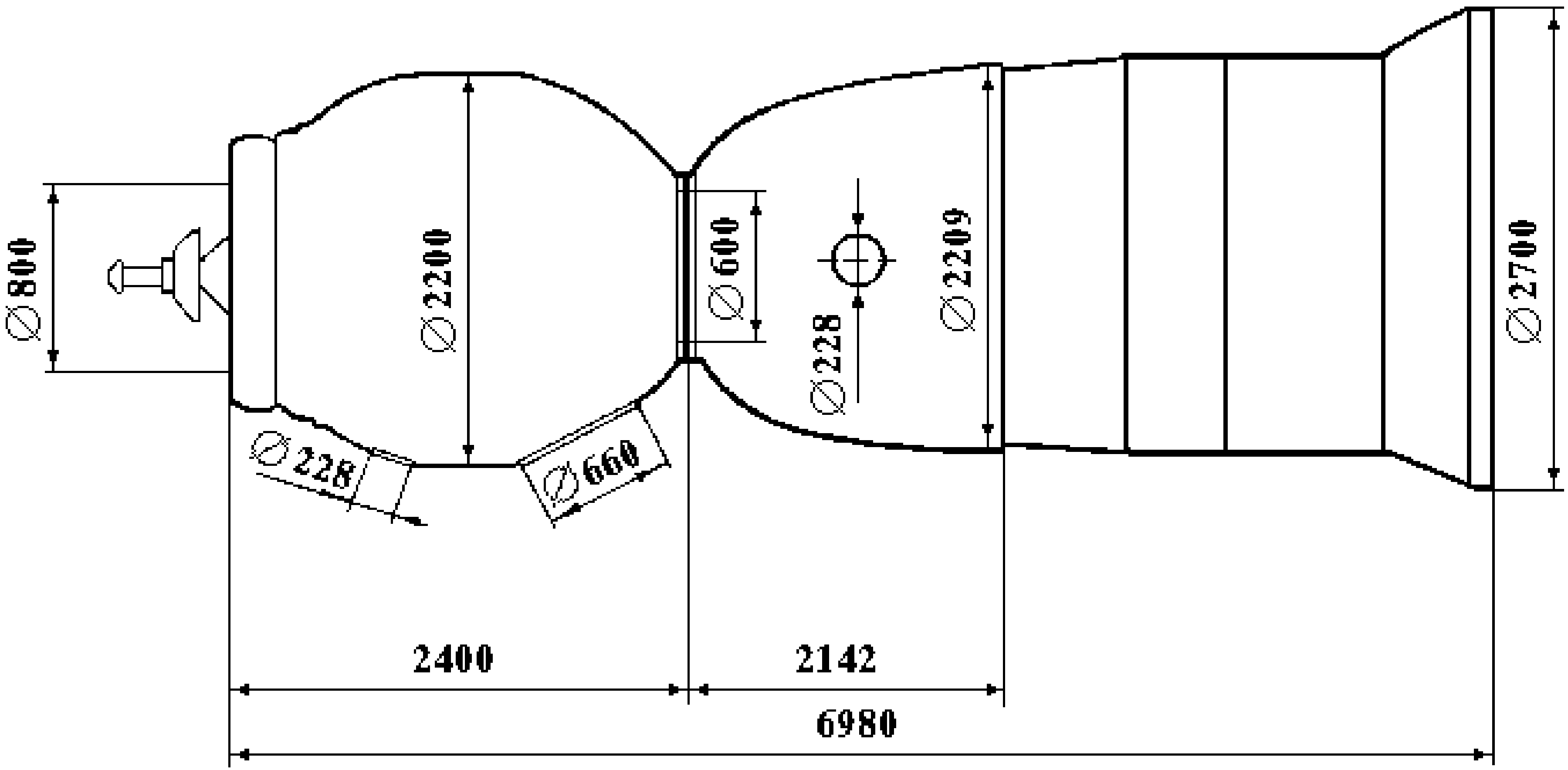


Fig. 13. Soyuz Spacecraft Principal Dimensions

Dimensions values are given in millimeters.

3.2. ПУЛЬТЫ УПРАВЛЕНИЯ (ПУ) (CONTROL/DISPLAY PANELS)

GENERAL INFORMATION ON THE SYSTEM

The crew transfer spacecraft control/display panels are designed to be operated by the crew for:
- issuing the spacecraft system control commands;
- spacecraft system functioning monitoring;
- time/space information acquisition;
- navigation status determination;
- data exchange with the БЦВК (Onboard Digital Computer Complex);
- КДУ (Combined Propulsion System fuel) consumption monitoring;
- TV data acquisition at the ВКУ Video Monitoring Device.

SYSTEM COMPOSITION

The following control aids are used for the crew transfer spacecraft control:
- пульт космонавта СА (ПК СА) (Descent Module Crew Display/Control Panel);
- блок ручного управления СА (БРУС) (СА Module Manual Control Unit);
- блок ручного управления БО (БРУБ) (БО Module Manual Control Unit);
- блок выдачи команды “КО” (БВК) (“Separation Contact” Command Issue Unit);
- пульт питания скафандра (ППС) (Space Suit Power Supply Panel);
- ручка управления спуском (РУС) (Descent Control Handle).

ПК СА (DESCENT MODULE CREW DISPLAY/CONTROL PANEL)

Th ПК СА (Descent Module Crew display/Control Panel) is shown in Fig. 1.

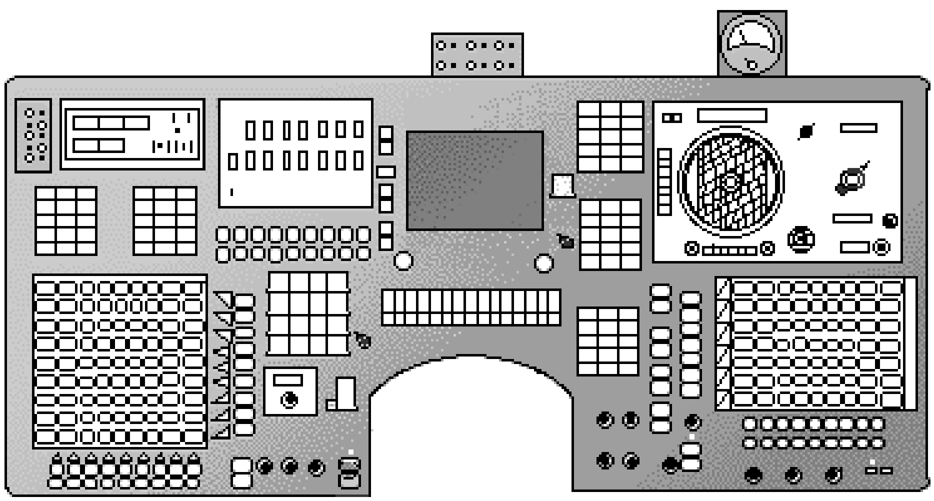


Fig. 1. ПК СА (DM Crew Display/Control Panel)

On the ПК СА front there are the following instruments and controls:
- командно-сигнальные поля (КСП-Л and КСП-П) (Command/Signal Panels: -Left and Right);
- табло сигнальные электролюминесцентные (ТСЭ1÷ТСЭ5) (Electroluminescent Indicator Displays);
- клавиши выдачи особо важных команд (ОВК) (Critical Command Keys);
- комбинированный электронный индикатор (КЭИ) (Combined Electronic Indicator);
- электронные часы (БЧК) (Onboard Clock);
- пульт ручного ввода информации (ПРВИ) (Manual Data Load Panel);
- индикатор навигационный космический “ИНК-2С” (Space Navigation Indicator);
- индикатор напряжения и тока “ИНТЗ-1” (Voltage & Current Indicator);

- КДУ (Combined Propulsion System) “СИРТ” Propellant Quantity Meter;
- circuit breakers;
- keys for issuing service commands;
- switches, knobs, LED lamps.

КСП's (COMMND-SIGNAL PANELS)

On the ПК СА front panel there are two КСПs (Command/Signal Panels): the Left one (КСП-Л shown in Fig. 2) and the Right one (КСП-П shown in Fig. 3).

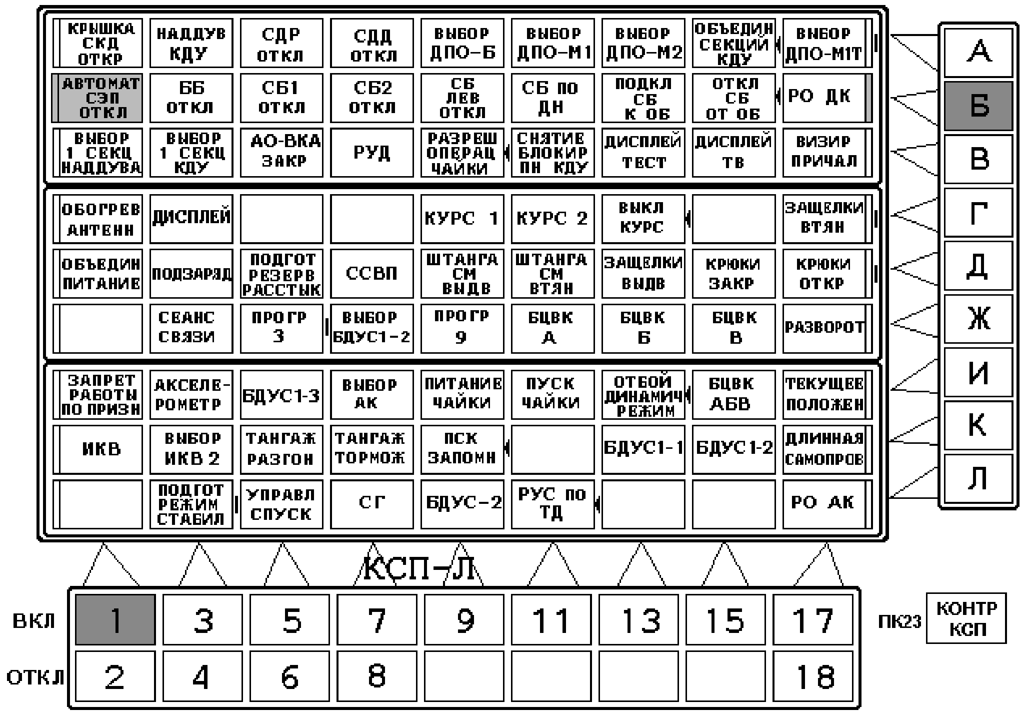


Fig. 2. КСП-Л

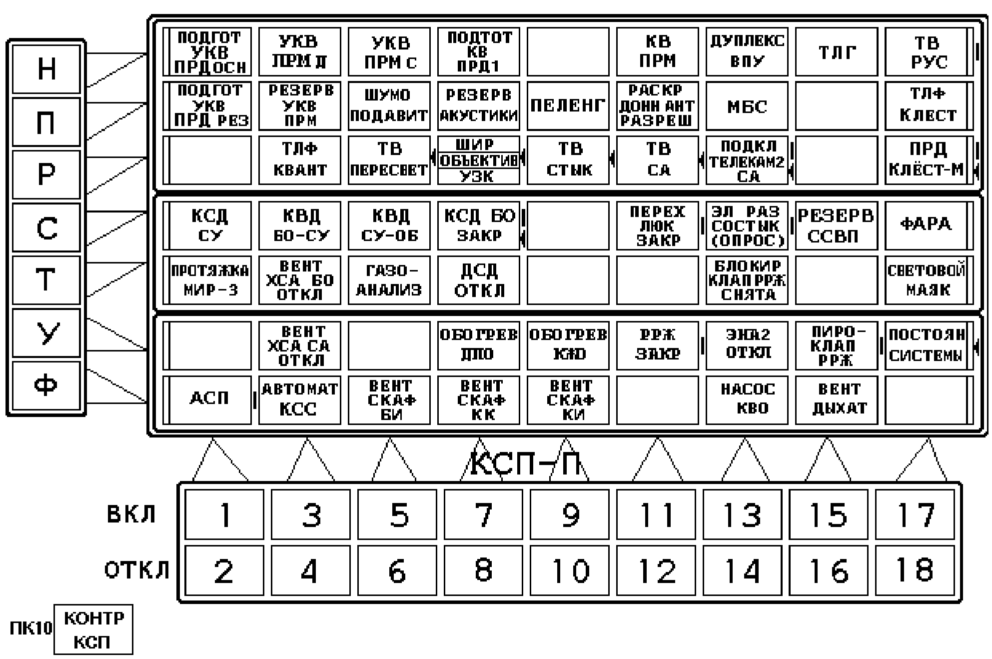


Fig. 3. КСП-П

КСПs are designed for:
- issuing onboard system control commands and their execution monitoring;
- system status monitoring by light indication.

Each КСП consists of:
- three indicator boards of blue/green luminosity;
- two keyboards: for line (system) selection and for issuing commands.

The line selection keyboard is vertical, the keys are fixed when pressed, mechanically interlocked and Cyrillic letter designated (For КСП-Л: А, Б, В Г, Д, Ж, И, К, Л and for КСП-П: Н, П, Р, С, Т, У, Ф). The extreme right and left indicators in each line have additional light segment which when lit tells you that this particular line is selected.
The command issue keyboard is horizontal, the keys are mechanically interlocked but not fixed when pressed and numerically designated: odds for “ON” commands and evens for “OFF” commands.
The КСП indicator lights can also go on and off when commands are being passed as issued by system automatic control, Interactive System Control, Program/Timing Control and КРЛ (Command Radio Link).

ТСЭs (ELECTROLUMINESCENT INDICATOR DISPLAYS)
These displays are designed to inform the crew on system status and operational modes.
There are five such displays on the Crew Display/Control Panel. ТСЭ1, ТСЭ2 and ТСЭ5 displays include green luminosity lights and have the purpose of displaying routine flight information (Fig. 4).

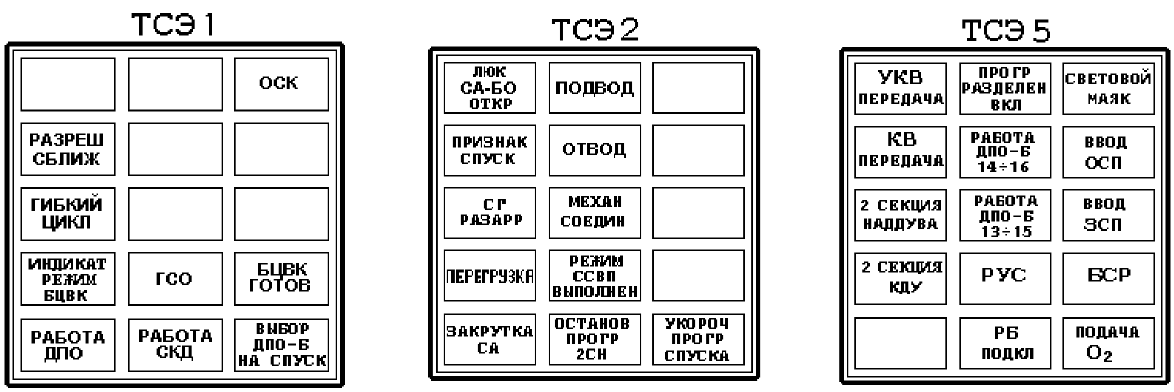


Fig. 4. ТСЭ1, ТСЭ2 and ТСЭ5

ТСЭ4 lights are yellow and its purpose is to display Caution/Warning information. Any ТСЭ4 light illumination is accompanied by a continuous sound signal (Fig. 5).

Fig. 5. ТСЭ4

ТСЭ3 red luminosity lights display emergency information. Any of these lights going on is accompanied by an intermittent audio signal and by separate red “Центральный огонь” (ЦО) (“Central Light”) flashing (Fig. 6).

Fig. 6. ТСЭ3

ОВК (CRITICAL COMMAND) KEYS
ОВК Keys are shown in Fig. 7.

Fig. 7. ОВК (Critical Command) Keys

Critical nature of the commands issued by means of these keys consists in irreversibility of the procedures launched as a sequence of these commands execution, and also in importance of these procedures as they have a great influence on the mission schedule.
For issuing critical commands on the ПК СА there are four keyboards of four keys each, and a separate keyboard of two keys:“ПОДГОТ. РАЗГЕРМЕТИЗ.” (CONFIG. DEPRESSUR.)and “РАЗГЕРМЕТИЗ.” (DEPRESSUR.).
All the keys are press-actuated, not fixed when pressed and mechanically interlocked to inhibit issuing more than one command at a time.

КЭИ (COMBINED ELECTRONIC INDICATOR)

The КЭИ (Combined Electronic Indicator) is shown in Fig. 8.

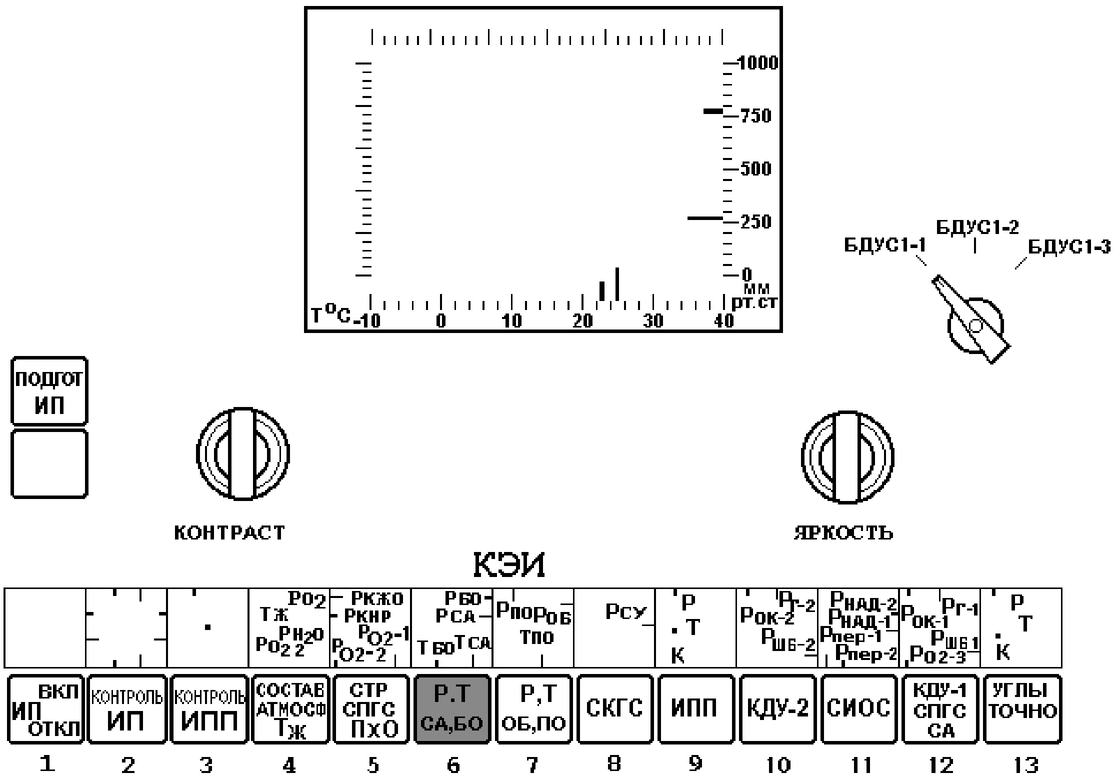


Fig. 8. Combined Electronic Indicator

The КЭИ purpose is to display:

- system analog parameters;
- spacecraft attitude parameters;
- TV images;
- БЦВК (Onboard Computer Complex) data while operating the computer in display mode;
- descent parameters in РУС (Manually Controlled Descent) mode;
- simultaneously TV image and БЦВК data;

Over each of the selection key there are graphical hints of parameters and scales to be displayed on the КЭИ screen when a particular key is pressed.

When the КЭИ session is over and a long duration non-operation interval is expected the КЭИ should be switched off. To do so it is necessary to press again “ИП ВКЛ.ОТКЛ” (Indicator Power ON/OFF) key which will de-energize the “Стрелка” equipment and to issue one of the OFF commands: “Дисплей” (Display), “ТВ СА” (DM TV), “ТВ СТЫК” (DOCK. TV).

During spacecraft descent when ОК-52 “Предварительное разделение” (Preliminary Separation) command is passed the КЭИ current mode is automatically switched off and “ТВ РУС” (Manually Controlled Descent TV) mode is switched on, the image frame for the mode being supplied by the “Klest” TV system.

While the КЭИ is being run in one of the modes (except “ТВ РУС” - Manually Controlled Descent TV mode) when a command for switching on another mode (“Дисплей” - Display, “Дисплей + ТВ” - Display + TV, “ТВ СА” - DM TV, “ТВ СТЫК” - Dock. TV) is issued by the crew the КЭИ Indicator will automatically transfer to the new mode.

БЧК (ONBOARD CLOCK)

The БЧК Clock is shown in Fig. 9.

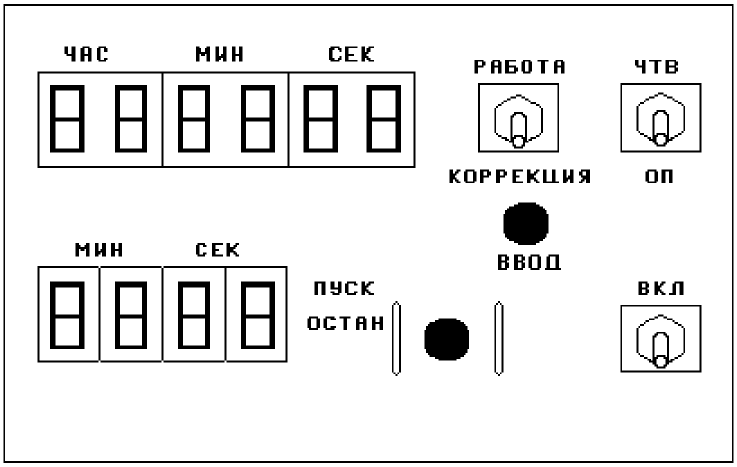


Fig. 9. БЧК (Onboard Clock)

The БЧК onboard electronic digital clock provides time reference information:

- current Moscow Time counting by seconds - "ЧТВ" (Clock of Current Time);
- preset time coming announcement - "ОП" (Announcement);
- "Announcement" time;
- timing, time interval measurements by means of Stop-Watch.

On the БЧК Clock front panel there are:

- "ВКЛ" (ON) switch to switch on the БЧК power;
- "РАБОТА-КОРРЕКЦИЯ"(Run/Correction) switch to select the БЧК run or correction mode;
- "ЧТВ-ОП" (Clock of Current Time/Announcement) switch to select either ЧТВ (current time) or ОП (preset time) data to be displayed on the upper indicators;
- "ПУСК.ОСТАНОВ.СБРОС" (Start/Stop/Reset) button for the Stop-Watch manual control;
- "ЧАС.МИН.СЕК" (Hours, Minutes, Seconds) digital indicators to display current or preset time data;
- "МИН.СЕК" (Minutes, Seconds) digital indicators to display Stop-Watch data
- "ВВОД" (Enter) button to enter current or preset time data;
- The БЧК is switched on by placing "ВКЛ" (ON) switch in the upper position while the ПК СА power is on.

The Clock is equipped with both built-in autonomous pulse generator and external high stability pulse input. The external pulses may come from either the АПВУ (Program-Timing Control Equipment) or КЛ110 TV unit.
During launch/injection and autonomous orbital flight phases the БЧК is time synchronized with the АПВУ (Program-Timing Control Equipment).
When the БЧК is time synchronized with the built-in generator the error is no more than 30 sec. a day.
The external pulse time synchronized БЧК maximal error is 4.5 sec.
The Stop-Watch can operate both in manual and automatic modes. The Stop-Watch automatic control is used for the propulsion system engine burn timing and has a higher priority level than that of the manual control.
When ОК-29 "Включение СКД" (Engine Fire) command is issued the Stop-Watch is stopped, reset and started. When ОК-30 "Отключение СКД " (Engine Cut Off) command is generated, provided the "МАНЕВР" (Maneuver) flag is present the Stop-Watch is stopped.
During descent phase (provided "СПУСК" (Descent) flag is present, the Stop-Watch is stopped on СП-7 "Касание" (Contact) automatic command.

The Stop-Watch is manually controlled by means of "ПУСК.ОСТАНОВ.СБРОС" (Start/Stop/Reset) button:

- pushing the button once makes the Stop-Watch start;
- pushing the button twice makes it stop;
- pushing it thrice resets the Stop-Watch, the indicators coming off.

ПРВИ (MANUAL DATA LOAD PANEL)

The ПРВИ Panel is shown in Fig. 10.

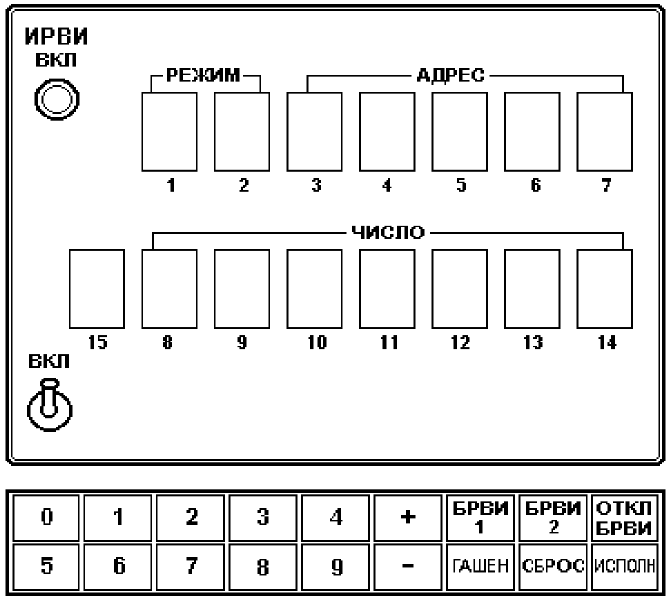


Fig. 10. ПРВИ (Manual Data Load Panel)

The ПРВИ Panel operating jointly with the Блок ручного ввода информации (БРВИ) (Manual Data Load Keyboard) enables the crew to:

- load/display the БЦВК (Onboard Computer Complex) command/set-up data;
- display data for the spacecraft СУД (Motion Control System) status check program;
- load/display setting data for the spacecraft СУС (Descent Control System);
- set ВКУ display modes for the БЦВК (Onboard Computer Complex) data.

When loading data the indicator digit windows are filled starting from window 1 to the right (from the most to the least significant digit). When the setting data are entered, if they are correct, one should press "ИСПОЛН" (Exec.) key. If while loading data the last digit entered is incorrect "ГАШЕН" (Delete) key should be pressed and the correct digit reentered.

"ИНК-2С" SPACE NAVIGATION INDICATOR

The "ИНК-2С" Indicator ("The Globe") presents the following data:

- spacecraft current geographical fix;
- number of orbits flown by the spacecraft by the given moment;
- time to go to shadow entering/leaving;
- estimated spacecraft landing site for the engine retrofire at the given moment.

The "ИНК-2С" Indicator appearance is shown in Appendix A.

The Indicator is an electromechanical device, simulating the Earth rotation as observed onboard the spacecraft by rotating "the Globe" in two axes (the spacecraft orbit axis and the Earth daily rotation axis). "The Globe" is driven in two axes by a step electric motor via reduction gears as commanded by pulses repeated at a frequency of 1 Hz.

The Indicator has a three position mode selector switch:

- "ОТКЛ" (OFF) position deenergizes the Indicator;
- "З" (Earth) position activates the current geographical fix indication mode;
- "МП" (Landing Site) position transfers the Indicator into estimated landing site display mode.

The spacecraft current fix is indicated both on the "Globe" map at the central cross-hairs and on latitude and longitude scales rotated by the same mechanism driving the "Globe" in orbital and Earth rotation axes.

The accuracy of the spacecraft geographical fix determination is < 100 km, and that of the landing site estimation - 150 km.

"ИНТ3-1" VOLTAGE & CURRENT INDICATOR

The "ИНТ3-1" Voltage & Current Indicator is shown in Fig. 11.

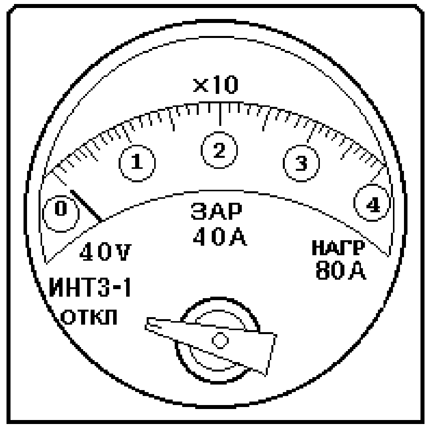


Fig. 11. Voltage & Current Indicator

This Indicator is designed for monitoring: voltage ("U") at the Power Supply System output buses, load current (I.н), solar battery current in autonomous orbital flight (I.сб) and the spacecraft accu battery charge current while in "Подзаряд" (Recharge) mode using the Orbital Module (ОБ) power supply (I.зар).

When using the Indicator the crew can monitor one of the above listed values at a time. There is a four position switch for selecting the value to be measured and a mechanical knob for adjusting the scale figure marking to the measured value range.

"ОТКЛ" (OFF) position of the switch is used in the spacecraft preservation mode.

"СИРТ" PROPELLANT QUANTITY METER

The Propellant Quantity Meter is shown in Fig. 12.

Fig. 12. Propellant Quantity Meter

The Meter measures and displays the КДУ (Combined Propulsion System) propellant quantity available. It is a device that automatically decreases a preset value corresponding to the quantity initially charged into the spacecraft tanks as the propellant is consumed by the propulsion system.

MANUAL CONTROL UNITS

The purpose of Блок ручного управ ления СА (БРУС) (СА Manual Control Unit - Fig. 13) and Блок ручного управления БО (БРУБ) (БО Manual Control Unit - Fig. 14) is power supply bus commutation of units and instruments and overcurrent protection of equipment in the СА and БО Modules.

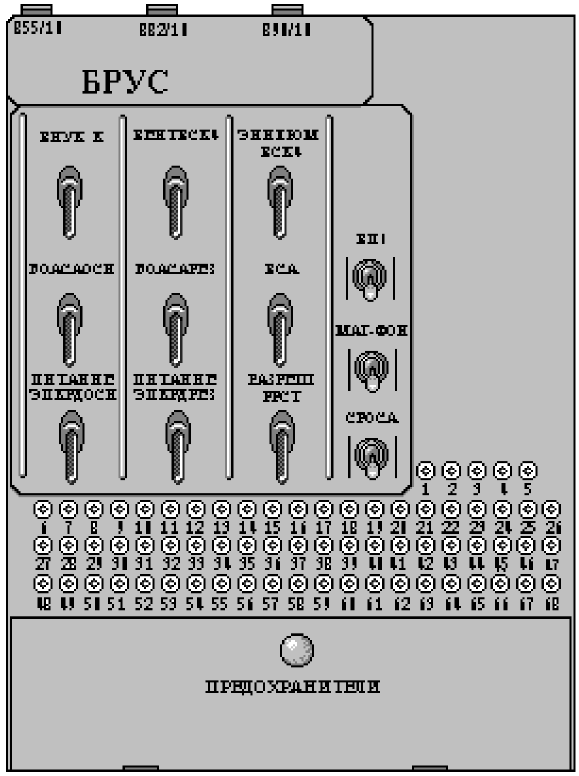


Fig. 13. БРУС (CA Manual Control Unit)

Fig. 14. БРУБ (БО Manual Control Unit)

The power supply buses are commutated by means of manual circuit breakers and toggle switches.
Both toggle switch commutated power supply circuits and non-commutated circuits of low current (< 5A) units are protected from excessive current by means of fuses.
The БРУС and БРУБ fuse state is monitored by means of LED lights on the unit front panels.

БВК ("SEPARATION CONTACT" COMMAND ISSUE UNIT)

The БВК ("Separation Contact" Command Issue Unit) is shown in Fig. 15.

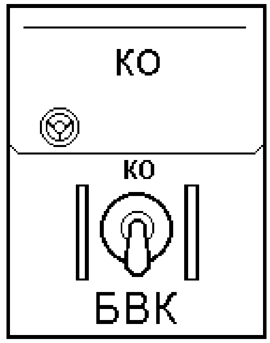


Fig. 15. БВК ("Separation Contact" Command Issue Unit)

In CA close to ПК CA Panel lower plane, to the left of the Flight Engineer's work-station there are two identical units for crew-issuing "Separation Contact" back-up command in case this command is not passed from the Launch Vehicle automatics.
On each unit there is one toggle switch with "ON" position designated as "KO" (Separation Contact) and one "KO" covered key.
In case the "KO" command is not passed automatically in preset time moment the crew should place the two toggle switches in "KO" position, open the "KO" key covers and simultaneously press the two "KO" keys. The crew must execute all the above mentioned operations within 15 seconds after the space-craft/Launch Vehicle scheduled separation time.

ППС (SPACE SUIT POWER SUPPLY PANEL)

The ППС (Space Suit Power Supply Panel) is shown in Fig. 16.

Fig. 16. ППС (Space Suit Power Supply Panel)

The ППС Panel is designed for commutation and protection of the "Orlan-D" EVA suit power supply circuits when the БО volume capacity is used for EVA egress.
Umbilical cables of "Orlan-D1, 2" suits are connected to X123/1 and X123/2 connectors located under Container 1 in the БО.

INTERNAL ILLUMINATION AIDS

The Internal Illumination Aids comprise operational and TV lights and a light with an autonomous power source (Lantern).
Operational illumination is provided: in the CA - a single “СД1-6” Luminary with adjustable light intensity, and in the БО - by two “СД1-5М” Luminaries with non-adjustable light intensity.
The light units of “СД1-6” and “СД1-5М” Luminaries are interchangeable.
TV lights in DM are switched on by “ТВ СА” (DM TV) command (Р-11 on КСП-П) and switched off by “ТВ СА” command (Р-12).
The “ФЭС” light with autonomous power source (Lantern) is used for illumination during transfers to un-lighted modules and in off-nominal situations.

РУС (DESCENT CONTROL HANDLE)

The РУС (Descent Control Handle) is designed for generating the CA roll control signals in the controlled descent mode and also for issuing the following commands to the Descent Control System:

- РУС Handle power (ПИТ);
- Free Gyro uncaging (РГ);
- Backup Ballistic Descent (БСР);
- Ballistic Descent (БС);
- Reduced Descent Program (ПР-5);
- Nominal Reentry (Т.с);
- Manual Attitude Control (РО);
- Manually Controlled Descent (РУС).

The РУС Handle stowed position is to the left under the ПК СА Panel, in operational position it is gripped by the Commander.

The РУС appearance is shown in Fig. 17.

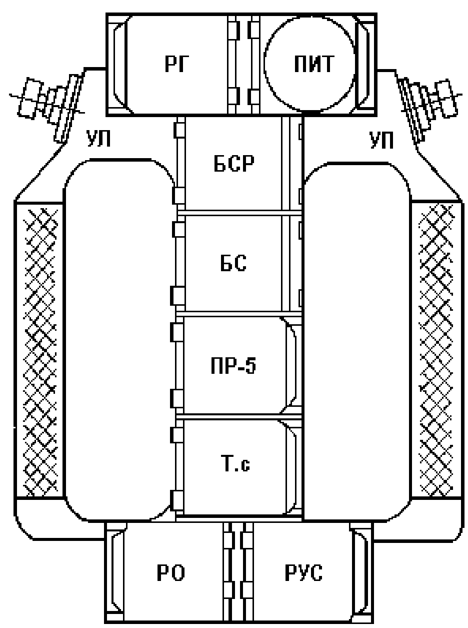


Fig. 17. РУС (Descent Control Handle)

THE SYSTEM OPERATIONAL LIMITS AND CHARACTERISTICS

When operating the КСПs one should take into account symbolic designations for types of commands which are shown to the right of the corresponding light:

< - command without indicator light;

II - only “ON” command;

</II - only “ON” command without indicator light.

The execution of commands without indicator light can be monitored by other indications.

Commands issued by means of keys: 9, 11, 13, 15 on КСП-Л do not have corresponding “OFF” commands, therefore there are no figures (10, 12, 14, 16) marked on the accompanying even keys.

After issuing a command the line selection key should be depressed (switched off) to prevent from inadvertent issuing of a non-desired command. To switch off a line (system) selection key one should press slightly any other line selection key, the previously selected line light will go off.

When two commands are simultaneously issued from the КСП and КРЛ (Command Radio Link) the latter is of a higher priority: while a КРЛ (Radio Link) command is being issued the КСП commands are inhibited.

While operating the КСПs one should keep in mind that the КСП-Л commands are powered from “Ce” buses configured in ПО Module which are de-energized after the spacecraft module separation during descent. That is why once the “Separation” command is passed the КСП-Л command issue capability is lost, however a part of indicator lights powered from “C” buses configured in CA will remain ON.

The КСП-П commands which are powered from “C” buses can be issued in all spacecrfaft flight phases including post-separation period.

On the ПК CA Panel there are two groups of fuses for excessive current protection of several instruments. The fuse status is monitored by means of LED lights. When a fuse is blown the corresponding red color LED goes on. The blown fuse should be replaced with a proper one of the CA Manual Control Unit spare fuses. If the same fuse is blown repeatedly the crew will replace it after consulting the ЦУП (MCC).

When the ПК CA is de-energized the crew will still be able to operate the following displays and controls:

- ОВК Keys;
- adjuster knobs: “ЯРКОСТЬ РАБ. ОСВЕЩЕНИЯ” (Operation Light Intensity) and “ВОСПРОИЗВЕДЕНИЕ” (Play);
- “НАСТРОЙКА РРЖ” (Liquid Flow Regulator Adjustment) switch;
- “ДАТЧИКИ ИПП” (Attitude Indicator Sensors) switch;
- radio communications controls;
- “ВКЛ. РЕЗ. БАТАРЕИ” (Backup Battery ON) key (ПК3);
- Voltage/Current Indicator;
- Fuel Quantity Meter;
- КЭИ Indicator in TV mode.

CREW OPERATIONS WITH THE SYSTEM

The ПК CA is energized/de-energized by means of two “ПУЛЬТ” (Panel) keys: “ПК7 ВКЛ” (ON) and “ПК8 ОТКЛ” (OFF) with protective cover. “ПУЛЬТ” keys are press activated, not fixed when pressed and mechanically interlocked.

To test performance of the КСП indicators one of the“КОНТРОЛЬ КСП” (КСП TEST): either ПК12 or ПК24 key on the ПК CA Panel should be pressed. While either of the keys is pressed all the КСП-Л and КСП-П light will be blue/green color illuminated. The test duration must not exceed 30 seconds.

To test performance of the ТСЭ (Electroluminescent Indicator Display) lights one of the “КОНТР.ТСЭ” (ТСЭ Test): either ПК11 or ПК23 keys on the ПК CA Panel should be pressed. While the key is pressed all the Indicator Display lights are constantly illuminated as well as two “Место посадки” (Landing Site) LED lights on the Navigation Indicator. Apart from that an intermittent audio signal will sound and “ЦО” (Central Light) will flash. The test duration must not exceed 30 seconds. When “КОНТР.ТСЭ” (ПК11 or ПК23) (ТСЭ Test) key is released the “ЦО” (Central Light) goes OFF, the sound audio stops sounding, the “Место посадки” (Landing Site) LED lights go OFF and the ТСЭ Indicator Displays retain their previous configuration.

In case of non-passage of commands issued from the КСП the command duration shaping circuit failure may be a probable cause. In that case it is necessary to connect ШПБК cap to ШПБК plug connector to the left of the Flight Engineer seat. After that the КСП-issued command duration will be defined by the key pressing time. This time should not exceed 1-2 seconds.

The audio signal accompanying Caution/Warning and Emergency indicator lights can be switched OFF by pressing “ОТКЛ.ЗВУКА” (Sound OFF) key (ПК21). When the sound is OFF the “ЦО”(Central Light) also

goes OFF. The indicator lights go OFF when the cause of their illumination is eliminated except the following indicator lights: “Вызов на связь” (Comm. Call), “Авария БЦВК” (БЦВК Failure) on ТСЭ4, “Авария ДК” (Discrete Circuit Failure) on ТСЭ3 which are put OFF by pressing “СБРОС АВАР.СИГНАЛ” (Emergency Signal Reset) key - ПК9.
The CA luminary is switched ON by means of “СРО СА” (CA Operational Lighting) toggle switch on the БРУС Unit and the lighting intensity is adjusted by means of “ЯРКОСТЬ РАБОЧЕГО ОСВЕЩЕНИЯ” (Operational Lighting Brightness) knob at the front of the ПК СА Panel.
The БО luminaries are switched ON by means of “СРО БО” on the БРУБ Unit.

3.3. СИСТЕМА ОБЕСПЕЧЕНИЯ ТЕПЛОВОГО РЕЖИМА (СОТР) (THERMAL CONDITION CONTROL SYSTEM)

THE COTP PURPOSE

The COTP is designed for:

- thermal stabilization of the spacecraft body and its elements during pre-launch and all flight phases;
- ensuring necessary thermal conditions in the pressurized modules in all flight phases;
- supporting humidity level in habitable modules within specified limits;
- ventilation of pressurized modules.

SYSTEM COMPOSITION

The COTP consists of the active part: Система терморегулирования (СТР) (Thermal Control System) and the passive part: Средства пассивного терморегулирования (СПТР) (Passive Thermal Adjustment Aids).
The CTP is a hydraulic system which includes several hydraulic loops: Контур жилых отсеков (КЖО) (Habitable Module Loop), Контур навесного радиатора (КНР) (Attached Radiator Loop), Контур водяного охлаждения (КВО) (Water Coolant Loop), Промежуточный контур подогрева (ПКП) (Intermediate Heating Loop) and Контур откачки конденсата (КОК) (Condensate Evacuation Loop).
The СПТР purpose is to avoid uncontrolled spacecraft/ environment heat exchange. The СПТР Aids include: экранно-вакуумная изоляция (ЭВТИ) (Shield Vacuum Thermal Insulation), heat sinks, thermal resistors and the special treatment of the spacecraft outer surfaces and its exterior elements.
The Soyuz spacecraft COTP block-diagram is shown in Fig. 1.

CTP SYSTEM

<u>КЖО (Habitable Module Loop)</u>

КЖО is a pressurized hydraulic loop. The heat agent is circulated along the loop as driven by the “ЭНА-3” Electric Pump Unit. The heat agent is fed to the жидкостно-жидкостный теплообменник (ЖЖТ) (Liquid/Liquid Heat Exchanger) in the AO Module. In the ЖЖТ the excess heat is transferred from the КЖО heat agent to the КНР heat agent. Then the agent is pumped through the piping to the CA where one half of its volume flow is fed to the Холодильно-сушильный агрегат (ХСА) (Cooling/Drying Unit) of that Module, and the other half is flown to the БО Module ХСА. From the БО the agent flows through the piping to the ЖЖТ of the active docking mechanism where it comes in heat contact with the ПКП heat agent. Then it goes to the docking mechanism heating channel and after that it is fed to the БО and CA Modules. From the pressurized modules the agent is pumped to the ПхО, where it thermally stabilizes the ПхО Module ДПО thrusters. Then it goes to the AO thus providing for the AO Module ДПО thrusters.
Then the full flow of the agent goes through the mechanical additive filter and the electric heater to the “ЭНА-3” Electric Pump Unit inlet. The Pump Unit operation is monitored by the pressure differential telemetry sensor. The loop pressure is monitored by a pressure sensor and by a pressure warning transducer. A thermal expansion compensator in the loop.

<u>КНР (Attached Radiator Loop)</u>

The КНР is a close d pressurized hydraulic loop and consists of the interior and exterior manifolds. The agent is circulated in the manifolds by means of the “ЭНА” Electric Pump Unit.
The interior manifold is for КЖО/КНР heat exchange in the ЖЖТ. The heat received by the КНР is used for the AO Module body thermal stabilization and for keeping the ПО Module gas environment within specified temperature limits.
The agent circulation in the loop is as follows: from the Pump Unit it goes to the ЖЖТ for receiving heat from the КЖО loop, then to the Газожидкостный агрегат (ГЖА) (Gas Liquid Unit) where it exchanges heat with the ПО Module atmosphere and finally passes along a pipe coil for the thermal stabilization of the AO body and the КДУ (Combined Propulsion System) units. Passing through the mechanical additive filter the agent is fed to the ЭНА1 inlet provided the Регулятор расхода жидкости (РРЖ) (Liquid Flow Regulator) is in closed position. A special device is built in the interior manifold to compensate for the agent volume variations.
The exterior manifold is for the excessive heat dumping by means of the Навесной холодильный радиатор (НХР) (Attached Cooling Radiator).
The agent circulation in the exterior manifold is as follows: from the “ЭНА2” Pump Unit it goes to the НХР and then through the mechanical additive filter to the ЭНА2 inlet provided the РРЖ is in closed position.
The interior and exterior manifolds are connected via the РРЖ. When it is in closed position two hydraulically separated manifolds are formed each having its own ЭНА.

If the interior manifold agent temperature is too high (which is testified by the liquid temperature sensor indication) it becomes necessary to use the exterior manifold for dumping out excessive heat by means of the НХР. To do so the РРЖ is transferred to the open position which makes the two manifolds one hydraulically united loop. The agent in the united loop is circulated by means of two ЭНАs operating in series. To enhance the СТР System reliability (to retain the capability of feeding the agent to the НХР in case of the РРЖ failure, i.e. when it cannot support the required agent flow rate) a pyro valve and two orifice plates are installed in the loop.
The interior and exterior manifold ЭНА performance is monitored by a pressure differential telemetry sensor installed in the pipe between the ЭНА inlet and outlet.
The loop agent pressure data is transmitted to the crew from the pressure sensor and the pressure warning transducer.

ПКП (Intermediate Heating Loop)

The ПКП loop is designed for the spacecraft and its active docking mechanism thermal stabilization during spacecraft/station joint flight in docked configuration while the majority of its systems are preserved. The ПКП loop has pressure tight hydraulic connections with the Mir Core Module СТР System manifolds via the docking assembly valves. The Core Module СТР heat agent goes through the docking assembly hydraulic couplers to the ЖЖТ, where its heat is transferred to the spacecraft СТР System КЖО loop agent.
The ПКП loop agent pressure is monitored by means of the pressure sensor and the pressure warning transducer.
There is a thermal volume variation compensator installed in the loop. The docking assembly coupling valves are detachable and self-locked.
Note: This loop is not used in the spacecraft of Soyuz TM type to be docked to the ISS. The spacecraft thermal stabilization while in the preservation mode is achieved by setting the Air Heater and using the Liquid Electric Heater installed at the inlet of the ЭНА (Electric Pump Unit) in the КЖО (Habitable Module Loop).

КВО (Water Coolant Loop)

The КВО loop purpose is to provide for the specified thermal conditions in case of the СА water splash landing. The СА cabin heat originated from the thermal shield heat accumulated during atmosphere reentry as well as from the СА equipment operation is transferred to the water coolant circulating in the ХСА heat exchanger. When simultaneously the valve pyro cartridge is fired and the water pump is switched on the outside water is pumped in. The pump drives the water through the loop at the flow rate of not less than 8 liters per minute.
When the КВО loop is in operation the СА Module ХСА 1В Manual Cock must be open and the fan switched on. The heat exchange between the КВО and КЖО loops is not controlled. The heat exchange intensity largely depends on the СА air/outside water temperature relation. If necessary the crew can adjust cabin air temperature by switching on/off the ХСА fan and the КВО loop pump.

КОК (Condensate Evacuation Loop)

The КОК loop is for the condensate transportation from the ХСА (Cooling/Drying Unit) to the Condensate Ccontainers and for its subsequent stowage. The loop is so designed as to allow the condensate to be pumped from the СА Module ХСА by the СА Manual Pump either to the СА or ВО Condensate Containers and also by the БО Manual Pump from the БО ХСА and from the СА ХСА to the БО Containers.
So the Manual Pump pumps the condensate. When the СА/БО Hatch Door is closed the condensate is pumped from the СА Module ХСА into the СА Container, for that purpose the 3В and 4В By-Pass Valves should be set at “Конденсат в СА” (Condensate to СА) position. In case the СА/БО Hatch Door is open the condensate is to be pumped from the СА Module ХСА to the БО Containers by means of the СА Manual Pump and for that purpose the 3В and 4В Valves should be positioned to “Конденсат в БО ” (Condensate to БО). The crew has the capability of using the БО Manual Pump for pumping the condensate from the СА Module ХСА to the БО Containers, and the 3В and 4В Valves in this case should be set at “Конденсат в БО” (Condensate to БО).
In order to support the КОК Loop operation during the spacecraft autonomous flight before descent the crew must see to it that the СА Container be filled minimally during the autonomous flight phase after the spacecraft injection into orbit.
There are two Condensate Containers in the БО Module. When one of them is full up the other one is filled. The Condensate Containers are equipped with quantity indicators. And increased Manual Pump handle force can be an indirect crew indication that the Container is full.

Ventilation System

The Ventilation System is designed for:

- ensuring necessary crew life support and comfort conditions, specifically in the line of uniformity of the atmosphere gas composition, temperature, humidity and air speed all around the spacecraft habitable volume;
- cooling the operating units and equipment and subsequently transferring heat to the CTP System agent in the ГЖА.

The Ventilation System is operating in all phases of the spacecraft prelaunch procedures and flight. The air circulation in CA and БО is maintained by means of the XCA fans and special air circulation fans in those modules. The air in the ПО Module is circulated by means of the ГЖА fans.

THE SYSTEM OPERATIONAL LIMITS AND CHARACTERISTICS

#	Technical Characteristics	Values
1	Air temperature in habitable modules	+18 ÷ +25°C
2	Instrument/assembly temperature in their location area	+0 ÷ +40°C
3	Air relative humidity	< 75%
4	Air speed in the habitation area	0.1 ÷ 0.8 m/s
5	Air speed in the instrument area	0.05 ÷ 1.5 m/s
6	Gas temperature in the ПО Module	0 ÷40°C
7	Operational pressure in all hydraulic loops	0.5 ÷2.0 kg/cm^2
8	CTP System service life	4500 hrs

CREW OPERATION WITH THE SYSTEM

The CTP crew operations are assumed to be those of the System health monitoring, its operation control as well as of reconfiguring the System when in station/spacecraft joint flight phase and at the end of this phase.

While in the spacecraft autonomous flight phase the crew executes the following operations:

- pumps out the condensate in two hours after the Launch Vehicle separation command (after that the pumping is repeated every four hours for two minutes);
- controls the Air Flow Regulator in the XCA of the CA and БО Modules according to the CA/БО Hatch door position;
- controls operation of the air circulation fans (BCA and ВБО) in the CA and БО Modules;
- controls the Ventilation Valve System (СДВ) shutters;
- switches off the БО Module XCA and air circulation fan before closing the CA/БО hatch lid (when the pre-descent program is over).

After the station/spacecraft docking the crew performs operations for the spacecraft preservation. The spacecraft preservation is to be executed within three hours after the transfer hatch opening. The crew:

- lays the air guide hose with fan and heater from the Orbital Module to the spacecraft (The heater and fan power supply receptacles are in the БО Module "Divan" back); the heater should be switched off for the crew sleep time;
- switches on an additional fan in the Core Module to direct air flow to the spacecraft;
- ensures operation of the united ПКП/Core Module CTP (“Kvant” Module CTP) hydraulic loop;
- turns the CA fan so as to direct air flow to the CA/БО hatch and then switches it on for continuous run;
- switches on the БО fan for continuous run as well, the air flow directed to the Core Module hatch;
- pumps the condensate from the CA and БО Module XCA into the БО condensate container and then switches off the two XCA, but the XCA fans are switches on;
- sets the РРЖ adjustment switch on the ПК CA at “17 градусов С” (17 degrees C) and then switches off the РРЖ;
- monitors the Ventilation Valve System (СДВ) Shutter closed position.

During the station/spacecraft joint flight the crew regularly monitors the following parameters of the space-craft preserved CTP System:

- air temperature in the CA and БО Modules;
- gas temperature in the ПО module;
- the КЖО and КНР loop agent pressure;
- the CA and БО Module XCA in off position;
- the РРЖ in closed position;

– the КЖО loop and ДПО thrusters heaters in off position.

When the joint flight is over the crew executes the СТР System depreservation.

Fig.1. Soyuz TM Spacecraft СТР (Thermal Control System) Functional Block Diagram

1. ССВП - Docking/Internal Transfer System; 2. БО - Habitable (Crew Resting) Module; 3. ВБО - БО Module Fan; 4. СА - Descent Module; 5. ВСА - СА Module Fan; 6. ПАО - Instrument/Assembly Module; 7. 3К - Container 3; 8. ДВН - Breathing Plenum (Forced) Ventilation Squib Valve; 9. ДВВ - Breathing Exhaust Ventilation Squib Valve; 10. 2К - Container 2; 11. ЭНА1 - Electric Pumping Unit 1; 12. НХР - Attached Cooling Radiator; 13. ДТЖ - Liquid Temperature Sensor; 14. 1СД - Pressure Switch Sensor 1; 15. ДМТ1 -Temperature Sensor (Telemetry) 1; 16. ДПО АО - Berthing/Attitude Control Thrusters in Assembly Module; 17. 3СД - Pressure Switch Sensor 3; 18. ДМТ3 - Temperature Sensor (Telemetry) 3; 19. 3Ф - Filter 3; 20. 5ГР - Hydraulic Coupler 5; 21. 3В - By Pass Valve 3; 22. 1Е - Condensate Container 1; 23. ПН90 24. ГЖА - Gas/Liquid Unit; 25. ПНТ1 26. 3Е - Condensate Container 3; 27. 2Е - Condensate Container 2; 28. 7ГР - Hydraulic Coupler 7; 29. 2НР - Manual Pump 2; 30. 4В - By Pass Valve 4; 31. 1НР - Manual Pump 1; 32. Н - Pump; 33. Д - Choke; 34. ЖЖТ - Liquid/Liquid Heat Exchanger; 35. 3ГР - Hydraulic Coupler 3; 36. 3М АО - Assembly Module Condenser Coil; 37. ПН86 38. ПН88 39. ПН 214 40. Д - Choke; 41. ЖЖТ - Liquid/Liquid Heat Exchanger; 42. ЭНА2 - Electric Pumping Unit 2; 43. 2ХСА - Cooling/Drying Unit 2; 44. Д - Choke; 45. 6ГР - Hydraulic Coupler 6; 46. ДПО ПХО - Berthing/Attitude Control Thrusters in Adapter Module; 47. ЖЖТ - Liquid/Liquid Heat Exchanger; 48. 2Ф - Filter 2; 49. РРЖ - Liquid Flow Regulator; 50. 2В - Valve 2; 51. 1ХСА - Cooling/Drying Unit 1; 52. ДТЖ - Liquid Temperature Sensor; 53. ПНТ3 54. ПНТ2 55. 1В - Valve 1; 56. 4ГР - Hydraulic Coupler 4; 57. ПН87 58. ЖЭН - Liquid Electric Heater; 59. 1Ф - Filter 1; 60. Д - Choke; 61. ПН85 62. ПН89 63. 2СД - Pressure Switch Sensor 2; 64. ДМТ2 - Temperature Sensor 2 (Telemetry); 65. ЭНА3 - Electric Pumping Unit 3; 66. 2ГР - Hydraulic Coupler 2; 67. 1ГР - Hydraulic Coupler 1; 68. 1К Container 1; 69. Д - Choke.

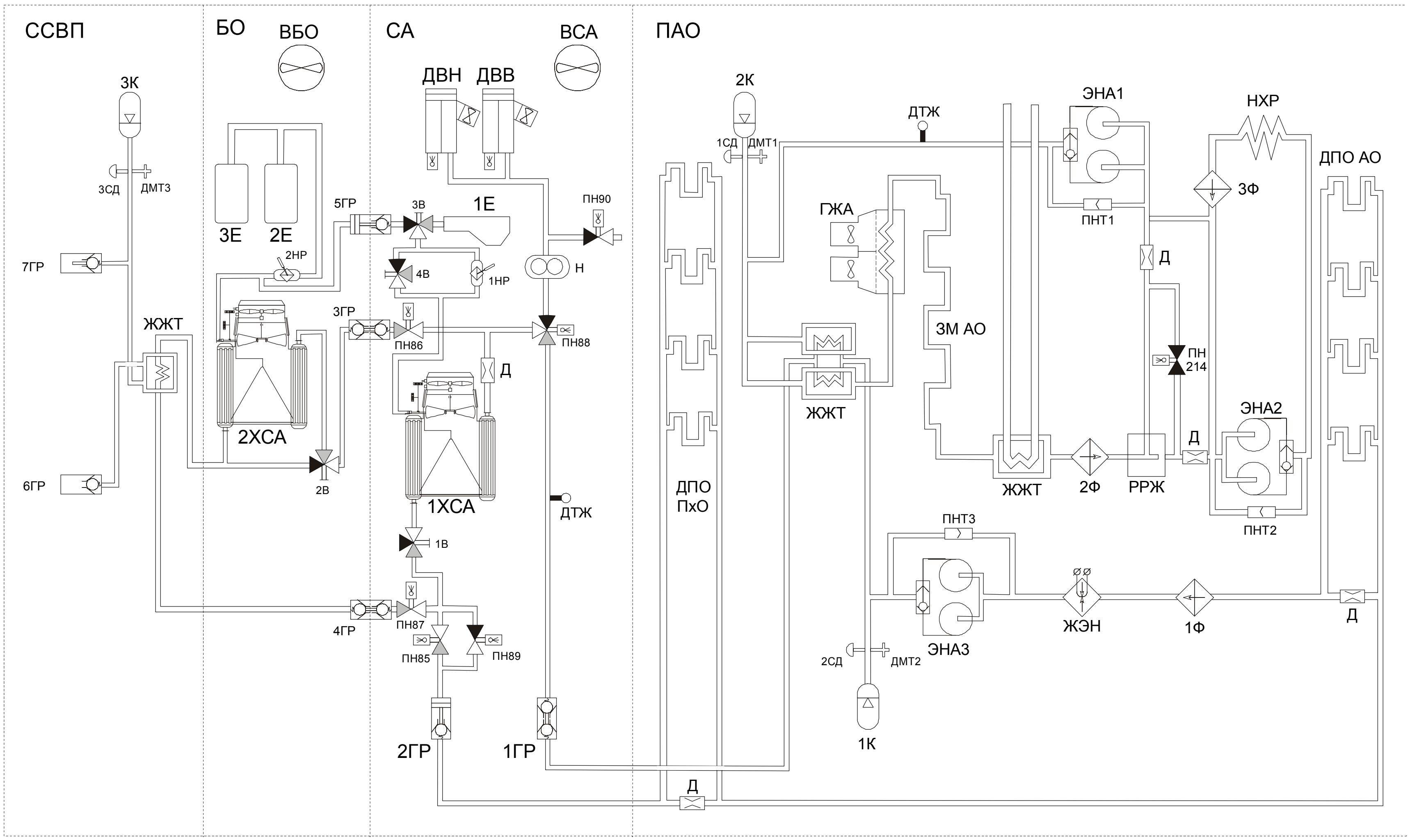


Fig.1. Soyuz TM Spacecraft CTP (Thermal Control System) Functional Block Diagram

3.4. СИСТЕМА УПРАВЛЕНИЯ БОРТОВЫМ КОМПЛЕКСОМ (СУБК) (ONBOARD COMPLEX CONTROL SYSTEM

GENERAL INFORMATION ON THE SYSTEM

The СУБК (Onboard Complex Control System) is designed for:

- program/logic control of the onboard systems;
- the spacecraft systems status and modes routine data collection, compression and transfer to the onboard displays and telemetry;
- electric power distribution to the onboard users and the СЭП (Power Supply System) protection from the current overload.

When describing the СУБК operation algorithms the basic terms are defined as follows:

Command is a voltage impulse of (34 - 23) V and of short duration (0,25 - 2 sec) that results in a reversible or irreversible change in the СУБК electrical circuitry or in the onboard systems status.

Flag is a memory element with two stable states which are used as logical conditions for command execution.

Operation is a reversible or irreversible change in the СУБК electrical circuitry or in the onboard system status which results in an analogous signal appearing or disappearing at its output. A part of СУБК operations originate conditions for command executions, i. e. are logical.

Generalized Command is a group of combined commands which are functionally different (i.e. originated by different sources: КРЛ (Command Radio Link) , АПВУ (Program/Timing Control Equipment), ПК СА , system automatics and on each of which several identical operations are executed.

Interactive Multisystem Control Command is a command issued to the СУБК by a system automatic control and used for other onboard system control.

SYSTEM COMPOSITION

Control commands coming from various sources (ПК СА, АПВУ, КРЛ, interactive commands from onboard systems) are sent to the Блоки обработки команд (БОКС БОКБ БОКП) (Command Processing Units). Those commands coming from onboard systems, ОВК (Critical Commands) several ПК СА commands are not processed in the decoders but are sent directly to the Command Processing Units. The Units perform logical processing of the commands and their duration and execution sequence shaping.

From the Processing Units the commands are sent to:

- Блоки силовой автоматики (БСАП, БСАБ, БСАС) (Actuation Automatic Units) - for commutating units/assemblies power supply;
- onboard systems - for mode setting;
- Pyro Cartridge Commutators - for cartridge activated device circuit commutation.

The СУБК communicates with the БЦВК by means of Interactive Multisystem Control Commands because the БЦВК is functionally a part of СУД (Motion Control System).
Command execution indication is generated by the system automatic control and provides for the crew capability to continuously monitor the СУБК and other systems fulfilling their functions.
БСАП (БСАБ, БСАС) Units function is the onboard systems power supply bus commutation and the СЭП System protection from overcurrent.
The Pyro Cartridge Commutators КПБ (СА, П) organize logical processing of cartridge activated devices control commands and implement the time/logic sequence of the spacecraft “division” (“Separation”) into modules.

The СУБК System block diagram is shown in Fig. 1.

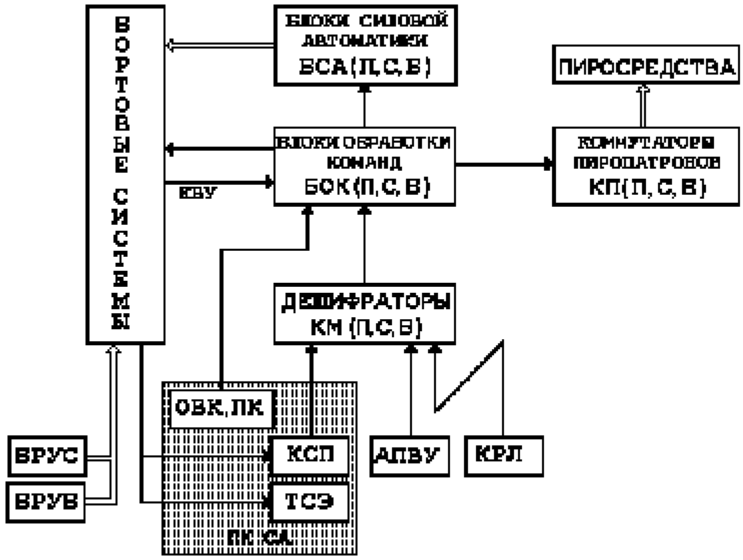


Fig.1. СУБК System Block Diagram

1. Onboard Systems. 2. Actuation Automatic Units. 3. Processing Units. 4. Puro Cartridge. 5. Cartridge Actuated Device Circuit Commutation. 6. Decoders.

Power Supply Distribution to the Modules

The electric power distribution circuitry belongs to hybrid type. The ПО Module central distribution unit - БСАП receives electric power from the СЭП System. There are three separable modules (ПАО, СА, БО) in the spacecraft composition which dictates a necessity of having separate power supply buses for the modules.
In the ПО central distribution unit - БСАП the following buses are configured:

- П buses, non-commutatable, for the ПАО users;
- Б buses, commutatable, fed via the cable mast and pressure sealed connectors to the БО distribution unit - БСАБ for the БО users;
- Се buses, commutatable, fed via the cable mast and pressure sealed connector plate to the СА distribution unit - БСАС.

Се buses energize С buses. Се and С busses are used for power supply to the СА users before the “разделение” (Module Separation) in the pre - descent phase. On the “Separation” command the С buses are fed from the СА batteries and the Се buses are de - energized.
Б buses are used in the СА only for the ПК СА display indications of the БО systems and units status.
The spacecraft main load Е buses after docking to the station ОБ Module are energized by the ОБ Module СЭП System via the ОБ/ОБ interface load connectors - ШРС1 and ШРС2.

The spacecraft modules electric power distribution diagram is shown in Fig. 2.

The СЭП System Protection from Current Overloads

For the current overload protection the following elements are used: overload relays, manually operated circuit breakers (АЗС) and fuses on the БРУС and БРУБ Units, РБС-У(Universal Onboard Network Power Outlet) and ПК СА.

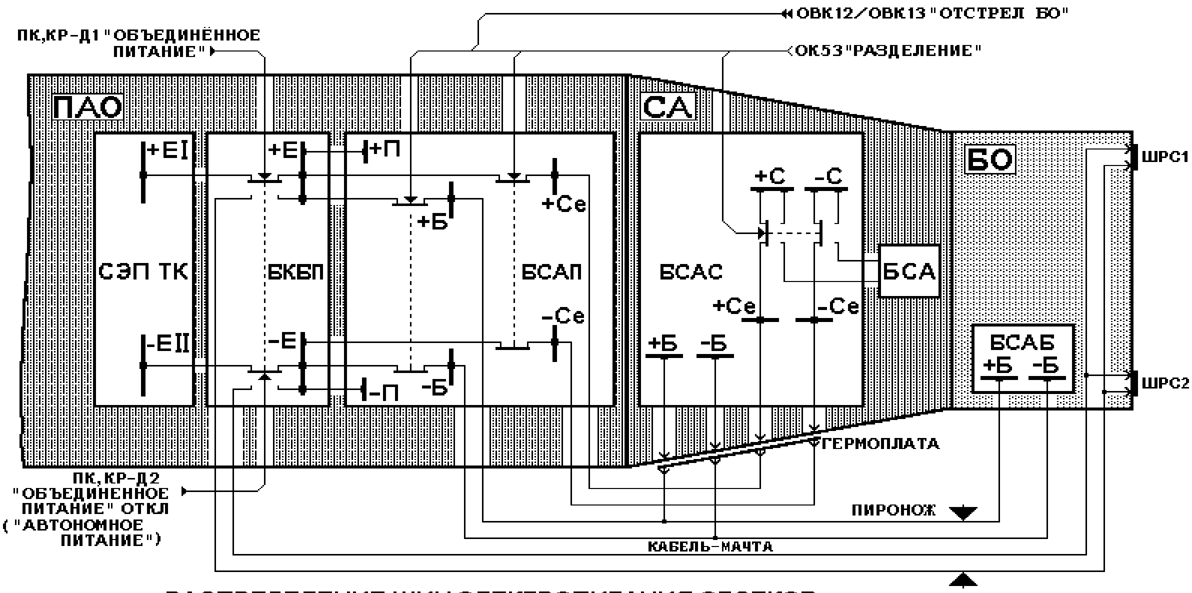


РИС. 2. РАСПРЕДЕЛЕНИЕ ШИН ЭЛЕКТРОПИТАНИЯ ОТСЕКОВ

Fig. 2. Spacecraft Modules Power Bus Distribution

1. The ПК СА Panel, КР-Д1 Command: “ОБЪЕДИНЕННОЕ ПИТАНИЕ” (United Power Supply). 2. The ПКСА Panel, КР-Д2 Command:“ОБЪЕДИНЕННОЕ ПИТАНИЕ” ОТКЛ (OFF), (“АВТОНОМНОЕ ПИТАНИЕ” - Independant Power Supply - ON). 3. ОВК12,ОВК13 Critical Command:“ОТСТРЕЛ БО” (БО Jettison). 4. ОК53 Generalized Command :“РАЗДЕЛЕНИЕ” (Separation). 5. Pressure sealed connector plate. 6. Cartridge actuated cutter (pyro-knife). 7. Cable-mast.

Аппаратура программно-временного управления (АПВУ) (Time/Program Control Equipment)

The АПВУ purpose is the spacecraft systems time/program control and its functions are:
- periodical time mark (tag) originating and sending to the onboard systems;
- originating the onboard system control “firm” programs.

АПВУ can run one of the possible seven “firm” programs at a time. The programs can be initiated by a command from the КРЛ Link, ПК СА and from onboard systems; The Soyuz spacecraft АПВУ provides for the following programs:

Пр. #1 - *“Short” communications program*, it switches on the equipment of the Radio Telemetry System and the “Kvant” (КРЛ) System for the time of communication session.

Пр. #3 - *“Long” communications program*, it switches off the Radio Telemetry, “Kvant” and TV Systems equipment before entering a long duration LOS zone (“deaf” revolutions - no ground communication), and switches on/off the Telemetry system buffer memory during the LOS zone.

Пр. #4 - *Antenna deployment program*, it deploys the “Kurs”, Communication and Telemetry System antennae, exterior appendages and configures the КДУ (Propulsion System) for operations after the orbit injection.

Пр. #5 - *Urgent descent program*, it provides for the reduced time preparation for the descent in case of emergency and in other situations demanding and urgent descent.

Пр. #9 - *Descent/maneuver program*, it is used for configuring the spacecraft for descent in back up modes.

Пр. #11 - *Separation program*, it implements the separation algorithm and is started automatically by Пр.5 or Пр9 step marks.

Пр. #12 - *Program for docking/undocking mode ДПО thruster control*, it controls ДПО-Б thruster burns for "approach"/"retreat", configures (resets) the ССВП System for a repeated approach/docking attempt in case of a miss and switches off the ССВП power.

Separation System

The Separation System purpose is to ensure the spacecraft division into modules and the module separation at the СА/ПАО and the СА/БО interfaces by means of cartridge activated devices and spring pushers.

The spacecraft separation is necessary for the СА getting rid of the ПАО and БО Modules before the descent for delivering the crew to the Earth. In case of a failure in the launch/injection phase the separation is executed on the САС (Launch Escape) System commands.
In the descent phase the spacecraft separation is executed on the command of one of the "Separation" Command sources: БЦВК, АПВУ (Пр.11), ПК СА (ОВК2 and ОВК9 Critical Commands) and Система термодатчиков (СТД) (Thermal Sensor System).
The БО separation (jettison) can be executed either automatically on the nominal separation schedule within the unified cyclogram or on the ОВК12 and ОВК 13 Critical Commands in case of the urgent descent before the СКД (Orbital Maneuver Engine) ignition for retrofire.
As a result of any separation command a sequence of two generalized commands: ОК-52 "ПРЕДВАРИТЕЛЬНОЕ РАЗДЕЛЕНИЕ " (Preliminary Separation) and ОК-53 "РАЗДЕЛЕНИЕ" (Separation) will be generated.

Система термодатчиков (СТД) (Thermal Sensor System)

The СТД purpose is to generate control commands and send them to the Separation System when the descending spacecraft reenters the denser Earth atmosphere.
The СТД System includes 6 thermal sensors mounted at the АО Module lower end ring frame. The sensors actuate when their surface temperature reaches 150 $\pm$ 10^{o} C, which corresponds to the altitude of (105 - 110) km.

The nominal separation procedure includes the following main operations:
- cartridge actuated devices inhibit removal;
- the СА Battery (БСА) connection;
- de-energizing the Се and Б power buses;
- the pyro knife actuation to cut the cables of the cable mast connecting БО/СА and БО/ПАО;
- the СА/БО interface pyro aids explosion after in 0,1 sec after the pyro knife actuation;
- The pressure sealed connector plate jettison in 1,5 sec after the БО actual jettison;
- The СА/ПАО interface pyro aids explosion in 0,35 sec after the connector plate jettison.

OPERATION LIMITS AND SYSTEM CHARACTERISTICS

An important feature of the СУБК System circuitry is the OFF command priority (as a rule) over the ON command to ensure absolutely the instrument de energizing in case of its off-nominal operation.
To enhance reliability of the pyro aids operation a two step control of their explosion is provided two commands: the preliminary one and subsequently the executive one being issued to actuate them.
The КСП command duration is set by the duration shapers (limiters) at 0,35 sec.
The КРЛ and АПВУ commands are sent to СУБК at a fixed duration of 0,25 sec.
The ОВК (Critical) and ПК commands do not have a duration shaper, the crew sets the duration of these commands being issued to the actuating switching elements by keeping the ОВК and ПК keys pressed for not longer than 1-2 sec. The exceptions are:
- ПК11, ПК23 commands "КОНТР.ТСЭ"(ТСЭ Test) and ПК12, ПК24 "КОНТР.КСП" commands (КСП Test) which should be kept pressed for not longer than 30 sec.;
- ОВК-12 ОВК-13 commands "ОТСТРЕЛ БО" (БО Jettison) are set fixed at 0,5 sec.;
- ОВК-7 command "ВКЛ СКД" (СКД ON - Ignite) is set at 0,2 sec.

The СУБК System includes the ШБПК cap plug providing the crew capability of inhibiting the КСП command duration shaper when it fails.

When the СА/БО hatch lid limit switches are failed the "РАЗРЕШ.РРСТ" (GO for Undock) toggle switch on the БРУС Unit enables the crew to set the same designation flag 148 which is the back up one for flag 19: "ЗАКР.ЛЮК СА-БО" (СА/БО Hatch Closed).

In off-nominal situations the БЦВК - originated separation cyclogram can be terminated by ПК-И13 “ОДР” (Dynamic Mode Termination) command; the АПВУ Пр.11 “Программы разделения” (Separation Programs) program can be terminated by ПК-Ж5 “ПРОГР.3” command.
When the separation is controlled with the ПК СА by means of the ОВК-2 “ПОДГОТОВКА РАЗДЕЛЕНИЯ” (Separation Config.) and the ОВК-9 “РАЗДЕЛЕНИЕ” (Separation) commands one should keep in mind that the only prerequisite of these commands execution is the “СПУСК” (Descent) flag which can be introduced by the ОВК-1 “ПРИЗНАК СПУСК” (Descent Flag) Critical Command. That means that there is a risk of the “separation” to take place in the autonomous orbital flight phase before the retrofire burn.

CREW OPERATION WITH THE SYSTEM

In case the nominal Launch Vehicle/Spacecraft separation at the final orbit injection phase has not occurred the crew uses the БВК Units to issue the “КО” command to the explosive bolts for the back up separation of the spacecraft from the Launch Vehicle third stage.
When the launch/injection is nominal and there are no situations to require an urgent descent the crew disconnects the СТД System from the Separation System by issuing the ОВК-16 “ТЕРМОДАТЧИК ОТКЛ” (Thermal Sensors Disconnect) command on the МСС instruction. On the ОВК-16 command the СТД System output is connected to the ТСЭ-3 “СРАБОТАЛ ТЕРМОДАТЧИК” (Thermal Sensor Actuated) indicator thus transferring the СТД System to the display mode.
During the spacecraft depreservation before undocking the СТД and АПВУ are energized by the ПК У17 “ПОСТОЯННЫЕ СИСТЕМЫ” (Constant Use Systems) command.
To terminate the АПВУ Пр. # 5,9,11,12 programs the crew is recommended to initiate the Пр. #3 program by means of the Ж-5 command from the КСП.

3.5. СИСТЕМА ЭЛЕКТРОПИТАНИЯ (СЭП) (POWER SUPPLY SYSTEM)

GENERAL INFORMATION ON THE SYSTEM

The СЭП System is designed for the electric dc power supply to the spacecraft onboard systems in all the flight phases.
The СЭП includes independent chemical power sources (ХИТ) and the unified power system.
The independent ХИТs are necessary for the power supply to the systems which are energized only in certain spacecraft flight phases and which require an independent power sourse.

SYSTEM COMPOSITION

The СЭП System block diagram is shown in Fig. 1.

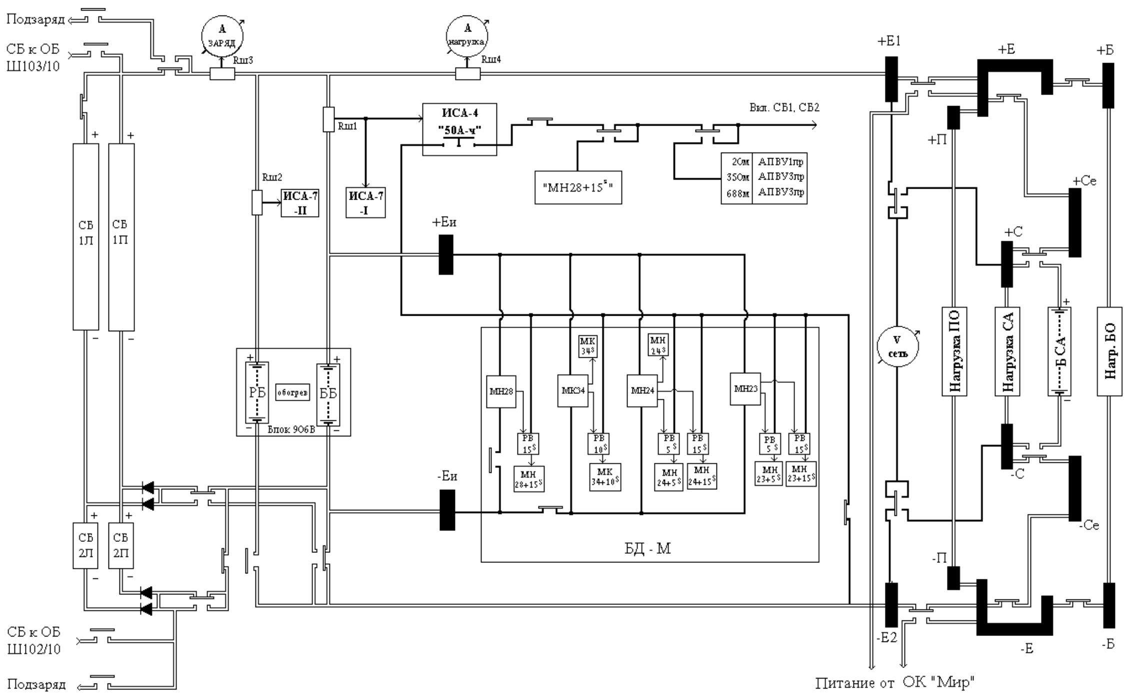


Fig. 1. The СЭП System Block Diagram

The СЭП comprises the following:

a) electric power sources:
- solar battery (СБ);
- buffer battery (ББ);
- back up battery (РБ);

b) control and display aids:
- блок датчиков (БД-М) (Sensor Unit);
- блок шунтов БШ) (Shunt Unit);
- integrating a/h counters (ИСА-4, ИСА-7-I, ИСА-7-II);
- блок коммутации источников питания (БКИП) (Power Source Commutation Unit);
- Voltage/Current Indicator (ИНТ).

Солнечная батарея (СБ) (Solar Battery)

The СБ is the electrical power primary source (generator). The СБ consists of the semiconductor photo cells which perform direct conversion of the Sun's radiation energy into the electric energy.
The СБ is made of two identical wings each having four panels. The СБ is mounted on the ПАО Module along the spacecraft planes II and IV.
The СБ is electrically subdivided into СБ1 and СБ2 sections connected in series to enhance its energetical and operational performance. The capability to switch off the left wing panels is provided by the wiring diagram.
The СБ area is 10 m^2.
Initially (at the moment of the "Контакт подъема" - "Lift Off Contact" event) the СБ panels are folded around the ПАО Module and covered by the nose aerodynamic cap. After the spacecraft injection into

orbit the panels are transferred to the operational position by means of the "Antenna Deployment Program" (the АПВУ Пр. № 4) commands for unlocking (releasing) the spring/rotary joint mechanisms.

The СБ location and structure are shown in Fig. 2.

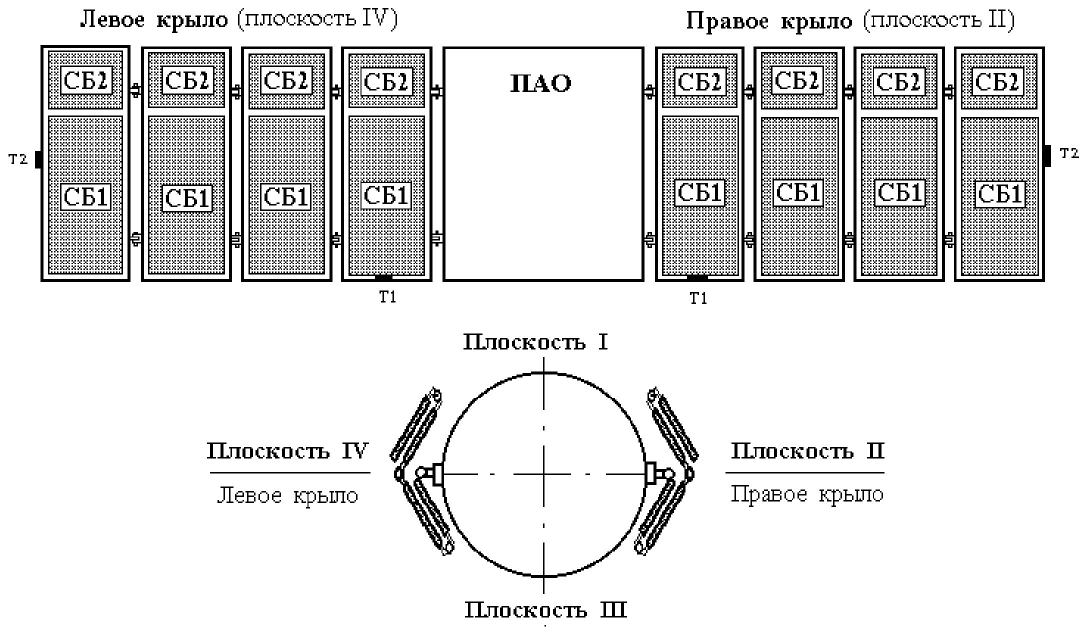


Fig. 2. СБ Location and Structure

1. Left Wing (Plane IV). 2. Right Wing (Plane II). 3. Plane I. 4. Plane III.

Буферная и резервная батареи (ББ, РБ) (Buffer and Back Up Batteries)
The ББ and the РБ batteries are chemical electric power sources (ХИТs) based on silver/zinc accu elements.
The ББ is constantly connected to the СЭП System output buses and provides for the onboard users power supply in case the СБ current is either lower than the load current or as low as zero (when in the shadow or when the Solar ray incidence angle to the СБ operational surface is greater than 60^{o}).
The РБ is designed to maintain the onboard network voltage and to ensure power supply to the onboard users in case:
– it is scheduled by the flight plan for the energy consuming flight portions;
– the onboard network voltage goes lower than the specified value (24,3 V).
Both the ББ and the РБ have four silver/zinc storage battery sections each. Structurally one ББ and one РБ sections are housed in one 906В Unit there being four such Units.
The СА battery (909А Unit) is designed for electric power supply to the СА users in the autonomous flight portion.
The 909А Unit is a chemical electric power source based on silver/zinc accu elements and comprises two sections.
The 909А Unit is installed in the СА in charged state and operates in discharge mode only.

Блок датчиков (БД-М) (Sensor Unit)
The БД-М Unit purpose is to generate and issue commands to the БКИП Unit for the operational procedure adjustment. The input voltage for all the sensors is the voltage across the measurement buses which are directly energized from the ББ terminals.

Блок шунтов (БШ) (Shunt Unit)
The БШ Unit purpose is to generate voltage signals proportional to the currents measured (the sign being taken into account) and to send them to the a/h counter inputs.

Интегрирующие счетчики амперчасов (ИСА) (Integrating a/h counters)

The ИСА counters are designed for measuring the algebraic sum of the quantity of electricity flowing in the ББ and РБ circuits.

Блок коммутации источников питания (БКИП) (Power Source Commutation Unit)
The БКИП Unit is designed for configuring buses and the СЭП System various operational modes.

Индикатор напряжения и тока (ИНТ3-1) (Voltage & Current Indicator)
The ИНТ3-1 Indicator is designed for monitoring the СЭП System main parameters:

- Voltage across the СЭП output buses (U.сэп), monitored with the ИНТ switch in the "40V" position, the voltage operating range being 23 ± 34 V (scale 0...40В);
- The СБ current (I.сб), monitored while the ИНТ switch is in the "I.зар/40A" position, the current operating range being 0 ± 30A (scale 0...40A);
- The load current (I.н), monitored when the ИНТ switch is in the "I.нагр/40A" position, the operating range of the load current established value being 0 ± 80 A (scale 0...80A).

When using the Indicator the crew can monitor one of the above mentioned parameters at a time. The switch "ОТКЛ" (OFF) position is used in the spacecraft preservation mode.

THE СЭП SYSTEM AUTONOMOUS OPERATION
The СЭП System main operational procedure control is accomplished either automatically or manually. The automatic operations mode is primary and the manual mode is auxiliary (back up).
In the automatic mode the СЭП operation is controlled by control commands generated by the СЭП automatic control aids depending on the ББ energetic status.
The ББ freshening charge mode is only possible if the СВ current I.сб is greater than the load current I.н. These parameters can be monitored by means of the ИНТ Indicator. This condition is also valid for the ББ/РБ joint operation case.

COMBINED POWER SUPPLY MODE
After the spacecraft docking to the station ОБ Module the СЭП is transferred to the Combined Power Supply Mode. The mode transfer is executed on the ПКСА (КРЛ) - Д1 "ОБЪЕДИНЕННОЕ ПИТАНИЕ" (Combined Power Supply) command. This command switches the spacecraft modules to power supply from the ОБ Module Power Supply System and the СБ is disconnected from the spacecraft СЭП output buses. The ББ remains connected to these buses and in this mode it has a function of a standby electric energy source for eventual need to transfer back to the autonomous operation mode.
On revolution 1-5 after docking the ББ and РБ undergo recharge since a part of their capacity has been consumed during the approach, berthing and docking operations. The ББ and РБ batteries are charged from the ОБ Module Power Supply System while the spacecraft СЭП System is in the Combined Power Supply Mode.
Transfer back to the Autonomous Power Supply Mode is accomplished by the following commands: ПКСА, КРЛ - Д1 "ОБЪЕДИНЕННОЕ ПИТАНИЕ ОТКЛ" (Combined Power Supply OFF), ПК СА, КРЛ -Д5 "ПОДГОТОВКА РЕЗЕРВНОЙ РАССТЫКОВКИ" (Back Up Undocking Config), ОВК-10 "АВАРИЙНОЕ ВКЛЮЧЕНИЕ ПИТАНИЯ" (Contingency Power ON).

OPERATIONAL LIMITS AND SYSTEM CHARACTERISTICS
The spacecraft СЭП System belongs to the continuously operating system type, therefore the КСП lights as a rule indicate the System elements going OFF while their nominal state is ON.
Measures to maintain the onboard network voltage within specified limits (23 ± 34 V) besides the СЭП System automatic control commands also include a special mode
envisaged in the FDF and named "Solar Orientation and Spin" Mode (Barbeque Maneuver) which is accomplished after a dynamic operation (maneuver). While in this mode the ББ capacity consumed during the dynamic operation is restored.

#	Technical Characteristics	Values
1	Onboard bus D.C. energy	< 85 A
2	Onboard network voltage	23 ÷ 34 V
3	ББ capacity guaranteed	340 A/h
4	ББ service life	100 discharge/ charge cycles
5	РБ capacity guaranteed for the first discharge (service life is two discharge /charge cycles)	280 A/h
6	СА Battery capacity guaranteed (after 180 day stowage)	100 A/h
7	СБ current/voltage when in Sun Orientation with accuracy not worse than ± 10 degrees	26 A 34 V

CREW OPERATION WITH THE SYSTEM

The СЭП System is designed for completely automatic operation without crew participation. However there are some manual controls and displays on the ПК СА, which enable the crew to monitor the СЭП operation and issue control commands in any moment. The System control is mainly exercised from the КСП-Л (Б and Д lines).

Besides the КСП commands the crew can connect the РБ by ПК-3 command. This command is executed by the РБ Battery voltage regardless of the СЭП output buses being energized or not.

The РБ connection is indicated by the ТСЭ-5 “РБ ПОДКЛ” (РБ Connect) light.

When under manual control the crew must maintain the ББ and РБ maximal charge level.

To ensure a higher voltage level during energy consuming operations the РБ is additionally connected to the ББ prior to those operations. The РБ is always connected prior to the approach and undocking procedures.

===

3.6. СИСТЕМА СТЫКОВКИ И ВНУТРЕННЕГО ПЕРЕХОДА (ССВП) (DOCKING AND INTERNAL TRANSFER SYSTEM)

PURPOSE OF THE SYSTEM

The ССВП is designed for:

- ensuring rigid mechanical link of the docking spacecraft and Mir station and at Russian Segment (RS) ISS side providing for a pressure sealed internal transfer passage between them (the assembly scheme is shown in Fig. 1);
- connecting/disconnecting common electric and hydraulic lines during docking/undocking procedures by means of connectors providing for power supply, control command and display communications and uniting the СТР System manifolds (only for Mir station);
- accomplishing the undocking procedures after the completion of the joint flight.

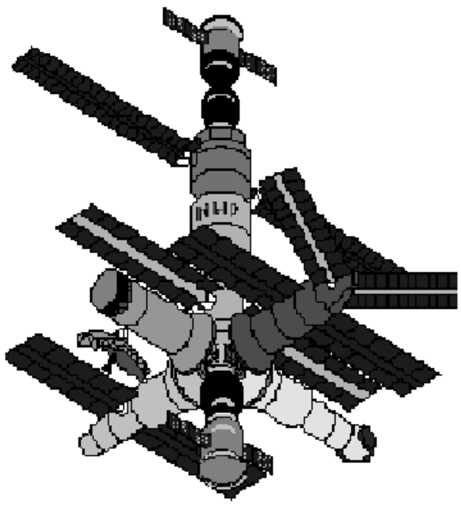


Fig. 1. (Spacecraft/Mir Station Assembly Scheme)

SYSTEM COMPOSITION

The ССВП is an electromechanical system and structurally implemented in three main elements: the Активный стыковочный агрегат (АСА) (Active Docking Assembly), Пассивный стыковочный агрегат (ПСА) (Passive Docking Assembly) and the automatic control units (their electric part). The АСА is installed on the spacecraft БО Module (Fig. 2). The ПСА is mounted on the station. The automatic control units are located in the БО Module "Сервант" ("Servant").

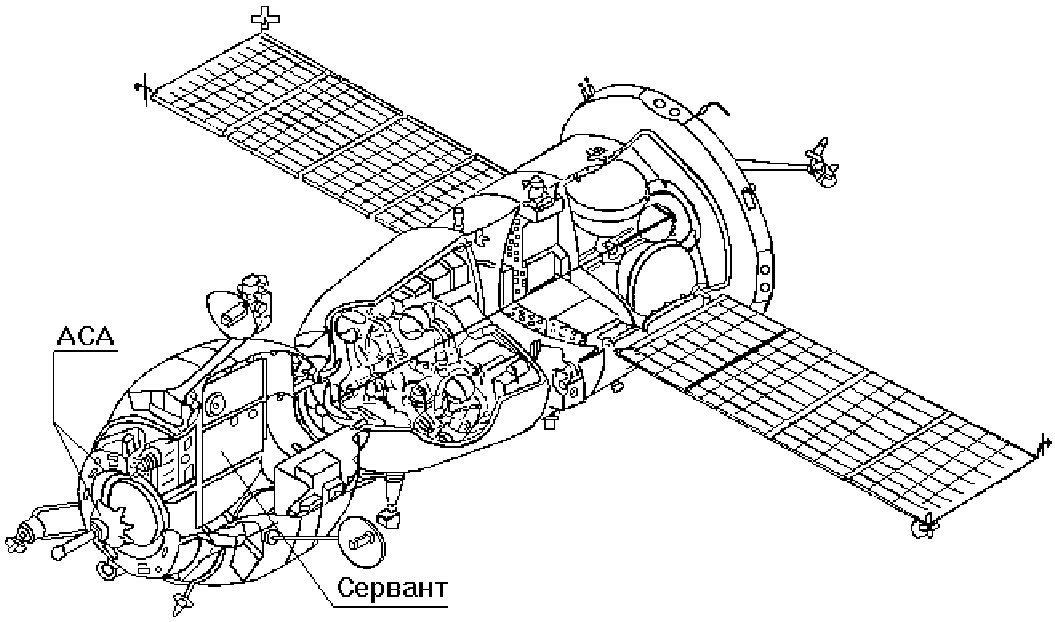
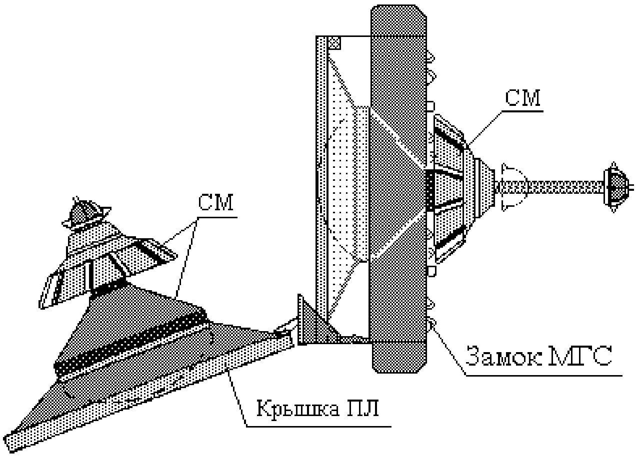


Fig. 2. (Spacecraft ССВП Main Element Location)

There are two automatic control units:
- Активный блок управления (АБУ-ССВП) (Active Control Unit);
- Блок коммутации стыковочного механизма (БК-СМ) (Docking Mechanism Commutation Unit).

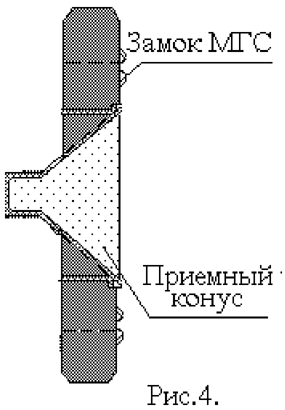
Besides the System includes the onboard cable network (БКС).



The ACA Assembly consists of the following main mechanisms and elements:
- Стыковочный механизм (СМ) (Docking Mechanism);
- Механизм герметизации стыка (МГС) (Interface Pressurisation Mechanism);
- Механизм герметизации крышки (МГК) (Transfer Door Sealing Mechanism);
- hydraulic connectors (2 pcs) (only for Mir station);
- electric connectors (4 pcs);
- spring pushers (2 pcs);
- contact sensors.

The ACA exterior appearance is shown in Fig. 3.

Fig. 3. (The ACA Exterior Appearance)
1. СМ (Docking Mechanism). 2. МГС (Interface Pressurization Mechanism) Locks. 3. ПЛ (Transfer Hatch Door).

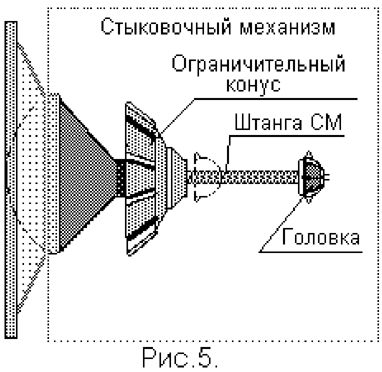


The ПСА consists of the following mechanisms and elements:
- Docking Receptacle Cone;
- Механизм герметизации стыка (МГС) (Interface Pressurization Mechanism);
- Механизм герметизации крышки (МГК) (Transfer Door Sealing Mechanism);
- Hydraulic connectors (2 pcs) (only for Mir station);
- electric connectors (4 pcs);
- spring pushers (2 pcs);
- contact sensors.

The ПСА exterior appearance is shown in Fig. 4.

Fig. 4. (ПСА Exterior Appearance)
1. МГС (Interface Pressurization Mechanism) Lock. 2. Docking Receptacle Cone.

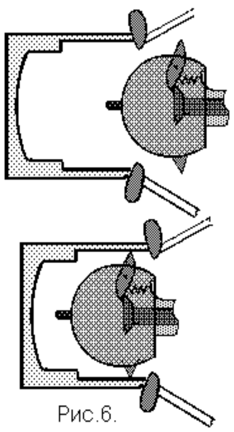
The ССВП Mechanism Design and Operation
The СМ Mechanism is mounted on the ПЛ (Transfer Hatch) Door, is fixed by four pyro bolts and is designed for:
- initial spacecraft aiming error compensation;
- docking impact energy absorption;
- ensuring the first mechanical link;
- spacecraft/station alignment;
- first mechanical link breakage;
- spacecraft/station structural latching and mutual alignment.



The CM Rod's function at docking is to act as a buffer element receiving the mechanical effort at the spacecraft/station impact and to transmit this effort to the absorption system. The CM Rod has a capability of moving forwards (выдвижение - extension) and backwards (втягивание - retraction) by means of the ПСМ (Docking Mechanism Drive) and besides it can проседать (retreat, actually move backwards) at the moment of the spacecraft/station impact ("Касание" - Contact).

The CM Rod exterior appearance is shown in Fig. 5.

Fig. 5. (CM Rod)
1. CM (Docking Mechanism) 2. Limiting Docking Cone. 3. CM Rod. 4. Head.



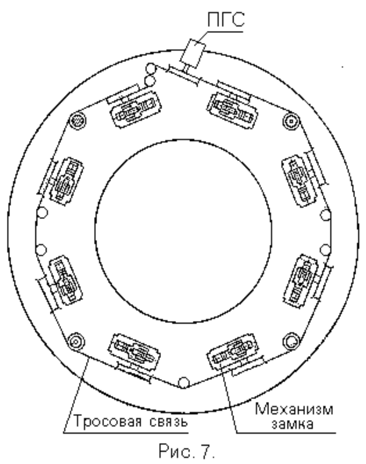
In the forward part of the CM Rod there are four Latches. The Latches can be in either of the two positions: extended or retracted, the extension and retraction being executed by the latch retraction mechanism driven by the Latch Actuator (ПЗ).

<u>First Mechanical Link</u>

During docking the CM Rod Head with the Latches extended enters the ПСА Receiving Cone. In the Cone Drogue there are four trapezoids shaped slots. When the Head enters the Drogue the Latches at first override the spring force and retract into the Head body (the Drogue diameter is less than the diameter of the Head with the Latches extended). Then the Head goes deeper into the Drogue and the Latches pass by the Drogue Stops entering the Drogue slots, the springs act upon the Latches returning them into the initial (extended) position (Fig. 6).

Fig. 6. (Before and After Passing the Stops)

The Stops fix the Head in the Drogue preventing the Latches from getting out. Thus the first mechanical link is achieved.
The first mechanical link can be broken by retracting the Latches or as a back up version by releasing the Stops. In an extraordinary case the first mechanical link can be broken by means of the cartridge-activated aids. To do so the four fixing pyro bolts are exploded, the CM Mechanism is separated from the ПЛ (Transfer Hatch) Door and remains in the ПСА Cone. After that the capability of docking to that ПСА is lost.
The Cone is mounted on the CM body and its function is to limit the spacecraft/station relative angle when mutually oscillating after the first mechanical link is established.



The **МГС** (Interface Pressurization Mechanism) is designed to ensure the second mechanical link, i. e. rigid and hermetically sealed connection of the spacecraft and station docked. The design of the ACA (Active Docking Assembly) МГС and the ПСА (Passive Docking Assembly) МГС is identical.
The МГС consists of:

- Привод герметизации стыка (ПГС) (Interface Pressurization Actuator);
- eight lock mechanisms.

All the МГС elements are located on the docking structural ring (Fig. 7). Each lock mechanism has two operational hooks. One of the hooks is active (movable) and the other is passive (stationary). The ПГС Actuator can move the active hooks to either "Open" or "Closed" position.

Fig. 7. (МГС Elements on the Structural Ring)

1. Cable link. 2. Lock Mechanism.

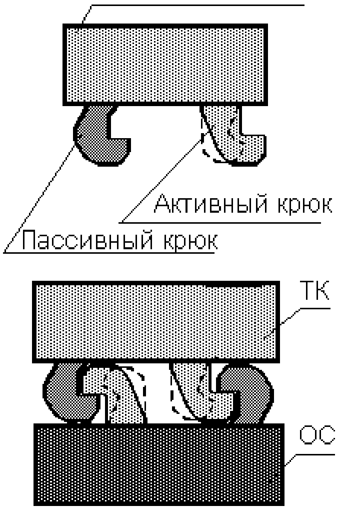


Рис. 8

After the spacecraft/station structural latching and alignment the spacecraft active hooks are positioned opposite the station passive hooks and the station active hooks opposite the spacecraft passive ones.

Second Mechanical Link

The second mechanical link is established by closing the hooks. The active hook at first rotates capturing the stationary hook of the partner Assembly and then goes deeper into the structural ring thus ensuring latching of the ACA and the ПСА structural rings (Fig. 8).

The interface pressurization is achieved by way of compressing the two concentric rubber ring sealings on the ACA structural ring by the ПСА structural ring (rubber/metal joint) during the second mechanical link formation.

The station active hooks are usually also closed to enhance the interface rigidity.

Fig. 8. (Second Mechanical Link)
1. The МГС Lock Mechanism. 2. Active Hook. 3. Spacecraft. 4. Orbital Station. 5. Passive Hook.

In case of extreme need there is a back up capability of opening the ACA Assembly active and passive hooks by means of cartridge actuated aids. These aids are pyro bolts that are located under the active and passive hooks. When the pyro bolts are exploded the active and passive hooks are opened and fixed in the open position by special springs. This results in the second mechanical link breakage regardless of whether the ПСА active hooks are open or closed. After that the spacecraft docking capability is lost.

OPERATIONAL LIMITS AND SYSTEM CHARACTERISTICS

#	Technical Characteristics	Values
1	Berthing parameters at the moment of contact: – Longitudinal approach speed Vx – Lateral approach speeds Vy, z – Roll angle mutual error – Pitch and Yaw angle mutual error – Relative angular rates	 0,1 ÷ 0,35 m/s < 0,1 m/s ± 10 degrees ± 7 degrees ± 0,6 degrees/s
2	Excentricity (Central aiming error)	± 340 mm
3	Maximal ПСМ Drive force at Rod retraction	1500 kg
4	CM Rod extension time	6 ± 9,5 min
5	CM Rod Head Latch extension/retraction time	2 ± 3 min
6	Maximal МГС force at structural Ring latching	20 tons
7	Maximal МГС force at structural Ring latching when ACA and ПСА Hooks are closed simultaneously	40 tons
8	МГС Hooks opening and closing time	3 ± 5 min
9	Total effort of the four spring pushers at separation	300 kg
10	Spacecraft/station separation velocity at pusher action	0,15 m/s
11	Transfer Hatch diameter	800 mm
12	System weight	200 kg
13	ACA Assembly service life	5 dockings/ undockings
14	ПСА Assembly service life	20 dockings/ undockings

The reason for the rather wide range of the ССВП electromechanism action time values is the spacecraft onboard network voltage instability.

CREW OPERATION WITH THE SYSTEM

The ССВП System is controlled by:
1) ПК СА commands;
2) Interactive Multisystem Control Commands from the АБУ-ССВП (Active Control Unit);
3) marks of Пр. № 12 Program of the СУБК System АПВУ Equipment;
4) КРЛ (Command Radio Link System).

The docking is nominally accomplished in the automatic mode the system status indication and commands being generated after the data of the following sensors.

<u>СМ sensors located on the Rod Head</u>
1) ДК1 Contact Sensors (4 pcs) are located under each of the four sectors forming the Head surface. They are the first to actuate during docking procedure (provided the berthing parameter values are kept within specified limits) and they send the Contact signal at the moment of the Rod and Cone contact;
2) ДЗГ Head Capture Sensors (2 pcs) are located at the backward part of the Head. They are the second to actuate during docking at the moment of the Head entering the Cone Drogue. These sensors signalize about the first mechanical link being established.
3) ДК2 Contact Sensors are located at the Head butt. During docking they issue two different signals depending on how the specified berthing parameter values are observed:
    - when the specified berthing parameter values are observed the ДК2 Sensors are the third (after the ДК1 and ДЗГ Sensors) to actuate when the Rod Headhits the Drogue bottom and issue signal of the first mechanical link fully established (сцепка - latching);
    - when the specified berthing parameter values are not observed (a miss) theДК2 Sensors issue the miss signal.

<u>МГС sensors located on the docking structural ring</u>
1) ДКР Undocking Monitor Sensors (2 pcs) actuate (disconnect) during retraction at docking when the gap between the docking rings is 40 mm at the moment they are acted upon by the partner Assembly spring pushers. The ДКР Sensors issue the first mechanical link breakage signal during undocking (their contacts connect).
2) ДЗС Interface Close Sensors (4 pcs) actuate when the gap between the structural rings is as small as 3,5 mm and issue the signal of the interfaced closed.
3) ДОГ Pressurization Sensors (4 pcs) actuate when the gap between the two structural rings is 1 mm (during the hook closure) and send out the signal of the interface pressurized.

The ССВП System block diagram is shown in Fig. 9.

The Docking procedure is an automatic sequence of the following operations:

1) Establishing the first mechanical link due to the АСА Rod Head Latches passing/fixing by the ПСА Receiving Cone Drogue Stops and the impact energy absorption by the АСА aids.
2) Contraction of the spacecraft and station (interface closure) due to the АСА Rod retraction and simultaneously their mutual alignment in three axes.
3) Formation of the second (rigid) mechanical link with simultaneous interface pressurization by closing the МГС Hooks.
4) The first mechanical link breakage by retracting the Rod Head Latches.
5) Rod retraction into the final position.

If the automatic procedure fails the crew completes docking by means of the ПК СА commands.

After docking the internal transfer tunnel pressurization is tested using the СКГС System aids and the transfer hatch doors are opened in the spacecraft and station.
The hatch doors are sealed/unsealed and opened/closed manually using the dismountable handle of the ССВП System kit. There is a capability of automatically closing and sealing the station transfer hatch door.

To enhance the interface rigidity after docking the ПСА Assembly МГС Mechanism hooks are also closed.
Undocking is accomplished after the transfer hatch doors are closed both in the spacecraft and station, pressure is released from the docking assembly (transfer tunnel) and subsequent transfer door sealing (pressurization) test by means of the СКГС System aids is conducted. To effect the undocking the spacecraft hooks are opened (the station hooks are opened beforehand) to break the second mechanical link and under the spring pusher effort the spacecraft and station are separated.

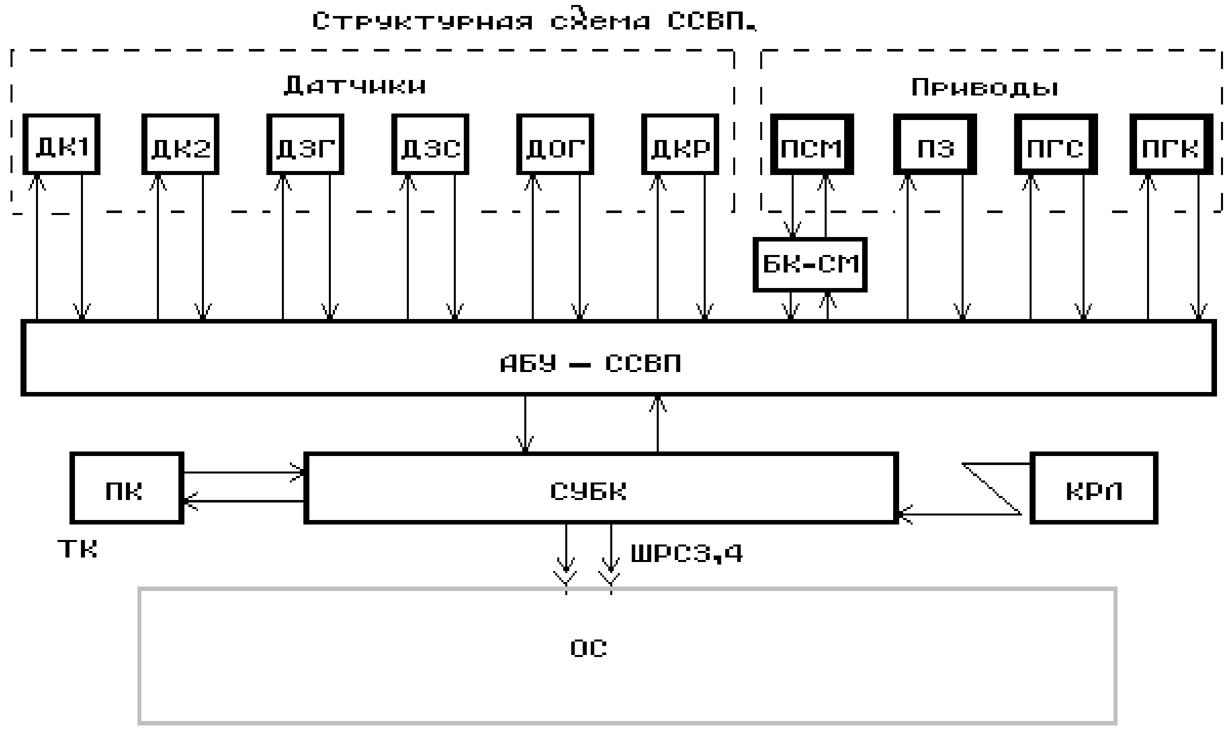


Fig. 9. ССВП System Block Diagram

1. Sensors. 2. Contact (Касание) Sensors -1 and -2. 3. Rod Head Capture Sensor. 4. Interface Close Sensor. 5. Pressurization Sensor. 6. Undocking Monitor Sensor. 7. Docking Mechanism Actuator. 8. Latch Actuator. 9. Intetrface Pressurization Actuator. 10. Door Sealing Actuator. 11. Docking Mechanism Commutation Unit. 12. Docking and Internal Transfer System Active Control Unit. 13. Spacecraft Crew Display/Control Panel. 14. Onboard Complex Control System 15. Command Radio Link. 16. Pressure Sealed Electric Connectors. 17. Orbital Station. 18. Actuators.

The System parameters are displayed on the КСП-Л, КСП-П and ТСЭ-2.

1. Forward. 2. Bach Off. 3. Mecanical Connection. 4. ССВП Mode Execute.

Besides a part of the automatic docking procedure data can be monitored by the crew via the ВКУ Video Monitoring Device display:

ССВП ГТ - ССВП READY

СЦЕПКА – LATCHING

КАСАНИЕ – CONTACT

ПРОМАХ – MISS

3.7. СРЕДСТВА КОНТРОЛЯ ГЕРМЕТИЧНОСТИ СТЫКА (СКГС) (INTERFACE PRESSURIZATION CONTROL AIDS)

СКГС PURPOSE
The СКГС Aids are designed for:
1. Spacecraft/station Interface (Link) pressurization monitoring after docking.
2. Pressure equalization between the spacecraft and station before opening the transfer hatch doors.
3. The transfer hatch doors sealing monitoring after they are closed before the spacecraft/station undocking.

СКГС COMPOSITION
The СКГС Aids include:
1. Клапан контроля малой полости (ККС) (Minor Volume Check Valve);
2. Клапан контроля большой полости (ККТ) (Greater Volume Check Valve);
3. Клапан выравнивания давления между БО и стыковочным узлом (КВД БО -СУ) (БО Module/ Docking Assembly Pressure Equalization Valve);
4. Клапан стравливания давления из стыковочного узла (КСД СУ) (Docking Unit Pressure Release Valve);
5. Мановакуумметр (МВ) (Vacuum Pressure Gauge);
6. Малогабаритный датчик давления (МДД) (Small Size Pressure Sensor) - 2 pcs.

Apart from that the Клапан выравнивания давления (КВД СУ-ОБ) (ОБ Module/Docking Assembly Pressure Equalization Valve) located onboard Mir station and RS ISS can be used for the spacecraft/station pressure equalization.

СКГС OPERATION
The Interface pressurization is achieved by two rubber sealing rings located at the spacecraft docking structural ring. While the spacecraft hooks are being closed the rubber sealing rings are compressed by the docking structural ring and thus pressurize (hermetically seal) the docking interface.
In the interface pressurization check mode and the transfer hatch door seal check mode the СКГС operation is based on creating a pressure differential between the volume monitored and the environment vacuum and measuring the pressure drop rate in the volume.
The volumes to be monitored are the большая полость (БП) (Greater Volume) and the малая полость (МП) (Minor Volume) which are formed after docking (shown in the diagram).
The pressure is measured by means of the МВ Gauge or the КЭИ Indicator (fed by the ММД Sensor data), the unit being mm of Hg (мм рт. ст.).

The СКГС principle of operation can be illustrated by using the block diagram (Fig. 1).

THE СКГС MODES:
– Interface Pressurization (Integrity) Check Mode;
– Spacecraft/Station Pressure Equalization Mode;
– Pre-Undocking Transfer Hatch Door Pressurization (Integrity) Check Mode.

<u>Interface Pressurization Check Mode</u>
The operation sequence in this mode is as follows:
1) Pressure is fed to the МП (The ККС and the КВД БО-СУ Valves are opened and the pressure is equalized between the МП Volume and БО Module);
2) Using the МВ Gauge the pressure change rate in the МП Volume is monitored (The ККС Valve is open, the ККТ and the КВД БО-СУ Valves are closed);
3) Pressure is fed to the БП (The ККТ and the КВД БО-СУ Valves are opened and the pressure is equalized between the БП Volume and the БО Module);
4) Using the МВ Gauge the pressure change rate in the БП Volume is monitored (The ККТ Valve is open, the ККС and the КВД БО-СУ Valves are closed).

<u>Spacecraft/Station Pressure Equalization Mode</u>
The operation sequence is as follows:
1) Open the ККТ, the КВД БО-СУ and the КВД ОБ-СУ Valves;
2) Using the МВ Gauge and the КЭИ Indicator monitor complete pressure equalization between the spacecraft and station.

Pre-Undocking Transfer Hatch Door Pressurization Check Mode
The operation sequence is as follows:
1) Open the КСД СУ Valve and release pressure from the СУ (Docking Assembly);
2) Using the MB Gauge monitor the pressure change rate in the БП Volume (the ККТ Valve is open, the КСД СУ Valve is closed).

SYSTEM OPERATIONAL LIMITS AND CHARACTERISTICS

#	Technical Characteristics	Values
1	MB Vacuum Pressure Gauge measurement range	1 ÷ 960 mm of Hg
2	MB measurement error	< 2 mm of Hg
3	КЭИ Indicator measurement range	1 ÷ 1000 mm of Hg
4	КЭИ measurement error	<95 mm of Hg
5	БП Volume	250 l
6	МП Volume	2,5 l
7	Pressure feed to БП: - from БО - from ОБ	 < 1 min < 30 min

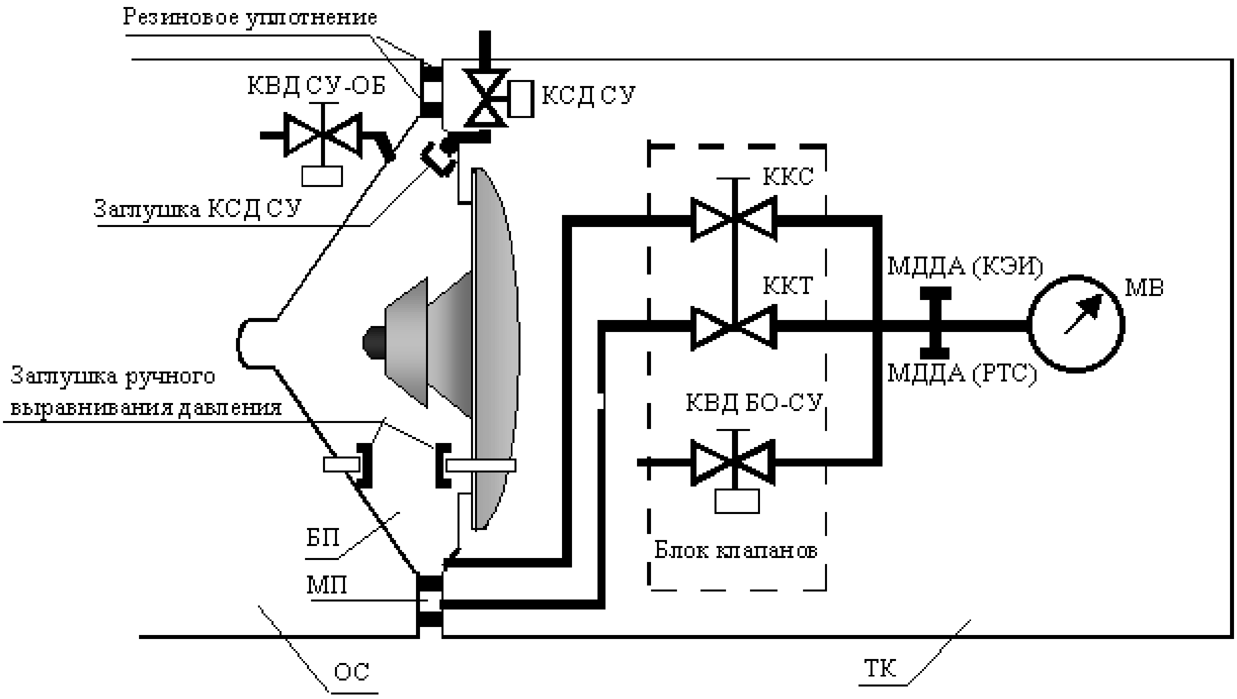


Fig. 1. СКГС Block Diagram

1. КВД СУ-ОБ - клапан выравнивания давления СУ-ОБ (стыковочный узел-орбитальный блок) - Docking Assembly/ОБ Module Pressure Equalization Valve; 2. КВД БО-СУ - клапан выравнивания давления БО-СУ (бытовой отсек-стыковочный узел) - БО Module/Docking Assembly Pressure Equalization Valve; 3. КСД-СУ - клапан сброса давления из СУ (стыковочного узла) - Docking Assembly Pressure Relief Valve; 4. ККС - клапан контроля стыка - Interface Monitor Valve; 5. ККТ - клапан контроля туннеля - Tunnel Monitor Valve; 6. МДДА (КЭИ) - манометрический датчик абсолютного давления (КЭИ) - Absolute Pressure Manometric Sensor (КЭИ); 7. МДДА (РТС) - манометрический датчик абсолютного давления (РТС) - Absolute Pressure Manometric Sensor (РТС); 8. МВ - мановакуумметр - Vacuum Pressure Gauge; 9 БП - большая полость - Greater Volume; 10. МП - малая полость - Minor Volume; 11. ОС - орбитальная станция - Orbiter; 12. ТК - транспортный корабль - Spacecraft; 13. Резиновое уплотнение - Rubber Sealing; 14. Заглушка КСД СУ - Docking Assembly Pressure Relief Valve Cap; 15. Заглушка ручного выравнивания давления - Manual Pressure Equalization Cap; 16. Блок клапанов - Valve Assembly.

3.8. СИСТЕМА РАДИОСВЯЗИ “РАССВЕТ” (СРС) (“RASSVET” RADIO COMMUNICATIONS SYSTEM)

THE “RASSVET” CPC SYSTEM PURPOSE

The CPC System purpose is to provide the crew communications with the ground. The basic crew/ground communications mode is two way duplex voice radio communications in VHF band. For communications with Mir Station and for off-nominal crew/ground communications two-way simplex mode in VHF band is used.

A peculiar feature of the CPC System is its being used during the CA Module descent and landing phase for radiating signals for the Search/Rescue Service direction finders. These signals are transmitted in two bands: VHF and SW. If he CA Module lands within the specified landing area its search is conducted using VHF direction finder signals. If the CA lands anywhere beyond the specified area the SW signals are used at first to determine the actual landing area and then in this area the CA is searched using the VHF band direction finding signals.

The main purpose of the SW band radio aids is the direction finding signal transmission. The SW band equipment is used for communications purposes only in case of the VHF band aids failure (in the parachuting descent phase radio messages are sent simultaneously in VHF and SW bands) and only in the simplex mode.

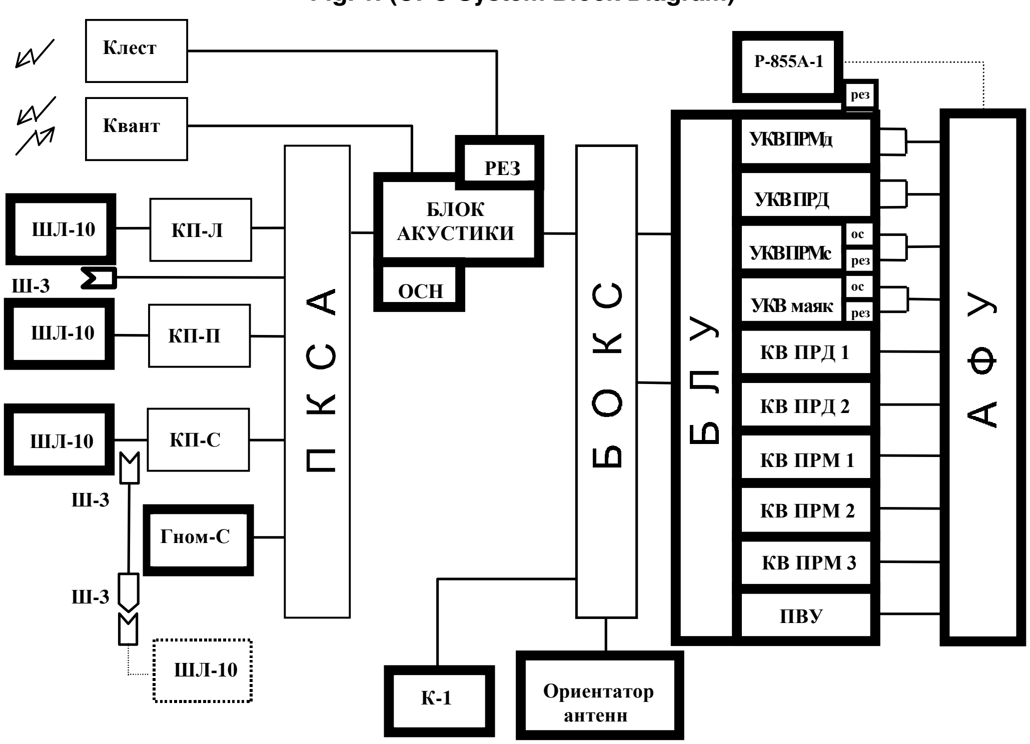
The CPC System also provides the intercom capability for the crew and all radio dialogue recording by the onboard “Gnom-S” tape recorder.

SYSTEM COMPOSITION

The CPC System includes (Fig. 1):

- VHF transmitters (primary and back up half-sets);
- duplex VHF receivers (primary and back up half-sets);
- simplex VHF receivers (primary and back up half-sets);
- VHF beams (primary and back up sets);
- SW transmitters: -1 and -2;
- SW receivers: -1,-2,-3;
- Программно-временное устройству (ПВУ) (Program/Timing Device);
- Блок логики управления (БЛУ) (Control Logic Unit);
- Acoustic Unit (primary and back up half-sets);
- Antenna deployment attitude controller;
- Telegraph key;
- “Gnom-S” onboard tape recorder and 4 cassettes;
- P-855A-1 emergency communication radio set;
- ШЛ-10 headsets.

Fig. 1. (CPC System Block Diagram)



The VHF transmitter is designed for the crew communication with the ground and with Mir orbital station and for the CA Module direction finding signal transmission in the descent/landing phase.
The duplex VHF receiver is for ground communication.
The Simplex VHF receiver purpose is for Mir station (RS ISS) communication and can be also used for ground communication in case of the duplex receiver failure.
The SW transmitter-1 is for ground communication while in orbit and in parachuting descent phase and also for transmitting direction finding signal while in descent/landing phase of flight.
The SW transmitter-2 is for the ground communication while parachuting and for transmitting direction finding signals in descent/landing phase.
The SW receivers-1 and -2 are designed for ground communication in the orbital flight.
The SW receiver-2 is primary for the orbital flight communication and the SW receiver-1 is used on the ground instructions.
The SW receiver-3 is for ground communication after landing.
The ПВУ Device purpose is for automatic issue of the direction finding signals and for the VHF and SW transmitter automatic control after the “Separation” command.

Антенно-фидерные устройства (АФУ) (Antenna/Feeder Devices)
Different antennae are used in different flight phases:

1. In the launch/orbit injection phase the antenna mounted on the Launcher Vehicle's "И" Unit is used (Fig. 3). This is an VHF band antenna and VHF band transmitters and receivers are connected to it. SW communication in the launch phase is impossible because there is no SW antenna available.
2. In the orbital flight phase the VHF communication is conducted using the АБМ-272 antenna (АБМ stands for Onboard Meter Band Antenna). The capability of the SW communication appears after the Solar Battery deployment via the АБМ-275 and АБМ -276 antennas (Fig. 3). The Solar Battery structural elements are used as the SW antennas.
3. In the descent phase the ABM-273 slot antenna is used (Fig. 3).which is mounted on the CA Module Hatch Door.

The SW communication in the descent phase is only possible after the parachute is deployed. From the parachute deployment up to the touch down both the SW transmitter 1 and SW transmitter 2 are connected to the Main Parachute rope antennae: the АБМ-264 (ОСП Primary Parachute System) and the АБМ-265 (ЗСП Back Up Parachute System) antennae (Fig. 3). The SW receivers are inoperative in the descent phase and are not connected to the antennae.
4. After landing when the "Пеленг" command is passed there is a capability of VHF communication via either combined SW/VHF АБМ-279 antenna if the CA Module position is vertical or via one of the three VHF АБМ-274 antennae at the spacecraft bottom if the CA Module lies on its side.
SW communication is also possible using the combined SW/VHF АБМ-279 antenna. If the CA is on its side and the АБМ-279 antenna has been deployed into the ground the crew will have to deploy the extension SW antenna.

“RASSVET” CPC SYSTEM OPERATIONAL LIMITS
When switching ON any transmitter (H1, П1, H7, P9 КСП -П commands) it is necessary to switch OFF all the ПРД keys and depress all the “Press to Talk” keys. Otherwise the transmitter would not switch ON.
When in the descent phase the use of the ПРД keys on the ПК СА is forbidden. The “Press to Talk” key is free for message transmissions but it should not be fixed when pressed.

CREW OPERATION WITH THE SYSTEM
The CPC System is controlled by means of the КСП-П. There are volume controls УКВ (VHF), КВ (SW), ВПУ (Intercom) and also ПРД and ОТКЛ keys. When switching ON any ПРД key all the three LED lights above those keys go on (Fig. 2).
At the middle work station there is a volume control of the onboard tape recorder “Воспроизведение” (Play) and the “КВ ПРМ” (SW RCVR) selector switch.
All the command passage is displayed on the КСП and the ТСЭ.
On the ТСЭ4 there is a yellow “Вызов на связь” (Communication Call) light which is accompanied by audio signal. The audio signal can be switched off by the “ОТКЛ ЗВУКА” (Sound OFF) key and the ТСЭ light - by the “СБРОС АВАР. СИГНАЛИЗАЦИИ” (Emergency Signal Reset).
On the ТСЭ-5 there are the following yellow lights:

- “УКВ ПРД” (VHF XMTR),
- “КВ ПРД” (SW XMTR).

After landing there is a capability of voice communication by means of the P-855A-1 emergency radio using both its own and CA Module antenna.

Spacecraft Communication in Orbital Flight Phase

Nominally crew-to-ЦУП (MCC-M) communication in the orbital flight phase is conducted through the VHF two-way (duplex) communication channel (H1, H2, П5 commands). The H13 "Дуплекс ВПУ"(Two-Way Intercom) command can be arbitrarily issued by the crew.

For communication from the БО Module a 20 m extension cable is used. The cable can be connected to any work station in the CA Module. If the "Дуплекс ВПУ" command has been issued the "Передача" (Transmitting) key can be pressed at any work station. If the command has not passed the "Передача" key should only be pressed at the work station to which the extension cable has been connected.

In case of the VHF two-way communication channel failure the crew-to-ЦУП communication is conducted via the VHF one way (simplex) channel (H1, H5, П5, H13 commands). For transmitting one must press the ТНГ (Push-to Talk) or the "Передача" key.

In case of communication off-nominal situation the crew can communicate via the SW channel (after the Solar Battery deployment) or via "Kvant" and "Klest" Systems.

In order to configure SW communication the following commands should be issued:
- H7 "Подг. КВ ПРД1" (SW XMTR CONFIG)
- H11 "КВ ПРМ" (SW RCVR)
- select ПРМ2 (RCVR 2) using toggle switch on the ПКСА (crew panel)
- press Push-to-Talk or the "Передача" key.

Communication via the «Kvant» System is a two-way type and the communication mode can be arranged within the same communication period. To configure communication via "Kvant" System:
- Standby till the System is ready to operate in the Telephone mode, the P3 - «ТЛФ КВАНТ» light goes ON automatically.
- press Push-to-Talk or the "Передача" key.

Communication via the «Klest» System is a one-way type and it will take some time for its arrangement both onboard the spacecraft and at the MCC. To configure communication via "Klest" System:
1. Rearrange connectors in БО:
   - Commutator X10A to Synchronizer X4W;
   - Synchronizer X10A to Commutator X10A.
2. Issue command: П17 "ТЛФ Клест" («Klest» Telephone).
3. Issue command: P17 "ПРД Клест" («Klest» XMTR).
4. Issue command: P11 "ТВ СА" (CA Module TV).
5. Press Push-to-Talk.

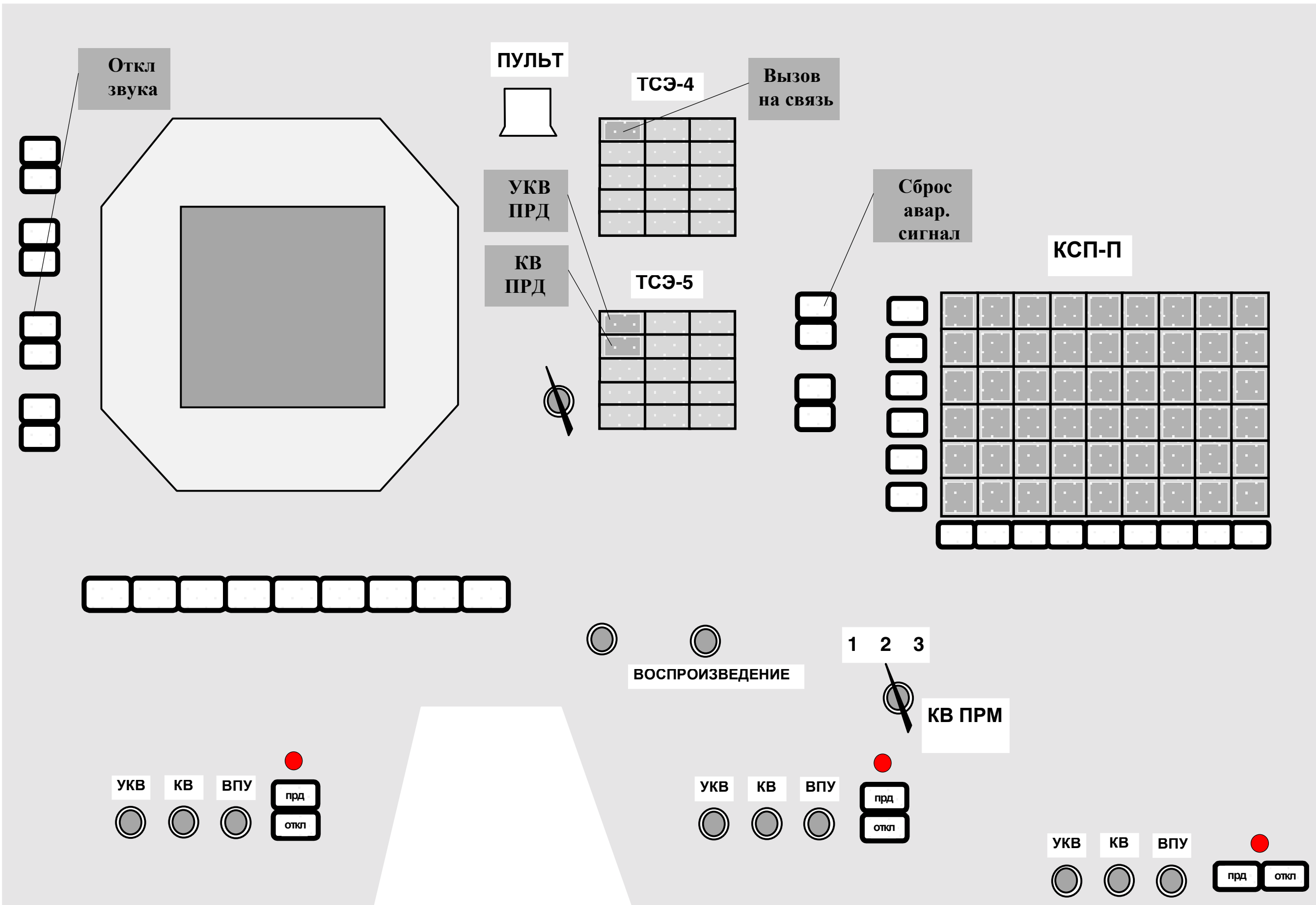


Fig. 2. (CPC System Controls and Displays)

Communication arrangement in all the Soyuz spacecraft flight phases is shown in Fig.3.

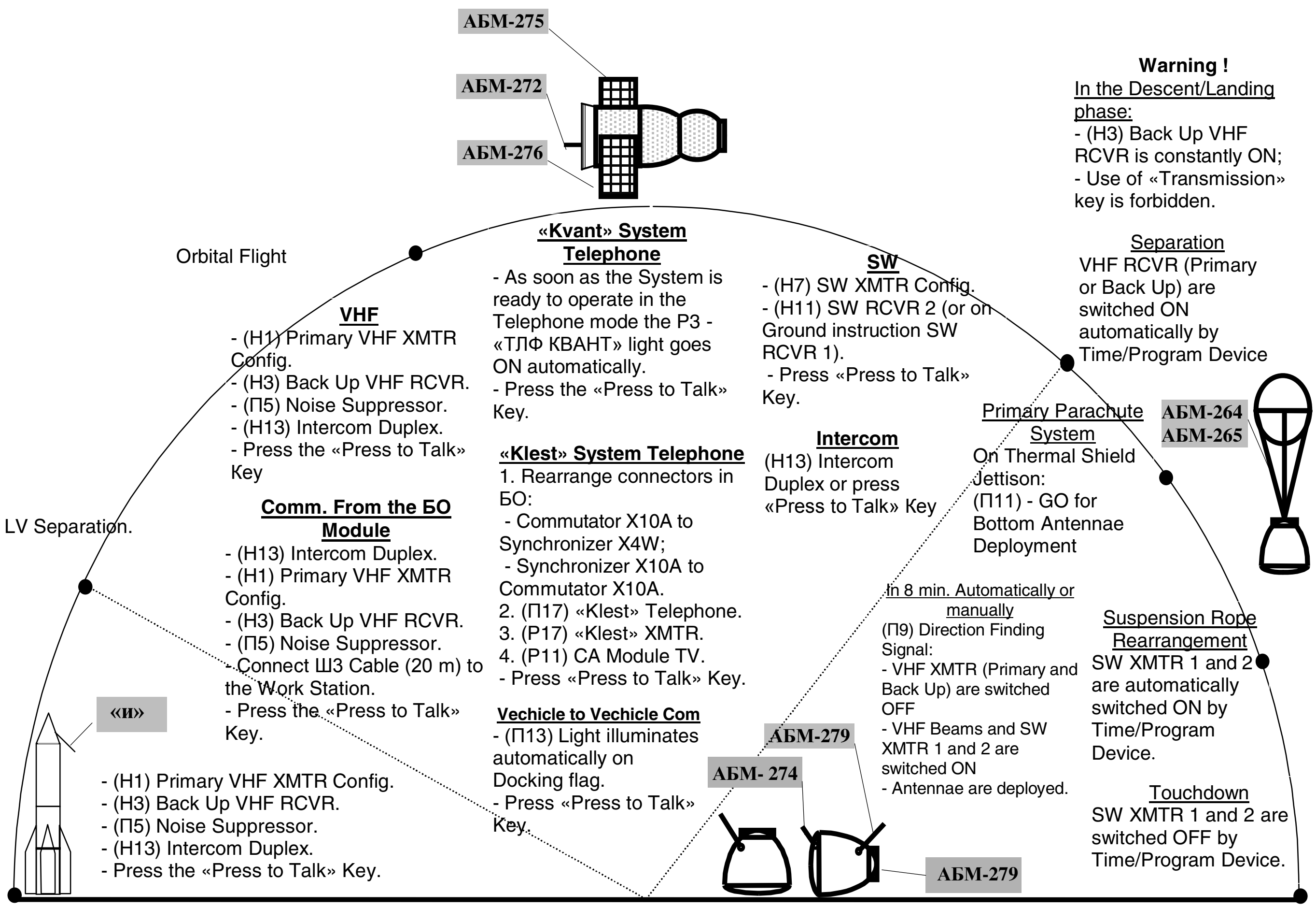


Fig. 3. (Soyuz Spacecraft Flight Phase Communication Arrangement)

THE ONBOARD "GNOM-S" TAPE RECORDER

The onboard tape recorder purpose is to record the crew/ground communication in all the radio links, to record the intercom voice communication and to play the records.
The tape recorder is energized via the БРУС toggle switch "МАГ".

The onboard tape recorder (Fig. 4) has three operation modes:
- recording;
- play;
- rewind.

Recording is the principal mode. Four cassettes are provided for the recorder:
- cassette 1, lift off, orbit injection and orbital flight ground communication;
- cassette 2, docking procedure;
- cassette 3, undocking to landing;
- cassette 4, spare back up.

Each cassette has its numerical designation. The cassettes should be inserted into the recorder in their numerical order.

Continuous recording time of each cassette in one direction is 90 minutes.

THE TAPE RECORDER OPERATION PROCEDURE IS AS FOLLOWS:

Before inserting the cassette press the Откл (OFF) key and then the Кассета (Cassette) key. After that insert the cassette into the cassette holder and close it. After the new cassette is inserted rewind it until the tape consumption counter reading is "2 - 3". Then press the Вкл (ON) key for recording. The recording is continuous.
At the beginning of the recording the cassette number, date, the recorded date headline, the speaker's call sign and the record start time should be dictated.
At the end of the recording the speaker should dictate the recording termination time, his call sign and the recording direction ("1" or "2").
In the record and play mode the tape recorder runs the cassette up to its end in direction "1" ("1" light is ON) and then automatically switches to direction "2" ("2" light is ON), runs it to the end in that direction and then stops ("0" light is ON). Every time the recorder is switched on again it always selects direction "1" automatically. So it is necessary to pay attention to the direction of just finished run each time the recorder is switched off. If it is direction "1" next time the recorder is switched on no additional operation is required. If it is direction "2" next time the recorder is switched on after pressing the ВКЛ (ON) key press "2" key to select direction "2".
Transfer from direction "1" (at the end of the run) to direction "2" in recording and play mode is automatic.

In the rewind mode the recorder stops at the end of the cassette in any direction ("0" light goes ON).

Voice communication in all radio links (USW, SW, Intercom, "Kvant", "Klest") is recorded.

To play the data recorded the headset should be connected to the recorder X3 socket.

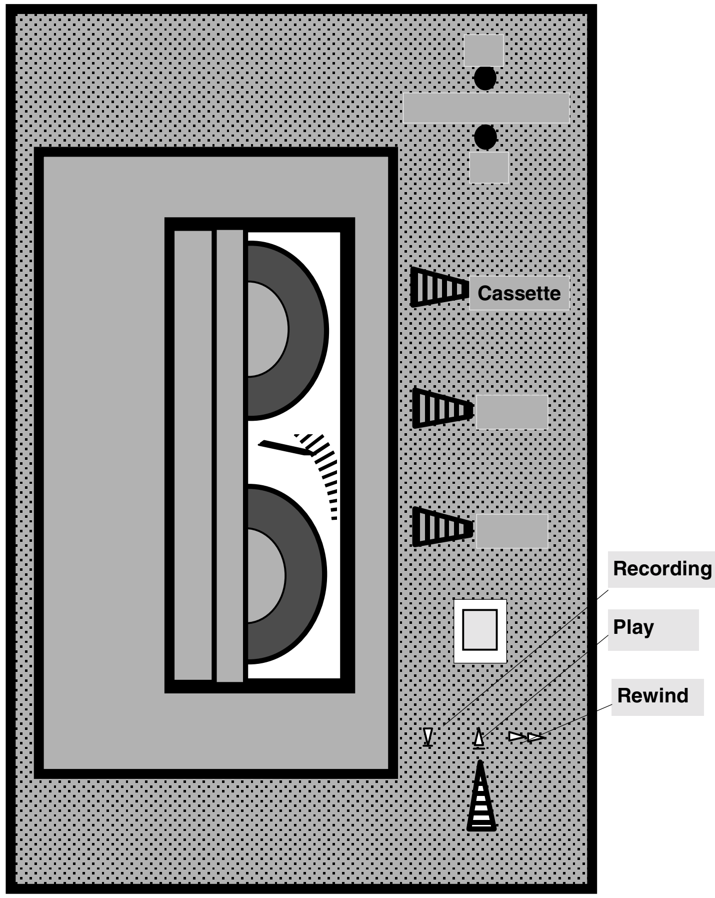


Fig. 4. “Gnom-S” Onboard Tape Recorder Exterior Appearance

3.9. ТЕЛЕВИЗИОННАЯ СИСТЕМА "КЛЕСТ" (ТВС) ("KLEST" TELEVISION SYSTEM)

TBC SYSTEM PURPOSE

The TBC purpose is to perform the following functions:

- Transmitting the crew TV image from the CA Module during prelaunch, launch/orbit injection and orbital flight phases;
- Spacecraft/Station docking procedure monitoring;
- Display of graphic data coming from the "Стрелка-ВКУ" (Strelka-VKU) sensor equipment;
- Display of data originated by the "Символ" (Simvol) equipment;
- Display of combined external TV camera and "Символ" (Simvol) data;
- Display of the spacecraft descent parameters in the controlled descent mode;
- Onboard Clock synchronization after the CA/БО separation.

SYSTEM COMPOSITION

The Soyuz spacecraft TBC System block diagram is shown in Fig. 1.

It includes:

- КЛ-101-02 external NV camera;
- КЛ-102А-02 CA Module TV camera;
- КЛ-102-05 CA Module second TV camera;
- КЛ-105 Commutation units (2 pcs);
- КЛ-106 Synchronizer;
- КЛ-107 видеоконтрольное устройство (ВКУ) (Video Monitoring Device);
- КЛ-110 Display Unit for "ручное управление спуском (РУС)" (Manually Controlled Descent) Mode;
- КЛ-108 Transmitter Unit;
- КР-77 Luminaries (4 pcs).

TV Cameras

The TV cameras' function is to convert the scene in their objective field of view into TV signal (the external camera is black and white and the CA Module cameras are color).

The external TV camera is used for approach/docking and attitude maneuver monitoring. It is equipped with two replaceable objectives: one of wide angle and the other of narrow angle.

There is a shutter in front of the objective used to protect the transmitting tube from direct solar rays. When the camera is switched on the shutter uncovers the objective and when the camera is switched off the shutter covers it.

There is "ТВ Пересветка" (Light Redistribution) Mode provided in the camera, which allows to decreasing the light specks in the image from brightly illuminated objects.

The objective is selectable and the "ТВ Пересветка" Mode is switched by control commands provided the camera is ON.

The CA Module TV cameras are used for the crew status monitoring in all flight phases.

The КЛ-102А-02 Camera is directed at the Commander and the Flight Engineer, and the КЛ-102-05 looks at the Cosmonaur-Researcher.

When the CA cameras are switched On the КР-77 luminaries are switched On.

Commutators

The commutators are used for commutation (distribution) of TV signals coming from the TV sources to the onboard TV users.

Synchronizer

The synchronizer functions are:

- to synchronize operation of the external TV camera and the "Символ" (Simvol) equipment;
- to sum up signals from the external TV camera and from the "Символ" (Simvol) equipment in order to form the combined image (Дисплей ТВ) (TV Display) Mode.

Видеоконтрольное устройство (ВКУ) (Video Monitoring Device)

The ВКУ function is to convert the TV signal into visual image. On the front panel there are brightness and contrast adjustment knobs.

Display Unit for Режим ручного управления спуском (РУС) (Manually Controlled Descent Mode)

The Display Unit for the РУС Mode converts the controlled descent parameters coming from the БЦВК into a TV signal.

The Display Unit operates in two modes:
– "program curve";
– "roll attitude rate".
The Unit generates six program curves and three apparent velocities accumulated values "descretes".

Radio Transmitter
The Radio Transmitter transmits the TV signal to the ground.

Luminaries
The luminaries are used to provide for necessary illumination in the CA Module during the TV cameras operation.
The luminaries are switched on simultaneously when the cameras are switched on.

TBC System Location
- TV cameras:
    - the external camera is located outside the БО between planes II and III. The camera optical axis is directed along the "- X" axis;
    - the КУ-152 CA Module camera is in the CA upper part on the starboard;
    - the КУ-152 CA second camera is in the CA upper part on the port side;
- Commutation Units:
    - one is in the БО behind the cover marked "XCA";
    - the other is in the CA on the port side at the level of the left seat;
- Synchronizer is in the БО behind the cover marked "XCA";
- ВКУ Video Monitoring Device is a part of the ПК CA panel;
- Display Unit for the Manually Controlled Descent Mode is in the CA between the parachute containers;
- Radio Transmitter is in the БО behind the cover marked "XCA";
- Luminaries are in the CA beside the cameras in pairs.

TBC System Technical Data:
- black and white image;
- frame size - 4/3;
- decomposition method - every other line;
- line scan frequency - 625 Hz;
- frame scan frequency - 25 Hz.

TBC System Operation
The TBC equipment operation modes are initiated by commands issued either from the КСП or via the КРЛ. The КСП - issued commands are listed in Table 1.

Table 1

Name of Command	**КСП Adress**	
	ON	**OFF**
"ТВ стык" (TV Docking)	P9	P10
"ТВ СА" (CA TV)	P11	P12
"Подкл ТВ2 СА" (CA Second Camera ON)	P13	
"Дисплей" (Display)	Г3	Г4
"Дисплей ТВ" (TV Display)	B15	
"ТВ РУС" (Manual Contr. Descent TV)	H17	H18
"ПРД Клест-М"("Klest" XMTR ON)	P17	
"ТВ пересвет" (Light Redistribution)	P5	P6
"Объектив ШИР/УЗК" (Wide/Narrow Angle Obj.)	P7	P8

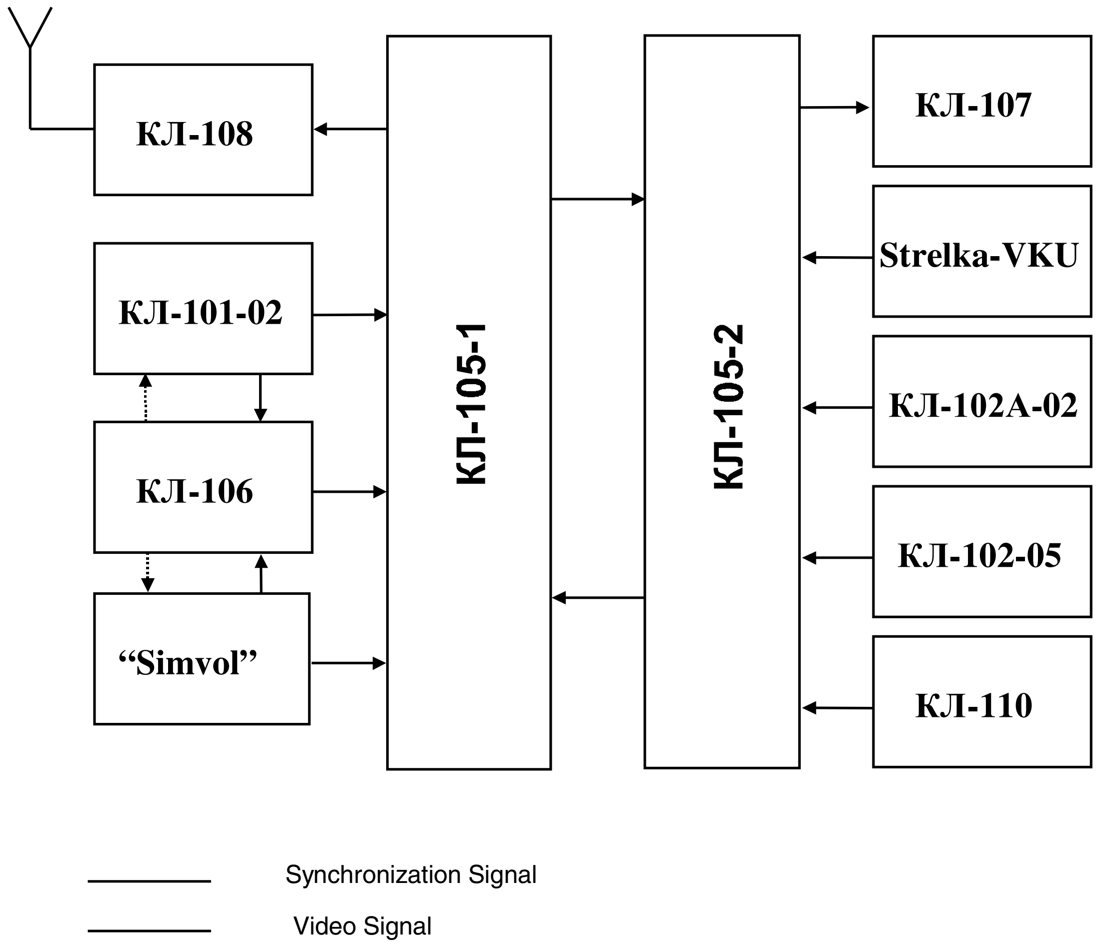


Fig. 1. (TBC System Block Diagram)

3.10. СИСТЕМА БОРТОВЫХ ИЗМЕРЕНИЙ (СБИ) (ONBOARD MEASUREMENT SYSTEM)

СБИ SYSTEM PURPOSE

The СБИ System is designed for ensuring two way multifunction radio communication and Soyuz spacecraft control in both orbit injection and orbital flight phases.

The СБИ System ensures execution of the following tasks:

- Measurement of the slant range to the spacecraft and its velocity radial component (РКО Mode);
- Spacecraft onboard systems control by means of functional commands (ФК Mode);
- Digital data exchange with the spacecraft БЦВК Complex and АПВУ Equipment via up and down radio links (ЦИ Mode);
- Two way Crew/Ground voice communication (ТЛФ Mode);
- Telemetry data downlinking (ТМ Mode);
- TV data downlinking (ТВ Mode);
- Onboard-to-Ground time synchronization;
- Downlinking the crew health status parameters;
- The spacecraft principal onboard system status monitoring when docked to Mir station or RS ISS;
- Issuing the “Авария носителя” (Launch Vehicle Failure) command into the САС (Launch Escape) System during Launch/Injection phase.

The Soyuz spacecraft СБИ System includes:

- БР-9ЦУ-3 Radio Telemetry System;
- Мир-3-А1 Multichannel Recorder.

БР-9ЦУ-3 Radio Telemetry System

The БР-9ЦУ-3 Radio Telemetry System is designed for sampling, memorizing, and converting the sensor data featuring the spacecraft onboard system operation and transmitting it to НИПs (ground tracking sites).
The БР-9ЦУ-3 is multichannel time division measurement equipment.

The БР-9ЦУ-3 equipment has the following operation modes:

- direct measurement/transmission (НП Mode) at the data rate of 25600 measurements per second;
- data recording on magnetic medium (tape) memory of the Запоминающее устройство (ЗУ) (Data Storage Unit)) at the data rate depending on the recording time mode. There are three recording time modes: 32, 130 and 960 min.;
- play (reproduction) of data recorded on the ЗУ memory;
- the ЗУ tape rewinding into the initial position for recording (исходное ЗУ).

The System Antenna Feeder Unit consists of two redundant АБМ-282 and АБМ-283 antennae. The АБМ-282 antenna is primary and is located on the АО Module flare. The АБМ-283 is the back up one and is mounted on the СБ extreme section on plane IV. The onboard transmitter is switched from one antenna to the other by КРЛ commands.
The БР-9ЦУ-3 can transmit data by means of both its own transmitter and the “Kvant-B” System transmitter.
The БР-9ЦУ-3 System units are located in all the spacecraft modules.

The БР-9ЦУ-3 System Operational Limits and Characteristics

#	Technical Characteristics	Values
1	Total weight	95 kg
2	Maximal data rate	25600 1/sec.
3	Channel sampling rate (ЛК channels)	50 Hz
4	Number of channels	8
5	Number of ЛК channels	64
6	ЗУ memory capacity	6 M words
7	Telemetry frame capacity	512 words
8	Word capacity	8 bits
9	Service life	1500 hrs

Crew operation with БР-9ЦУ-3 Equipment

The БР-9ЦУ-3 Equipment operation is controlled by means of the СУБК commands, ПВУ program marks and ground - issued commands.

The crew can switch the direct measurement mode ON or OFF by switching ON or OFF communication session (Ж-3 and Ж-4 "Сеанс связи" (Communication Session) КСП-Л commands). There are no other manual Control/Display aids for the БР-9ЦУ-3 equipment.

Мир-3-А1 Multichannel Recorder

The autonomous multichannel Мир-3-А1 recorder is used for recording the spacecraft system operation parameters in principal dynamic flight portions on the armored cassette magnetic tape.

The Мир-3-А1 Recorder is located in the СА at the crew console frame between planes III and IV. The armored cassette is returned back to the ground together with the crew and is post flight processed using special equipment.

When the Мир-3-А1 Recorder is switched ON the КДУ (Combined Propulsion System) parameters (Р.О1 and Р.Г2) and the СИОС (Descent Reaction Control System) parameters (Р.пер1 and Р.пер2) are only recorded on the Recorder magnetic medium and the crew cannot display them on the ПК СА Panel КЭИ Indicator. If the crew is monitoring these data they will disappear from the КЭИ screen at the moment of the Recorder switching ON.

Мир-3-А1 Equipment Operational Limits and Characteristics

#	Technical Characteristics	Values
1	Total weight	18,5 kg
2	Maximal data rate	6000 1/sec.
3	Channel sampling frequency	31,25 Hz
4	Number of analog channels	64
5	Number of digital (signal) channels	128
6	Continuous operation time	76 minutes
7	Service life	50 hrs

Crew Operation with Мир-3-А1 Recorder

The Мир-3-А1 Recorder is switched on by two commands issued sequentially:

- "прогрев" (Heating) on which the equipment electronics is energized;
- "протяжка" (Tape Transport) on which the tape transport mechanism is started.

The Launch Control Complex, generated by the onboard automatic control aids and issued by the crew can issue these commands. When the КСП-П Т-1 "Протяжка Мир -3" (Mir-3 Tape Transport) is issued both heating and tape transport are switched ON simultaneously and on the Т-2 command both are switched OFF. This operation is executed on the ground instruction in order to prevent eventual tape sticking during a long duration space flight.

If the КСП-П Т-1 "Протяжка Мир -3" light illuminates that is the crew indication of the Recorder being in operation.

Soyuz spacecraft СБИ System/Mir station Complex СБИ System interface

In order to enhance the capability of monitoring the spacecraft system major parameters when docked to the station there are special БР-9ЦУ-3 units installed onboard Mir station to which the spacecraft sensor outputs involved are commutated. After docking the outputs of these БР-9ЦУ-3 units are electrically connected to the station Telemetry System.

The major parameters transmitted to the Mir station СБИ System are:

- pressure of propellant components in storage tank (КДУ System);
- pressure of pressurization gas in spheric bottles (СИОС System);
- pressure and temperature in spacecraft modules;
- pressure and temperature in loops/manifolds of the СОТР System;
- pressure in the oxigen pressurization bottle in the СА.

3.11. РАДИОТЕХНИЧЕСКАЯ СИСТЕМА СБЛИЖЕНИЯ “КУРС” (РТСС) (“KURS” RADAR RENDEZVOUS SYSTEM)

PTCC “KURS” PURPOSE

The “Kurs” PTCC System is designed for measuring the parameters of the spacecraft / station relative motion during their rendezvous.

The “Kurs” PTCC System ensures target search and acquisition at the range of not less than 300 km.

In order to realize the approach mode the spacecraft PTCC is measuring the following relative motion parameters:

- range ρ;
- range rate ρ’;
- target line of sight angle in heading η and in pitch ϑ;
- radio direction angle in heading η and in pitch ϑ;
- relative roll angle γ;
- line of sight angular rate Ω.

The data measured are sent to:

- Motion Control System (СУД) for executing the approach mode;
- Crew display for the approach procedure monitoring;
- Telemetry System for the approach procedure monitoring by the ground.

SYSTEM COMPOSITION

The PTCC System includes the following antennae (Fig. 1):

2AO Antenna

The η and ϑ angles measured by 2AO Antenna are used for the spacecraft directing at Mir station. The Antenna is fixed to the folding rod at the docking assembly flare between planes II and III.

AC Antenna

This Antenna is used for measuring the following relative motion values: ρ, ρ’, η, ϑ, γ, Ω. The Antenna is fixed to the rod on the БО body in plane I.

2АСФ Antenna

This Antenna is used for measuring radio direction parameters (η, ϑ) transmitted from the Mir station. The Antenna is fixed to the rod on the БО Module in plane IV.

AKP1 and AKP2 Antennae

These are used for transmitting/receiving signals in the spacecraft full sphere and for receiving ρ and ρ’ parameters. The AKP1 Antenna is on the БО between planes III and IV and the AKP2 Antenna is on the Propulsion System compartment between planes I and IV.

AKP3 Antenna

The AKP3 Antenna operates jointly with the 2AO Antenna in the attitude control mode. The AKP3 Antenna is mounted on the Propulsion System compartment between planes 1I and IV.

Electronic Equipment

The Electronic Equipment of one PTCC set includes (Fig. 2): приемник (ПРМ) (Receiver); передатчик (ПРД) (Transmitter); Logic Unit; sensors of relative attitude (η, ϑ), line of sight angular rate (Ω), relative range (ρ), range rate (ρ’), relative roll angle (γ), radio direction angles (η, ϑ); Device for data exchange with БЦВК; эталонный генератор частоты (ЭГЧ) (Reference Frequency Oscillator); Test Generator; filters: Built-in Test Equipment.

Based on the test results the Built-in Test Equipment generates either the System Ready for Operation Signal or a measurement channel failure Signal. The test results are sent to the БЦВК which performs analysis of the first and second PTCC System sets, selects the better one and initiates its operation.

The electronic units are housed in a container which is located in the БО “Диван” (Divan). There are two sets of the electronic units in the container, one being primary and the other back-up to enhance the reliability.

The crew monitors the relative motion parameters and the PTCC operational status by using the ВКУ (Video Monitoring) Device in formats 43 or 44.

The КСП-Л is used for the PTCC System equipment control.

The approach procedure data and parameters measured by the “Kurs” System equipment are displayed in formats Ф.43 “Сближение” (Approach) or Ф.44 “Причаливание” (Berthing) (See Appendix B). The format is selected by means of the ПРВИ (Manual Data Load Panel) on the ПК СА.
The format area is subdivided into subject sites in which specific information on relative motion parameters, “Kurs” equipment modes and current flight situation is displayed.

In the right part of Ф.43 format there is a chart of attitude angles η, ϑ and roll angle γ.
The heading angle (η) is read on the axis of abscissae. The pitch angle (ϑ) is measured on the axis of ordinates. The relative roll angle (γ) is read in the upper part of the chart on the axis of abscissae. The above mentioned angular coordinates are indicated in the phase plane as brightness marks (crosses). The cross deflection from the origin determines the line of sight deflection from the spacecraft longitudinal axis.
The object sites displaying numerical data are marked with symbols, which denote:

η, ϑ, γ - pitch, heading and roll accordingly;
Ωz, Ωy - line of sight attitude rate projections;
ρ - range (km);
ρ’ - range rate (m/sec);
η, ϑ - radio direction angles (degrees).

Graphical data on the ρ, ρ’, η, ϑ values or numerical data on the ρ, ρ’, η, ϑ, Ωz, Ωy values are coming to the corresponding subject sites designated accordingly either from the prognosis (forecast) or from the “Kurs” System equipment.
The “Kurs” System equipment is controlled either automatically (from the БЦВК) or manually by means of the КСП-Л commands: “Курс-1” (Г9) or “Курс-2” (Г11) switching ON either set 1 or set 2 of the “Kurs” System equipment. Nominally the flight plan provides for automatic switching ON of the “Kurs” equipment.

SYSTEM OPERATIONAL LIMITS AND CHARACTERISTICS
As there are two sets of the “Kurs” equipment onboard the spacecraft it is possible to select either of them.
At first one set of the “Kurs” equipment is switched ON. When it enters the operation mode it is subjected to testing. In case the test results are negative there may be the following equipment failures:

- Set failure;
- AC mode failure;
- “ρ” panel display failure;
- berthing mode failure;
- failure of viewing angle display.

The test results are sent to the БЦВК and memorized. Then the next “Kurs” equipment set is switched ON and driven to the operational mode with its subsequent testing. The test result are also memorized by the БЦВК. Based on the test results the БЦВК selects the best (healthy) set and uses it in the approach procedure.

“Kurs” Equipment Nominal Operation Cyclogram

When the tests are completed the “Kurs” equipment enters functional operation mode.
The БЦВК issues the “Круговой поиск” (Circular (All-around) Search) command and sends it to the “Kurs” equipment. On this command AKP1 and AKP2 antennae are connected to the Receiver and Transmitter in turn. This enables the spacecraft to receive signals radiated by the station “Kurs” equipment and to radiate signals in full sphere. On the ВКУ Device the “Круг П” (Circular Search) light goes ON.
On board the Mir Orbital Complex its “Kurs” equipment is also operating in the Circular Search Mode, i. e. the AKP1 and AKP2 antennae in turn receive and transmit signals in full sphere.
This Mode lasts no more than a minute that is until one of the spacecraft AKP antenna begins to receive signals from the Mir Complex. When the reception becomes stable the spacecraft “Kurs” equipment generates the Сигнал наличия цели (СНЦ) (Target Acquisition) command. On that command the Search Mode is terminated but the AKP1(2) antenna that was the source of the СНЦ command generation remains connected to the receiver and transmitter. The СНЦ command initiates the spacecraft-to-station pointing mode. The 2AO antenna starts operation measuring angular errors in η, ϑ between line of sight and the spacecraft longitudinal axis. The error in η, ϑ is fed to the Motion Control System which rotates the spacecraft in η and ϑ angles simultaneously aligning the spacecraft longitudinal axis with the line of sight. At the Ф.43 (44) format η and ϑ numerical values appear and also on the phase plane the cross starts moving. When the angular error in η and ϑ decreases down to less than 5^{o}

the “Kurs” equipment generates the “Автосопровождение” (Auto Tracking). On the Автосопровождение command the AKP1 and 2AO antennae are withdrawn from operation and the AC antenna operation is initiated by connecting it to the receiver and transmitter. Using this antenna the spacecraft attitude relative to the Mir Orbital Complex is maintained in response to η and ϑ error signals and also the line of sight angular rate Ω measurement is initiated. The Ω numerical values begin to appear at the Ф.43 (44) format. On the “Автосопровождение” command range (ρ) and range rate (ρ’) measurement channels are switched ON. As soon as the spacecraft “Kurs” starts measuring ρ and ρ’ the “Захват” (Lock-In) command is generated and ρ, ρ’ numerical values from the “Kurs” equipment are displayed at the Ф. 43 (44) format. Information on ρ, ρ’, Ω is sent to the spacecraft Motion Control System which computes the necessary thruster burns and issues commands to initiate them.

At the range of ρ=10 km the БЦВК issues the “Тест К” (“Kurs” Test) command and sends it to the “Kurs” equipment. On this command measurement of η, ϑ, ρ, ρ’, Ωz, Ωy is terminated and the test mode is initiated for checking up the ρ and ρ’ measurement channels serviceability and the range channel calibration. The test lasts less than 100 seconds. When it is completed the AKP1 and AKP2 antennae start operating and the “СНЦ” command is generated. Then using the 2AO antenna the angular error is diminished and subsequently the “Автосопровождение” and “Захват” commands are issued. At the range of ρ<1 km the 2АСФ antenna is connected to the receiver and is used for measuring η and ϑ radio direction angles. This angles are sent to the СУД System and to the Ф.44 format and used while flying around the Mir Complex relative to the selected docking unit. When the fly-around maneuver is completed the БЦВК issues the “ЗАВ КОН” (Station Keeping within the Cone) command. On this command the “Kurs” equipment transfers from the “Захват” Mode to the “Причаливание” (Berthing) Mode. The Motion Control System running to zero η and ϑ radio direction angles brings the spacecraft to the Mir Complex longitudinal axis. Then the γ roll angle measuring and running to zero is initiated. When the angular error value in η, ϑ, γ is small enough to ensure the automatic berthing the crew using the ПРВИ panel issues the “Разрешение причаливания” (GO for Berthing) command into the СУД System. The СУД System moves the Soyuz spacecraft to the Mir Complex at a specified velocity (range rate) and the two space vehicles get docked. When the “Касание” (Contact) command is issued the “Kurs” equipment is switched OFF.

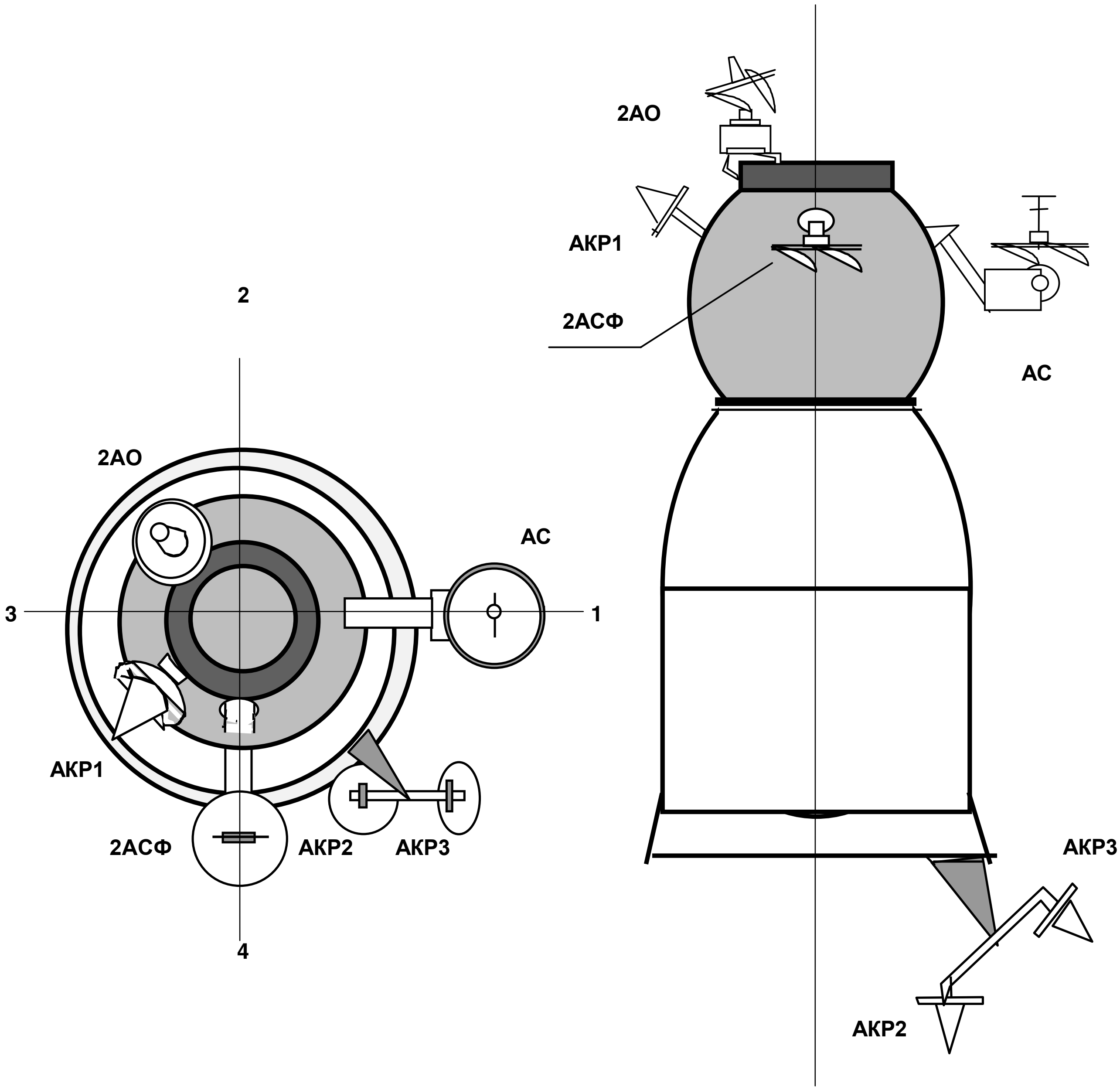


Fig.1. (PTCC System Antennae Layout)

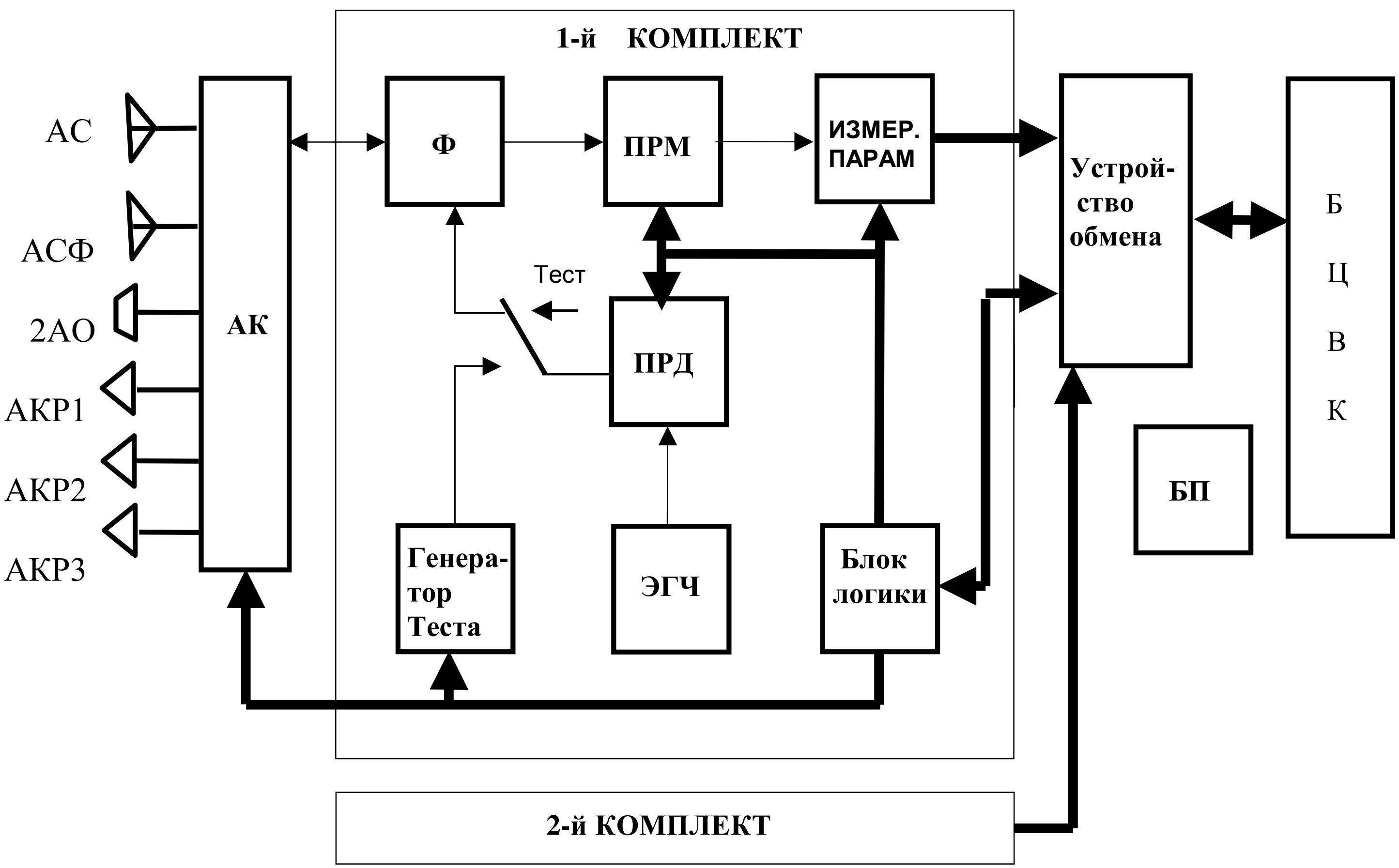


Fig.2. (PTCC System Electronic Equipment)

1. AK Antenna Complex. 2. Filter. 3. Receiver. 4. Transmitter. 5. Test. 6. Set 1. 7. Test Generator. 8. Reference Frequency Oscillator. 9. Logic Unit. 10. Parameter measurement. 11. Device for Data Exchange with БЦВК. 12. Power Supply Unit. 13. Set 2.

3.12. ОПТИКО-ВИЗУАЛЬНЫЕ СРЕДСТВА (ОВС) (OPTICAL-VISUAL AIDS)

The Soyuz spacecraft optical-visual aids (ОВС) include:
- Визуальная система космонавта (ВСК-4) (Periscope);
- Визир ночного управления(ВНУК-К) (Night Time Control Visor);
- Визир пилота (ВП-1) (Pilot Visor);
- Лазерный дальномер (ЛПР-1) (Laser Range Finder).

ВСК-4 COSMONAUT VISUAL SYSTEM

ВСК-4 Purpose
The ВСК-4 Cosmonaut Visual System is designed for the spacecraft attitude monitoring in orbital flight phase, docking procedure monitoring and space object visual observation.

ВСК-4 Composition
The ВСК-4 has external and internal (cabin) parts which are installed on the window located in the CA Module at the spacecraft “-Y” axis. The instrument visor axis is 6 ° inclined relative “-Y” axis.

The external part consists of the central viewing tube and the peripheral tubing unit . The instrument line of sight can only be in two fixed positions: 0 degrees (“Ориент”) (Attitude Monitor) and 84 degrees (“Причал”) (Berthing). The position is changed by turning the mirror unit in the central tube head using an electric motor.
The cabin part includes the instrument body with elements of the two optical systems and the control knob panel (Fig. 1).

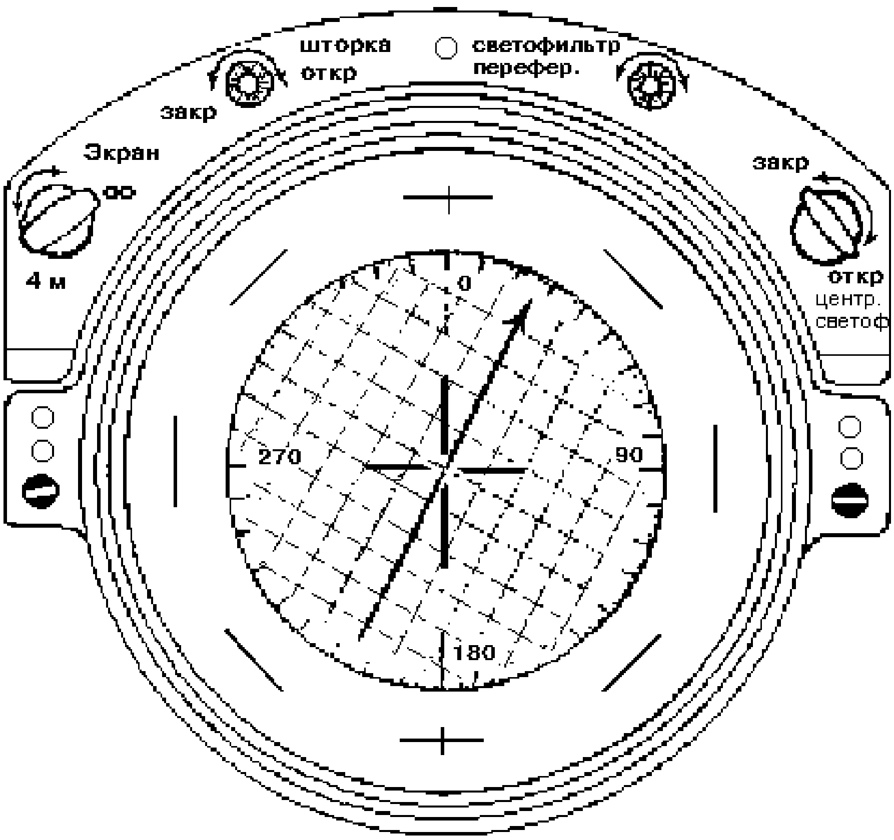


Fig. 1. (ВСК-4 Screen and Control Knob Panel)

1. Screen (Contrast) knob. 2. Shutter ON/OFF knob. 3.Periferal Light Filter knob. 4. Central Light Filter knob.

The “Центр. Светофильтр” (Central Light Filter) knob is used to insert a neutral light filter into the central optical system field of view.

The “Экран” (Screen) knob is used for focus adjustment by moving the screen along the visor axis.
Rotating the “Светофильтр перифер” (Peripheral Light Filter) knob a dark light filter can be introduced into any of the eight peripheral tubes.
The “Шторка” (Shutter) knob purpose is to shut off the field of view of all the eight peripheral tubes simultaneously.

ВСК-4 System Operational Limits and Characteristics

#	Technical Characteristics	Values
1	Central system field of view angle	15°
2	Central system magnification	(0,7 – 0,1)
3	Central system lens aperture diameter - not less than	77 mm
4	Visor axis angle relative to central system axis	0 and 84 °
5	Field of view angle of each peripheral system visor tube: – in radial direction – in tangential direction	 14° 30°
6	Peripheral system magnification	(0,09-0,01)
7	Peripheral system lens aperture diameter - not less	60 mm
8	Power supply voltage	27 +7 V - 4
9	Power consumption	15 W

Crew operations with the ВСК-4
Throughout all the orbital flight the crew uses the ВСК-4 as the principal instrument for monitoring the spacecraft attitude and attitude maneuvers for which the visor axis is set into the “Ориент” position by КСП-Л В-18 command.

The basic attitude - orbital Earth coordinate system (ОСК) with preset heading angle is considered established when the reference object (Earth) apparent run direction in the central system field of view is parallel to the heading indicator stroke rotated at the preset angle. And the Earth horizon in the screen peripheral zone must be parallel to the corresponding strokes or coincide with them.

For approach/docking the visor line is set in the “Причал” position by the КСП-Л В-17 command. At the range of 2 km the crew selects the screen according to the illumination conditions. In the shadow the lens screen is used and in the sunlight the matte screen is preferable. At this range it is possible to estimate the range using the screen grid. Charts and tables for range determination by the target angular size are included into the FDF ((“Nominal Modes”).

ВНУК-К NIGHT TIME CONTROL VISOR

ВНУК-К Purpose
The ВНУК-К Night Visor is used for visual monitoring the spacecraft heading attitude through the ВСК-4 at the shadow part of the orbit and for observing faintly illuminated object through the window.

ВНУК-К Composition
The ВНУК-К consists of (Fig. 2): collective, objective, electronic/optical converter ЭОП(brightness converter) and biocular.

The Infrared rays are passing through the collective (adapter of ВСК-4 and ВНУК-К optical systems), then through the objective and are focused at the ЭОП converter input plane. The ЭОП converts the IR signal into video image which is viewed by the cosmonaut via the biocular. The biocular and objective are fixed to the ЭОП by screwed joints and the collective is connected to it by means of special pin locks.
For the spacecraft heading attitude monitoring a rotatable grid is used.
The ВНУК-К Visor principal controls are located at the ЭОП converter:

- “Сеть” toggle switch - for power supply switching ON;
- “Яркость” knob - for brightness adjustment;
- Grid control knob.

The Visor field of view can be closed by means of a shutter located in the collective, the shutter control knob having only two positions: “Откр” (Open) “Закр” (Closed).

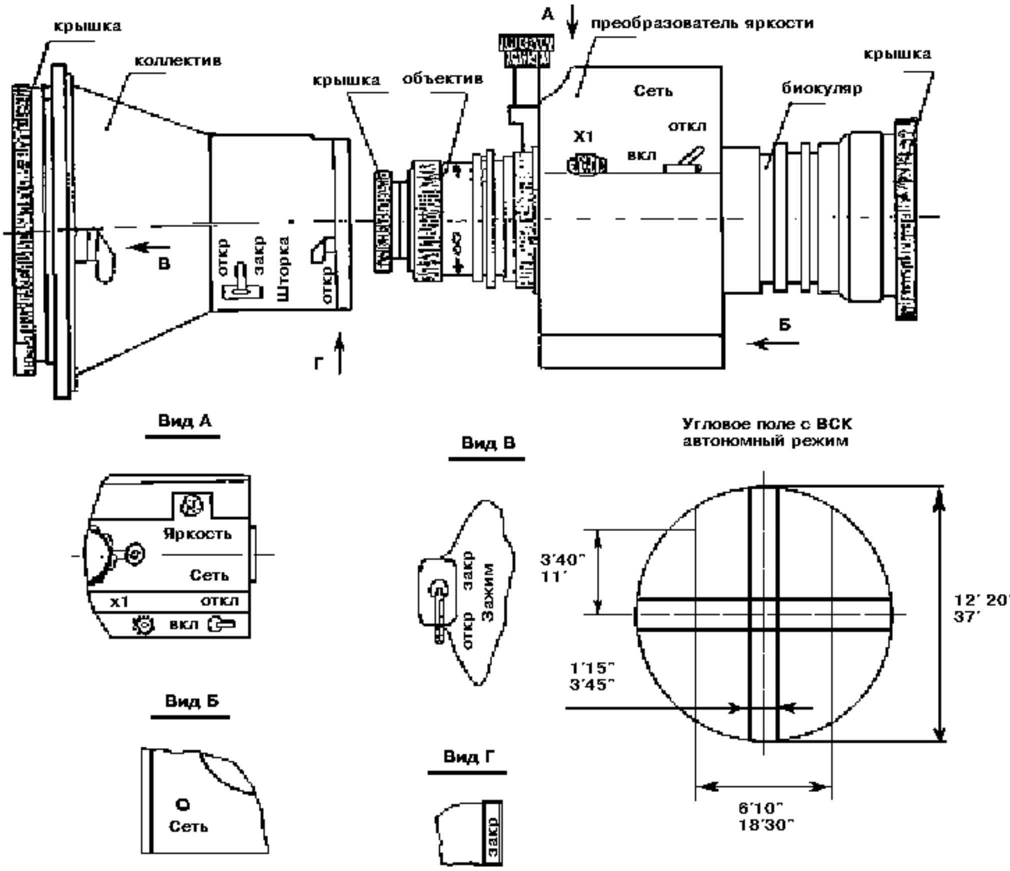


Fig. 2. (ВНУК-К Composition)

1. Крышка - Cover; 2. Коллектив - Collective; 3 .Крышка - Cover; 4. Объектив - Objective; 5. Преобразователь яркости - Brightness Converter; 6. Биокуляр - Biocular; 7. Крышка - Cover; 8. Сеть - Power; 9. Вкл - ON; 10. Откл - OFF; 11. Шторка - Shutter; 12. Откр - Open; 13. Закр - Close; 14. Откр - Open; 15. Вид А - View A; 16. Вид В - View B; 17. Угловое поле: с ВСК, Автономный режим - Field of View: with BCK, Autonomous Mode; 18. Яркость - Brightness; 19. Сеть - Power; 20. Откл - OFF; 21. Вкл - ON; 22. Зажим - Clamp; 23. Закр - Close; 24. Откр - Open; 25. Вид Б - View Б; 26. Вид Г - View Г; 27. Сеть - Power; 28. Закр - Close.

ВНУК-К System Operational Limits and Characteristics

#	Technical Characteristics	Values
1	Objective relative aperture	1:1,8
2	Objective focal distance	36 mm
3	Field of view angle: - with ВСК-4 - in autonomous mode	 12, 20° 37°
4	Brightness gain : - with ВСК-4 - in autonomous mode	 600 900
5	Grid rotation	20+1°

Crew Operation with ВНУК-К

ВНУК-К is used at the shadowed part of the spacecraft orbit for monitoring orbital attitude system (ОСК) and for the target acquisition and its attitude monitoring during approach and docking in the shadow.
When operated jointly with the ВСК-4 it is necessary to: take the covers off, open the shutter, switch ON the "Сеть" toggle switch at the ВНУК-К and using the "Яркость" knob adjust the image brightness to optimal level. To monitor the spacecraft heading attitude using the "Сетка" knob match the grid vertical strokes with the terrain run direction and read the angle on the knob scale.

When the ВНУК-К is operated in autonomous mode it is necessary to dismount he collective. Other operations are similar to those of the joint mode with the ВСК-4. After every 5 hours of the ВНУК-К continuous operation an interval of 30 minutes is necessary.

ВП-1 PILOT VISOR

ВП-1 Purpose

ВП-1 instrument is a visor designed for the observation of reference objects located in the infinity and for the estimation of the angle to the object observed (for instance Mir station (ISS) while executing manual approach).

ВП-1 Composition

The ВП-1 Visor consists of (Fig. 3): the half-transparent glass 7 and the Integral Light Unit 4.

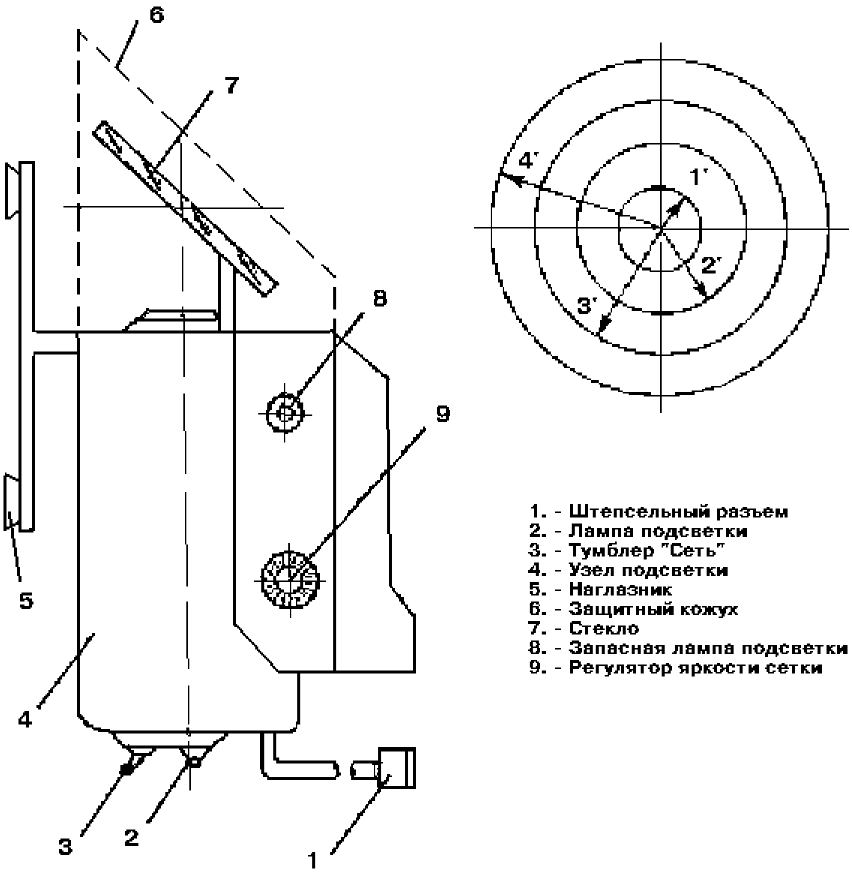


Fig. 3. (ВП-1 Visor)

1. Plug Connector. 2. Light Lamp. 3. Power Switch. 4. Integral Light Unit. 5. Eye Shield. 6. Protective Cover. 7.Glass. 8. Back Up Light Lamp. 9. Reticle Brightness Adjustment Knob.

The Integral Light Unit is used for generating the reticle collimation image at the Glass. In the Launch/Orbit Injection phase the instrument with the protective cover is stowed in the right seat container. ВП-1 is installed befor approaching on БО cupola.

ВП-1 System Operational Limits and Characteristics

#	Technical Characteristics	Values
1	Field of view angle	10°

2	Magnification	1
3	Output aperture diameter	18 mm
4	Output aperture offset from the instrument axis	110 mm
5	Power Supply Voltage	27 V

Crew Operation with ВП-1

To start operations the Integral Light Power (Toggle Switch 3) should be switched ON and the reticle brightness should be adjusted using knob 9.

Prior to descent the Visor is stowed in the БО and is jettisoned together with this Module.

ЛПР-1 LASER RANGE FINDER

ЛПР-1 Purpose

The ЛПР-1 instrument is a laser range finder designed for measuring range to the objects located within 145 - 6000 m while executing orbital station manual approach.

ЛПР-1 Composition

ЛПР-1 is a special instrument (Fig. 4). It has two oculars (eye pieces): the optical ocular (right) for the target observation and aiming, the indicator ocular (left) - for measuring range to the target. In case of low illumination level the ЛПР-1 reticle strokes can be lighted by LED light “ПОДСВЕТ ВКЛ” toggle switch. Range to the target closest to the ЛПР-1 is measured by pressing “ИЗМЕРЕНИЕ 1” button.

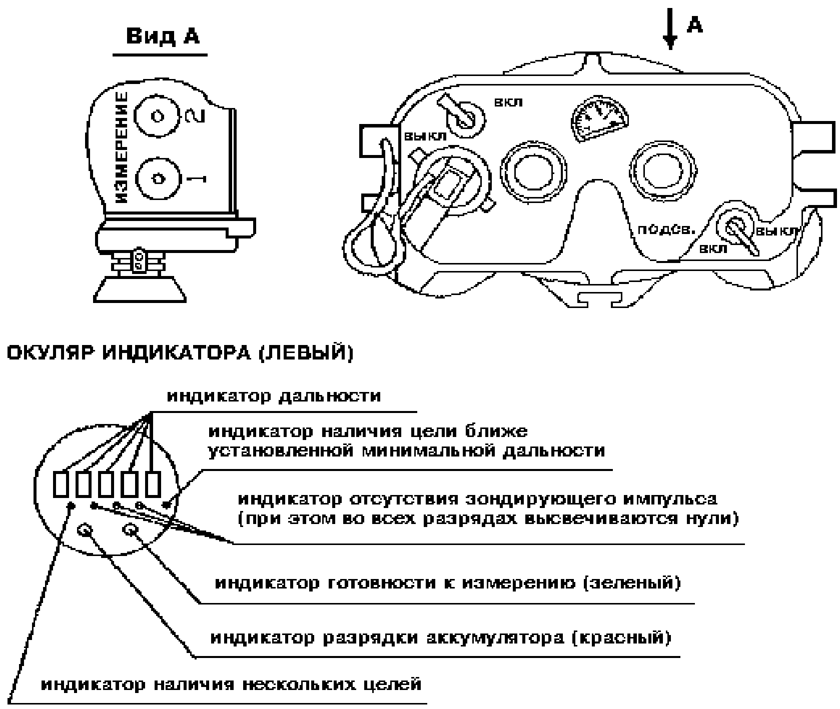


Fig. 4. (ЛПР-1 Laser Range Finder)

1. Indicator Ocular (Left). 2. Range Indicator. 3. Indicator of a Target Available Closer than Minimal Preset Range). 4. Probe Pulse Absence Indicator (Zeros appear in all digits). 5. Ready for Measurement Indicator (green). 6. Storage Battery Discharge Indicator (red). 7. Target Plurality Indicator.

ЛПР-1 Operational Limits and Characteristics

#	Technical Characteristics	Values
1	Ranges to be measured through the window	145-6000 m
2	Measurement error	±10 m
3	Visor field of view angle	6,7°

4	Warm up time for measurement	5 s
5	Time for measurement data display in the left ocular	4±1 s
6	ЛПР service life (single battery powered)	300 measurements
7	Continuous operation time	5 hrs

Crew Operation with the ЛПР-1

For the ЛПР-1 operation it should be mounted on the cupola/window of the БО Module by means of a special bracket. Then it is necessary to check up if there are power supply aids (storage batteries) in the ЛПР-1 and to make sure all the ЛПР-1 toggle switches are in OFF position.

Before starting the ЛПР-1 operation it is necessary to lock it to the bracket, set the protective cover and connect the umbilical. The umbilical is used for the ЛПР-1 connection to the БВК-1 special instrument/calculator which is designed for calculating the approach range rate on the basis of two ЛПР-1 range measurements.

To operate the ЛПР-1 it is necessary to switch on power by means of the “ВКЛ” toggle switch and to energize the Integral Light Unit by the “ПОДСВЕТ ВКЛ” toggle switch (if the target is observed against the dark background). By rotating the right ocular rim set the ЛПР-1 contrast image.

If when switching the ЛПР-1 power ON the red light indicating the battery discharge illuminates in the left ocular it is necessary to replace the power supply battery.

For the ЛПР-1 instrument 5 doubtful measurement of every 20 measurements are admissible.

Target Range measurements

Aim the ЛПР-1 at the target via the right ocular. Then press and hold the “ИЗМЕРЕНИЕ 1” button, in 5 seconds the green indicator light must illuminate in the left ocular which will indicate the ЛПР-1 readiness for measurements. When the green light is ON release the “ИЗМЕРЕНИЕ 1” button. If the laser ray hits the target in the left ocular red range indicator lights will illuminate in the left ocular (range is displayed in meters). If the laser misses the target zeros will appear in all the indicator digits.

For the second range measurement it is necessary to repeat the above mentioned operation steps.

When the ЛПР-1 operation is completed it is necessary to switch OFF the power (“ВЫКЛ” switch) and the Integral Light (“ПОДСВЕТ ВЫКЛ” switch).

In the Launch/Injection phase the ЛПР-1 is stowed in the БО Module.

Prior to descent the ЛПР-1 is stowed in the БО and is jettisoned together with this Module.

3.13. КОМПЛЕКС СРЕДСТВ ОБЕСПЕЧЕНИЯ ЖИЗНЕДЕЯТЕЛЬНОСТИ (КСОЖ) (COMPLEX OF LIFE SUPPORT ARTICLES)

КСОЖ PURPOSE

1. Maintaining necessary microclimate parameters (P, T, gas composition) in the spacecraft habitable modules;
2. Ensuring the crew survival in contingency situations;
3. Providing the crew with potable water and food rations;
4. Collection, isolation and stowage of crew physiological wastes (urine and solid excreti).

КСОЖ COMPOSITION

The КСОЖ Complex consists of:

- Средства обеспечения газового состава (СОГС) (Atmosphere Revitalization System);
- Комплекс средств спасения (КСС) (Survival Aid Complex);
  - Средства подачи газовой смеси (СПГС) (Gas Mixture Supply System);
  - Автоматика КСС (АКСС) (Survival System Automatic Equipment);
  - Комплект индивидуального защитного снаряжения (КИЗС) (скафандр) (Individual Protective Equipment Set) (Space Suit) (Section 3.14);
- Средства водообеспечения (СВО) (Water Stock/Supply);
- Средства обеспечения питанием (СОП) (Food Rations);
- Ассенизационно-санитарная установка (АСУ) (Туалет) (Waste Management System/Toilet);
- Средства контроля герметичности стыка (СКГС) (Interface Pressurization Control Aids) (Section 3.7);
- Носимый аварийный запас (НАЗ) (Post Landing Survival Kit) (Section 3.21).

The КСОЖ Complex ensures:

1. Life support of 2 man or 3 man crew in the spacecraft pressurized modules (СА or СА+БО) within the period of 4.2 days of its autonomous flight.
2. Life support of the crew, the space suits donned, in the depressurized СА Module within the time period of 125 min.

СРЕДСТВА ОБЕСПЕЧЕНИЯ ГАЗОВОГО СОСТАВА (СОГС) (ATMOSPHERE REVITALIZATION SYSTEM)

СОГС Purpose:

1. Maintaining the oxygen partial pressure (PO2) in the module within specified range at the specified degree of its integrity by issuing control signals from the gas analyzer to the O2 supply valve;
2. Cleaning atmosphere in the habitable modules and filtering out injurious additives.
3. Monitoring atmosphere composition in the habitable modules by the O2, CO2 and H2O partial pressure indications.
4. Issuing emergency signals when the PCO2 exceeds the specified upper threshold value and when the PO2 decreases below the specified lower threshold value.
5. Issuing emergency signal when the pressure decreases below the preset value.
6. Ensuring pressure equalization and release from the spacecraft pressurized modules.
7. Maintaining the specified gas composition in the СА atmosphere in case of failure to open the СА/БО Hatch door.
8. Pressurizing the СА parachute container displacement cavity at the touch down.
9. Pressurizing the БО Module with oxygen prior to launch.
10. Filling the ПО with inert gas (Nitrogen).

The СОГС Composition and Location

The СОГС includes:

1. Средства очистки атмосферы (СОА) (Atmosphere Purification Aids);
   - Блоки очистки атмосферы СА и БО (БОА СА, БОА БО) (СА and БО Atmosphere Purification Units);
   - Регенератор (РГ) (Regenerator);
   - П1 ÷ П2 Purification Cartridges.
2. Газоанализатор (ГА) (Gas Analyzer).

3. Датчик сигнализатор давления (ДСД) (Pressure Emergency Sensor).
4. Агрегаты стравливания и выравнивания давления (АСВД) (Pressure Release and Equalization Aids):
   - клапан выравнивания давления СА-БО (КВД СА-БО) (СА/БО Pressure Equalization Valve);
   - клапан стравливания давления из БО (КСД БО) (БО Pressure Release Valve).
5. Система наддува вытеснительной емкости (СНВЕ) (Displacement Cavity Pressurization System).

The СОГС System Main Characteristics
The СОГС System is capable of maintaining the following principal gas composition parameters (provided that there is 2 or 3 man crew, the overall pressure is 450 - 970 mm Hg, one-crewman mean O2 consumption rate is 25 l/hr and CO2 excretion is 20 l/hr) within the time period of 4,2 days at the preset level of the module pressurization:
- carbon dioxide partial pressure P.CO2<10 mm Hg;
- oxygen partial pressure 140 <P.O2 <310 mm Hg and P.O2 < 40% Po (overall pressure);
- water vapor 8 <P.H2O <15 mm Hg;
- harmfull elements - not to exceed specified values.

БОА Unit

The БОА Unit Purpose is to delete CO2 and harmfull elements generated by crew human physiology and equipment operation from the module atmosphere.

БОА Composition and Location:
- Fan Unit (Primary and Back-Up).
- ЭПД Motor Electronic Switch.
- Purification Cartridges: П1 - in the CA, П2, П3, П4 П5, П6 - in the БО.
- Perforated cover - at the CA Module Back Up Fan inlet.

The design of the БОА-СА and the БОА-БО is identical
The БОА-СА is stowed under the Cdr seat, the БОА БО is in the lower part of the “Сервант” (Servant).

БОА Technical Characteristics:
- Purification Cartridge service life: 60 man-hours
- Primary Fan air flow rate: 180 l/min.
- Back Up Fan air flow rate: 120 l/min.
- Purification Cartridge replacement: when P.CO2 = 10 mm Hg.
- Fan power consumption: 7.5 W .

Purification Unit Sequence of Operation

Launch/Orbit Injection: The БОА CA is operational, the БОА БО is idle.
Orbital flight: The БОА БО is operational, the БОА CA is idle. Cartridge replacement in the CA.
Approach/Docking: The two units are operational (СА/БО Hatch door is closed).
Docked Configuration: The two units are idle. Spacecraft preservation. New Cartridge in the CA.
Descent: Prior to closing the СА/БО Hatch door the БОА БО is operational and after it is closed the БОА CA Unit is operational.

Purification Cartridge Replacement Principles

The Purification Cartridges are replaced according to the flight plan schedule and on the ground instruction. However the following requirements should be observed:
1. A new Cartridge should be used for each flight phase:
   - П1 - for orbit injection;
   - П3 - for orbital flight;
   - П5 - for docked configuration flight.
2. When a new Cartridge is initiated in the CA, the old one should be used in the БО until its service life expires.
3. When P.CO2 = 10 mm Hg the Cartridge is to be replaced
4. In case of the Газоанализатор (ГА) (Gasoanalyzer) CO2 channel failure the Cartridges are to be replaced according to their service life.

РГ Regenerator

РГ Purpose: maintaining the CA atmosphere composition in case of failure to open the CA Hatch door. The Regenerator service life is 51 man-hr.

The regenerator should be started when after landing any of the three parameter values are:
- P.O2 < 140 mm Hg;
- P.CO2 > 10 mm Hg;
- T.CA < 15 ^{O} C.

ГА Gas Analyzer

The ГА Purpose is:
- to monitor constantly the module atmosphere separately in P.O2, P.CO2, and P.H2O parameter values;
- to issue control signal to the ЭПК-РД (Electropneumatic Valve for Pressure Adjustment) oxygen supply valve;
- to issue ON command to the ТСЭ-3 “СОСТАВ ВОЗДУХА” (Composition of Air) emergency light.

ГА Characteristics

Parameters	**P.O2**	**P.CO2**	**P.H2O**
Range (mm Hg)	0(80)-350	0-25	0-35
Error (mm Hg)	± 12	± 1.5	± 2
Control command to the O2 Supply Valve: (mm Hg) - ОТКР ЭПК-РД - ЗАКР ЭПК-РД	 160 185	 - -	 - -
Emergency Signal (mm Hg)	≤ 120	≥ 20	

The ГА “warm up” time for the operational mode is 1 hour.

ДСД Caution/Warning Pressure Sensor

ДСД Purpose is to issue caution/warning signal when the Module atmosphere pressure is lower than the preset value.

ДСД composition
ДСД is structurally arranged as a unit composed of:
- МДД small size pressure sensor;
- electric circuit;
- setting controls.

ДСД Controls
On the ДСД front panel there are:
- multiposition switch for the pressure setting;
- pressure range switch;
- “Сигнализация” (Signalization) Toggle switch.

ДСД Technical Characteristics
The ДСД overall pressure range is subdivided into two ranges:
- 420 - 690 mm Hg
- 720 - 990 mm Hg.

There are 20 setting points in the overall range at 30 mm Hg interval between them.
The pressure error at the sensor actuation is ±20 mm Hg.
When the sensor actuates the ТСЭ-3 “ДАВЛЕНИЕ СА ПАДАЕТ” (CA PRESSURE FALLING) illuminates.

КВД СА-БО Pressure Equalization Valve

The КВД СА-БО Pressure Equalization Valve purpose is to equalize the СА/БО pressure.

КСД БО Pressure Release Valve

The КСД БО Pressure release Valve purpose is to release pressure from the БО Module.

CHBE Pressurization System
The CHBE Pressurization System purpose is to pressurize the displacement cavity in the parachute container to ensure stable floating of the CA Module in case of a splashdown landing.

КОМПЛЕКС СРЕДСТВ СПАСЕНИЯ (КСС) (SURVIVAL AID COMPLEX)

КСС Purpose: maintaining life and operation support of a three man crew in the depressurized CA Module in all flight phases in order to ensure safe return to the Earth. The КСС Diagram is shown in Fig. 1.

The КСС Composition:
- Средства подачи газовой смеси (СПГС) (Gas Mixture Supply System);
- Автоматика КСС (АКСС) (Survival System Automatic Equipment);
- Комплект индивидуального защитного снаряжения (КИЗС) (скафандр) (Individual Protective Equipment Set) (Space Suit) (Section 3.14);

СРЕДСТВА ПОДАЧИ ГАЗОВОЙ СМЕСИ (СПГС) (GAS MIXTURE SUPPLY AIDS)

The СПГС Purpose:
1. O2 supply into the space suits when the CA is depressurized.
2. O2 supply into the CA either automatically or manually for P.O2 adjustment.
3. O2 stowage in pressure tanks.
4. Excess pressure relief in the spacecraft modules.
5. CA/Environment pressure equalization when descending both nominally and with the CA depressurized.

The СПГС Composition and Location
1. Gaseous O2 Stowage Aids:
   - 4 spherical tanks (located on the ПхО frame and set in pairs (Sections 1 and 2);
   - 1 cylindrical tank (located in the CA under the Flight Engineer seat).
2. Oxygen Equipment
   - Metal/ceramic filters;
   - Pneumatic connections;
   - Check valves;
   - Reducers;
   - Electric/pneumatic valves: ЭПК-РД, ЭПК-П, ЭПК-СД(1,2);
   - Electromechanical valve: ЭПК-ПСА;
   - Manual turn valves: РПВ-1,2.
3. Блок автоматического регулирования давления (БАРД) (Automatic Pressure Control Unit).
4. O2 Pressure Sensors in the Tanks;
5. Tank Wall Temperature Sensors

СПГС Technical Characteristics:

The СПГС Aids ensure:
- O2 supply at the pressure of 4.5 atm into three “Сокол-КВ2” space suits at the flow rate of 23.5 l/min into each suit for the time period of 125 min in case of the CA depressurization (90 min - from the ПхО Module and 35 min from the CA);
- periodical O2 injection into the CA automatically during the 4.2 days of the spacecraft autonomous flight at the operational flow rate of 6 l/min.;
- three pressurization (integrity) tests of the three space suits with O2 consumption of 240 l for one test;
- gaseous O2 stowage in 4 ПхО tanks, 20 l/220 atm. each and in 1 CA tank, 1l/230 atm;
- excess gas discharge from the CA when the pressure rises up to 950 mm Hg subsequently maintaining the pressure within the range of 740 - 870 mm Hg;
- CA depressurization in emergency cases and maintaining PO2 in CA below 10 mm Hg;
- CA/environment pressure equalization at the safe altitude of 5.5 km and maintaining pressure differential within 0.1 atm during descent both in nominal mode and when the CA is depressurized;

- CA O2 stowage tank pressure relief prior to landing down to the safe value of 10 atm;
- crew capability to monitor O2 stowage tank pressure using the КЭИ Indicator.

БАРД Automatic Pressure Control Unit

The БАРД Unit functions are:
- excess pressure relief from the CA and maintaining it within the range of 740 - 870 mm Hg;
- CA/environment pressure equalization when descending both nominally and with the CA depressurized;
- CA depressurization in case of pressure drop to 400 mm Hg (pure oxygen breathing) to prevent atmosphere overoxidation and in case of fire;
- CA pressurization prior to landing for eventual water surface splash down.

АКСС Survival System Automatic Equipment

The АКСС function is to control the СПГС actuators.

The following operations are executed on the АКСС commands:
1. The ЭПК-П valve opening for the O2 supply to the space suits from the СПГС tanks when the CA pressure decreases down to 400 mm Hg.
2. The ПКГ (БАРД) squib valve explosion for the excess pressure relief when the CA or CA+БО pressure increases up to 950 mm Hg.
3. The ЭПК-РД valve automatic closing and locking in that position when the module pressure drops down to 550 mm Hg.
4. The ПКГ (БАРД) pressurization squib valve and the ПКС (БАРД) pressure relief squib valve explosion for the CA depressurization.
5. The ЭПК-ПСА opening on the CA/ПхО separation.
6. The ЭПК-СД 1, 2 valve opening on the bottom thermal shield jettison for the CA oxygen tank pressure relief to safe value.
7. Control of the space suit fan operation using the КСП-П via the ПЗВС Space Suit Fan Circuit Breaker Panel.
8. Issuing data display signals to the ПК-CA Panel.

АКСС Composition and Location
1. The “Argus” pressure sensor is on the CA bottom.
2. The БАСС Automatic Equipment Unit is in the same place as the “Argus”.
3. The ПЗВС Panel is under the Flight Engineer seat
4. The ПБК Valve Inhibit Switch is to the left and under the ПК-CA Panel.

СИСТЕМА ВОДООБЕСПЕЧЕНИЯ (СВО) (WATER SUPPLY SYSTEM)

СВО System Purpose is potable preserved water supply to the crew.

СВО Composition:

In the БО:
- water stowage tank;
- manual pump;
- protective unit;
- drinking dispenser;
- three individual mouthpieces.

In the CA:
- two feed tanks;
- special drinking dispenser;
- three individual mouthpieces.

In the БО the СВО System equipment is located in the “Диван” (Divan) (opposite to the ingress hatch).

СВО Technical Characteristics:

- stowage tank capacity: V=20 l;
- feed tank capacity: V=0,85 l;
- stowage time:
  - in the stowage tank: 360 days;
  - in the feed tank: 120 days;
- silver content in the water: 0,2 mg/l;
- rated water daily consumption by a crew member: 1,7 l;
- stowage tank water load: for 3 men – 19,7 l; for 2 men - 12 l.

СРЕДСТВА ОБЕСПЕЧЕНИЯ ПИТАНИЕМ (СОП) (FOOD AIDS)

СОП function is to stow and deliver food rations for the crew and provide for the food waste collection and isolation.

СОП Composition

1. Stowage aids in the БО Module "Сервант" (Servant) (Daily food rations are located in envelopes).
2. Food delivery aids:
   - СПП-3 (spoon and fork);
   - СПП-4 (can opener and the "колокольчик" (handbell) squeeze tube opener)
3. Envelopes for food wastes.

Each crew member has its own food ration marking:

КК-1,2 for the Commander;
БИ-1,2 for the Flight Engineer;
КИ-1,2 for the Cosmonaut-Researcher.

The СОП Aids provide for three meals a day with the unheated food stuffs.
The daily ration meal taking procedure is defined by the checklist enclosed in the food ration. Each daily food ration amounts to about 3000 kcal.

АССЕНИЗАЦИОННО-САНИТАРНАЯ УСТАНОВКА (АСУ) (WASTE MANAGEMENT SYSTEM)

АСУ function is collection, isolation and stowage of the crew physiological wastes.

АСУ Composition:

In the БО:

- solid /liquid waste collector;
- wring receptor;
- urine collector;
- filter/fan;
- АСУ panel;
- inserts and replaceable rings.

In the СА:

- urine collector (3 pcs.);
- terminal;
- replaceable rings.

АСУ Technical Characteristics:

- System service life: 12,6 man-days;
- Collector capacity: 10,8 l;
- Fan air flow rate: 250±30 l/min;
- Rated one man daily urine excretion: 1,2 l.

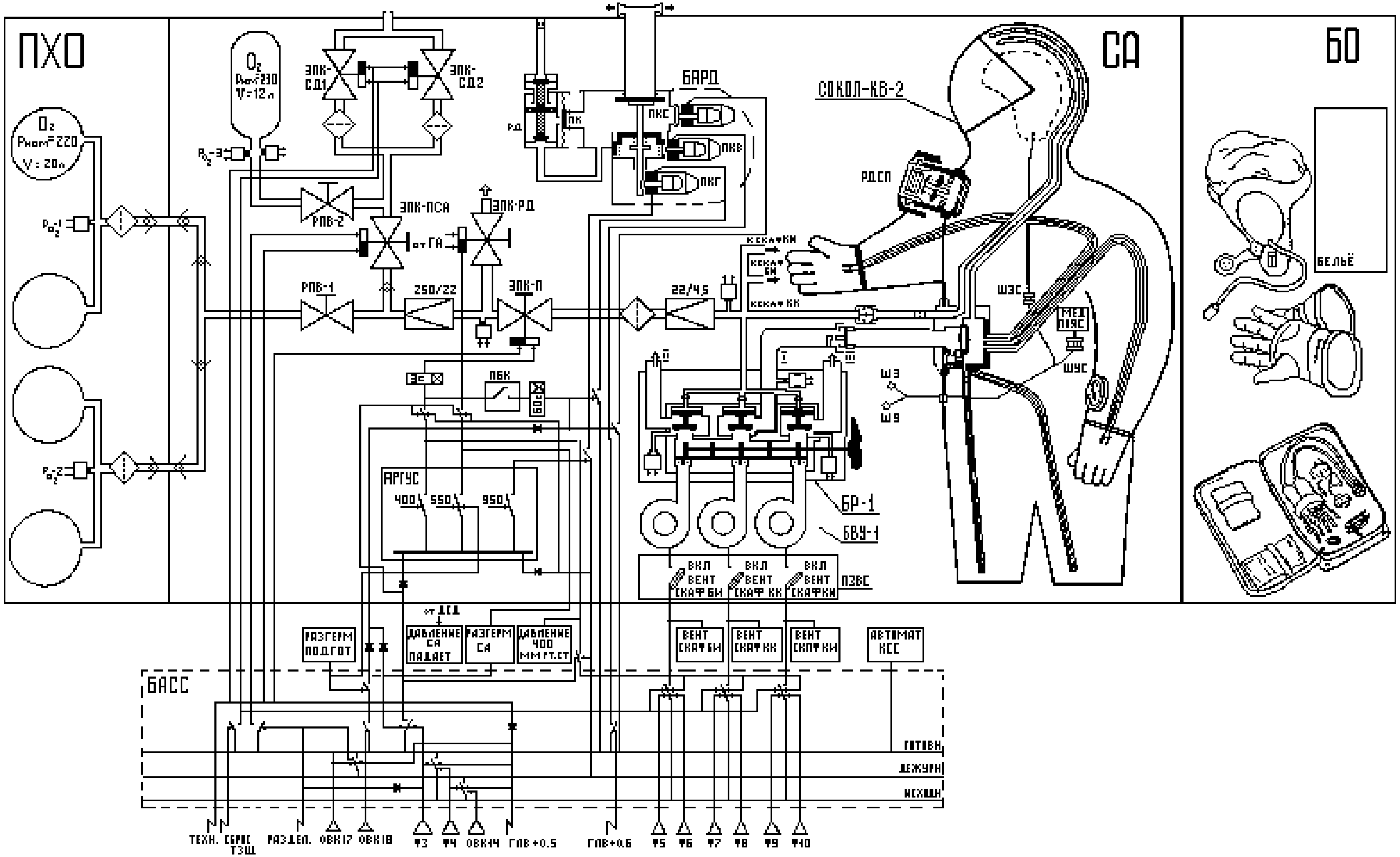


Рис. : Комплекс средств спасения (КСС)

Fig.1. KCC Survival Aid Complex

3.14. СКАФАНДР "СОКОЛ-КВ-2" (СКФ) ("SOKOL-KB-2" SPACE SUIT)

SPACE SUIT PURPOSE

The "Sokol-KB-2" Space Suit is the principal element of the КИЗС Individual Protective Equipment Set which is a part of the Soyuz spacecraft KCC Survival Aid Complex.
The "Sokol-KB-2" Space Suit is designed for maintaining life and operation support of the Soyuz crew in cooperation with spacecraft systems in case of the CA Module depressurization in critical flight phases (launch/orbit injection, docking / undocking / redocking and descent).
The КИСЗ Set jointly with the KCC Complex makes it possible to prevent the low pressure effect on the crew in case of the CA depressurization maintaining pressure in the Space Suit about 300 mm Hg by continuous oxygen supply.
In case of the CA splashdown landing after the crew egress the Space Suit ensures a crew member water buoyancy and stability by means of the "Neva-K" buoyancy collar and a capability of lifting him up on board hovering helicopter.
The KCC Complex which includes the КИЗС Set is designed for maintaining the crew life support parameters within the limits ensuring the crew safe return in case of the CA depressurization during launch/orbit injection, docking, undocking, redocking and descent flight phases. In that case the KCC issues emergency signals to the ПК CA Panel, automatically supplies oxygen to the space suits, prevents the CA atmosphere from overoxydation, equalizes the CA and environment pressure, switches on space suit fans during descent and relieves pressure from the CA oxygen tank prior to landing.

SPACE SUIT COMPOSITION

The Space Suit set includes:
- "Sokol-KB-2" Space Suit (cuff mirror incl.)
- "ГП-7А 1"pressure tight gloves (hygienic gloves incl.);
- ШЛ-10 headset;
- underwear.

The Space Suit auxiliary equipment set includes:
- cotton/flax socks;
- launch highboots;
- launch gloves;
- launch scarf (for cold season launch).

The Space Suit spare equipment set for the Soyuz spacecraft includes:
- ГП-7А pressure tight gloves;
- ШЛ-10 headset;
- underwear, socks;
- maintenance kit.

The maintenance kit is designed for the space suit flight maintenance as its nominal usage procedure and includes:
- stowage envelope;
- space suit drying aid;
- glove drying aid;
- pressure tight helmet glass textile protective cover;
- package for helmet glass oiling;
- electric connector plugs;
- rubber tight plaits for pressurizing the "appendices".

The maintenance kit is located in the БО Module, fixed to the wall near the "Сервант" (Servant).

Besides the "Sokol-KB-2" Space Suit the КИЗС Set includes:
- БР-1 distribution unit;
- БВУ-1 onboard fan unit;
- "Neva-K" buoyancy collar.

SPACE SUIT DESIGN

The space suit has soft type structure and is a two layer combination garment with built in soft helmet, footgear and removable gloves.

The space suit principal diagram is shown in Fig. 1.
There is an opening in the front part for the space suit donning, on the left hand cuff the pressure differential indicator is fixed and on the right hand cuff there is a removable mirror for the donned space suit ext e-rior inspection (in particular for checking up the helmet locks).
The space suits are manufactured for standard sizes and for basically seated position for the cosmonaut comfort in the spacecraft seat. In order to allow for a cosmonaut specific anthropometric features individual fitting aids are provided.
The space suit consists of two shells: internal pressure tight envelope and external structural shell.

Pressure Tight Envelope
The pressure tight envelope is designed to ensure the space suit pressurization and is made of rubberized capron fabric and in the joint areas - of rubberized knitted fabric.
There is a “big appendix” in the envelope (for the space suit donning) and a “small appendix” in the lower part (for urination). The “appendices” are made of rubberized cotton fabric and are pressurized by means of two rubber tight plaits.
Fixed to the pressure tight envelope internal part are elastic pipelines for ventilation and for oxygen supply. Ventilation pipelines are laid to the trousers, sleeves and helmet. Pipelines feeding air to the feet are connected to the ventilation insoles. The oxygen supply pipe is laid to the helmet.
A neck curtain is pasted in the throat part of the envelope in order to prevent water from leaking into the suit when the cosmonaut is floating. In the initial position the curtain is stowed under a cover which is attached to the envelope throat by means of a drawstring. In case of a splashdown landing the cosmonaut pulls the drawstring and the curtain is released and then by pulling the curtain band ends he tightens the neck curtain The pressure tight envelope is attached to the structural shell.

Structural Shell
The structural shell is designed for maintaining the space suit shape under differential pressure and for the pressure tight envelope protection. The shell is made of lavsan fabric and has built in structural bands with clasps in the sleeves, top part, and trousers area for the space suit fitting.
The space suit is donned through the structural shell opening which is covered by means of two structural zippers. The “big appendix” is fabric-reinforced along the zippers to prevent it from jamming.
In the “small appendix” area there is a physiological opening in the shell which is secured by lacing it up and covered by a fabric flap with velcro fastener.
The space suit frontal opening is reinforced by a transversal structural band which locks the shoulder joint cords and by a spring lock in the waist area.
In order to provide for the space suit mobility freedom there are soft joints in the structural shell shoulder, elbow and knee areas. The shoulder joints are additionally equipped with cord connections for a better mobility.
There is an adjustable frontal tightening band with a spring lock used to compensate for eventual space suit excess stretching out by the pressure differential.

Pressure Tight Helmet
The pressure tight helmet is manufactured integral with the space suit top and consists of the following elements:

- shell - the suit top part extension;
- pressure tight joint;
- glass;
- ventilation and oxygen manifolds.

The helmet is tightly locked when its two half-frames get in full contact. The pressure tight joint is fixed closed by means of two locks located on the helmet lower half-frame. At the moment of each lock closing its latch actuates and a specific click is heard.
The latch has a mechanical flag indicator which is protruding from the lock body in case it is not fully closed.

The helmet is unlocked by rotating the lower half-frame handle down and to the right up to the limit. This will move the lower half-frame arch until its bosses contact the latch and release them from the upper half-frame hooks.
There are ventilation and oxygen manifolds in the helmet for air and oxygen supply accordingly. The ventilation manifold has a receptacle for fixing the suit pressure charging. This operation is accomplished when the cosmonaut is floating after the splash-down landing and the neck curtain has been tightened.
The helmet glass is made of strong polycarbonate material with yet a decreased abrasion resistance. To prevent the glass from scratches on the outside surface it is covered with the organic glass protector which is taken off after the crew ingress prior to launch.

ГП-7А Pressure Tight Glove

The ГП 7А glove is a rubber pressure tight glove which is covered by fingerless structural shell with lock ring for connection to the suit sleeve.

The rubber glove consists of a finger part and the cuff part attached to it. The finger part has the capron knitwear reinforcement layer covered with rubber. At the finger flexion points there are bulges made for finger mobility enhancement. The cuff part is made of rubberized knitwear. The structural shell is made of lavsan fabric. The glove is connected to the suit cuff by means of the lock ring in which a hollow rubber hose (the "дутик"). The glove can be rotated about the longitudinal axis by the turnable hand connector at the suit sleeve.

The pressure tight gloves are manufactured in three sizes: III, II Б and IV which correspond to the palm half-grip of 8, 8.5 and 9 cm.

To provide necessary physiologic / hygienic conditions for the crew member operation in the gloves hygienic cotton gloves are to be put on prior to the pressure tight gloves donning.

Регулятор давления скафандра с подсосом РДСП-3М-01 (Air Suction Suit Pressure Regulator)

The РДСП-3М-01 pressure regulator is designed for maintaining necessary absolute pressure in the space suit in case of the CA depressurization and for building up pressure differential during pressurization tests.

The regulator has two pressure modes (0.4 and 0.27 kgf/cm^2) and its functions are:

- to maintain preset absolute pressure (0.4 or 0.27 kgf/cm^2) and to build up pressure differential (pressure adjustment);
- to prevent the suit pressure differential from rising above 0.45 kgf/cm^2 (safety relief valve);
- provides for the crew capability of breathing the outer air while the helmet is closed and there is no suit ventilation (air suction).

The pressure regulator main parts are:

- body with three stops;
- valve with evacuated bellows (aneroid) and springs;
- cover with locks.

The bellows is the regulator sensitive element its operation principle being based on its elastic deformation / acting pressure relationship. The cover is the manual pressure adjustment aid.

The pressure regulator ensures one of the following conditions in the space suit depending on the cover position:

1. When the cover is in the "0.4" position (i.e. at the medium stop):

- if the CA pressure is normal the bellows is compressed and the valve is open forced by the under-valve spring and the suit interior volume is connected to the environmental atmosphere; there is a capability of breathing the outer air while the helmet is closed and there is no suit ventilation;
- in case of the CA depressurization the bellows expanding gradually closes the valve at the level of P.CA=300 mm Hg and absolute pressure of 0.4 kgf/cm^2 is maintained in the suit.

2. When the cover is in the "Закрыто" (Closed) position (i.e. at the lower stop) the valve is closed forced by the over-valve spring and with the oxygen supply the pressure differential of 0.45 kgf/cm^2 is maintained in the suit. This mode is used in the suit pressurization tests.
3. When the cover is in the "0.27" position (i. e. at the upper stop) in case of the depressurized CA the bellows expands maximally and the load force acting on the valve is less than in the "0.4" cover position so the valve will close at a lower pressure level - at P.CA=200 mm Hg. And the absolute pressure of 0.27 kgf/cm^2 is maintained in the suit. This mode is used when it is desirable to enhance the suit mobility for a short time period of no more than 5 minutes in the depressurized CA.

In order to transfer the regulator from the "0.4" to the "0.27" position it is necessary to pull the cover and screw it out till the upper stop.

In order to transfer the regulator from the "0.27" to the "0.4" position it is necessary to screw the cover in till the medium stop, pull it, pass the stop and then screw the cover out till that stop.

In order to close the pressure regulator it is necessary to screw the cover in from the medium stop to the lower stop then pull the cover and make sure it is screwed in home. The reverse operation is accomplished by screwing the cover out till the medium stop.

While the suit usage in flight is nominal the pressure regulator cover is to be in the "0.4" position except for presuurization test periods.

Указатель избыточного давления (УДиС-К) манометрического типа (Pressure Differential Manometric Indicator)

The УДиС-К pressure differential manometric indicator is designed for visual monitoring of the space suit pressure differential:

Р.ИЗБ = Р.СКФ - Р.СА

The indicator is implemented as a manometric capsule, its interior volume being connected to the space suit interior. The indicator principle of operation is based on the relationship between the pressure differential value and the elastic deformations of the manometric capsule - the indicator sensitive element which when deformed converts the pressure differential value into the capsule upper center linear displacement. This displacement is transmitted by the transfer/multiplying mechanism to the indicator pointer.

The indicator scale is graduated from 0 up to 0.45 kgf/cm^2, the graduation marks being spaced at 0.02 kgf/cm^2.

Space Suit Electric Equipment

The electric equipment is designed to provide for the crew member radio communication (X3 umbilical) and medical monitoring (Ш9) with the space suit donned.

It consists of the pressure tight electric lead through fixed to the suit shell, interior and exterior conductor bunches for the headset and medical harness connections to the spacecraft onboard systems.

Maintenance Kit

The maintenance kit is designed for the space suit flight maintenance as its nominal usage procedure. The kit is located in the БО Module, fixed to the wall near the "сервант".

OPERATION WITH THE SPACE SUIT

The "Sokol-KB-2" is a ventilation type space suit.

While in nominal flight normal life support conditions in the suit are maintained by its venting with the cabin air. The air is fed to the suit by the onboard ventilation unit from the CA atmosphere at the flow rate of 180 - 200 nl per minute, that being sufficient for removing excess heat, breathing wastes and moisture from the suit. The coming air is fed through the elastic piping to the helmet, to the sleeves and to the feet by three approximately equal flows. The air goes out of the suit via the open helmet or via the pressure regulator when the helmet is closed.

In case of the CA depressurization life support conditions are ensured by constantly supplying oxygen into the suit from the stowage tanks. When the pressure in the CA falls down to 400 mm Hg the ventilation air supply to the suit is terminated and the constant oxygen supply is initiated. The suit ventilation manifold is isolated from the CA atmosphere (in the БР-1) and oxygen is pumped into the helmet. The oxygen flow rate of 20 - 23.5 nl per minute is enough for the breathing wastes and moisture removal from the helmet. When the CA pressure falls down to 300 mm Hg the pressure regulator closes maintaining absolute presure in the suit at 0.4 kgf/cm^2 level. The pressure regulator also provides for the excess oxygen outlet from the suit.

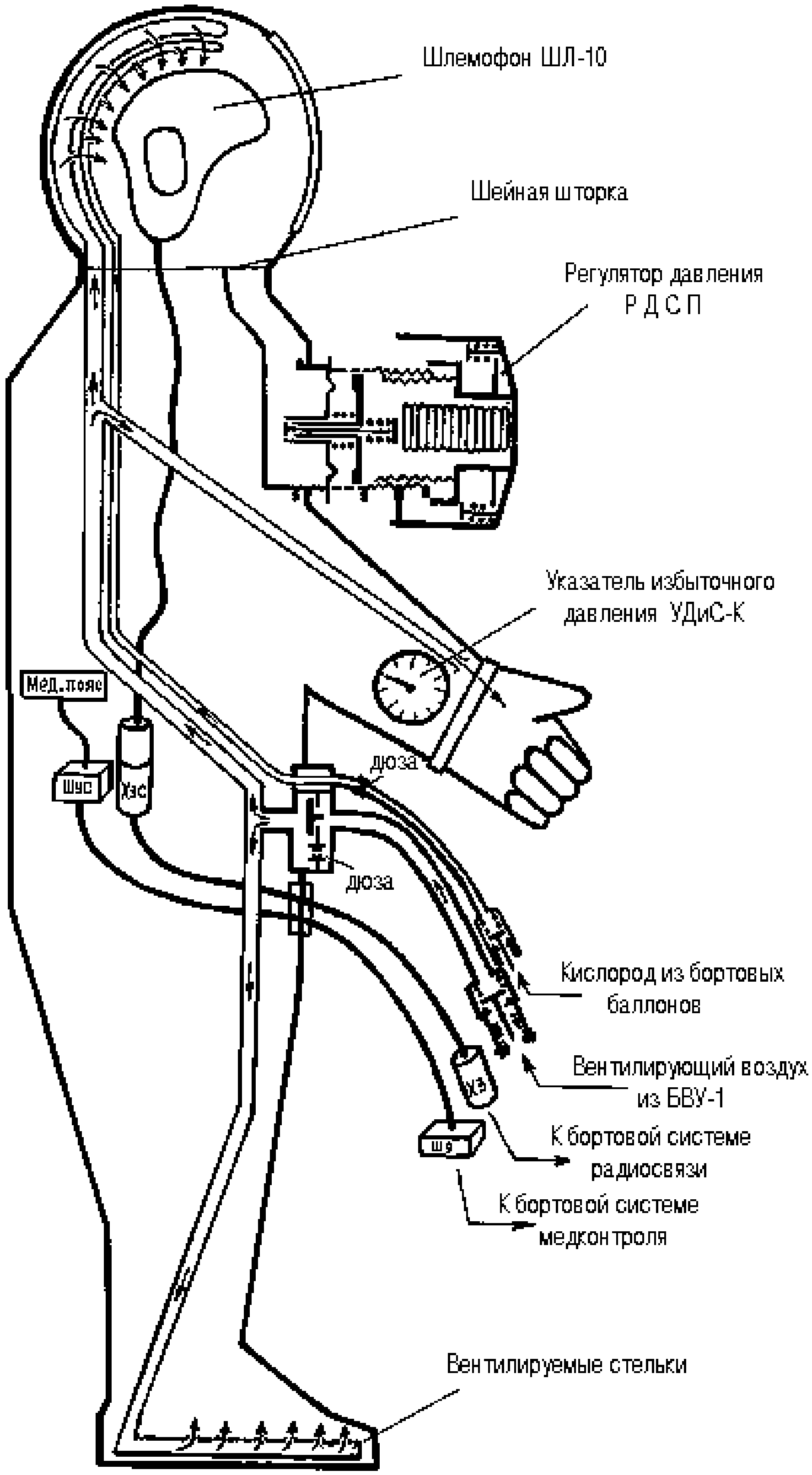


Fig. 1. "Sokol-KB-2" Space Suit Principal Diagram

1. ШЛ-10 Headset. 2. Neck Curtain. 3. РДСП Pressure Regulator. 4. УДиС-К Pressure Differential Indicator. 5. Oxygen Supply from Stowage Tanks. 6. Ventilation Air from БВУ-1 Unit. 7. To Onboard Radio Communication System. 8. To Onboard Medical Monitoring System. 9. Ventilated Insoles. 10. Medical Harness. 11. Nozzles.

3.15. СИСТЕМА УПРАВЛЕНИЯ ДВИЖЕНИЕМ (СУД) (MOTION CONTROL SYSTEM)

GENERAL INFORMATION ON THE SYSTEM

The СУД System is designed to perform the following Soyuz spacecraft control tasks:

– automatic and manual spacecraft attitude establishment and attitude hold relative to various basic coordinate systems;
– automatic attitude maneuver in any coordinate system base for programmed rotations to preset attitude angles;
– automatic execution of the propulsion system engine burn cyclogram during orbit maneuver;
– automatic solving of the spacecraft center of mass motion control problem during the orbital complex approach and during descent;
– automatic System/equipment status monitoring, dynamic operation execution monitoring and System reconfiguration in case of equipment failure;
– data display to the crew on each dynamic mode execution procedure, on System parameters, on malfunctions and failures.

The СУД System includes two control circuits: analog and digital.

In the digital circuit the incoming data processing and the control signal shaping and issuing is accomplished by the БЦВМ Computer Complex.

In the analog circuit the incoming data processing and the control signal shaping and issuing is accomplished by means of various analog units.

The СУД System has a wide built in system of automatic testing and fault detection based on the principle of: "One СУД fault tolerance for the Flight Plan execution and two fault tolerance for the safe crew return".

A combination of redundancy on the interconnection, unit and function levels and capability of system reconfiguring achieve this principal realization.

SYSTEM COMPOSITION

The СУД System block diagram is shown in Fig. 1.

The СУД includes the following elements:

– Бортовой цифровой вычислительный комплекс (БЦВК) (The Onboard Digital Computer Complex), the СУД System core element ensuring performance of all the tasks in the orbital flight, rendezvous and descent flight phases;

– СУД System automatics units (ПУ КС-020, БУПО, БУСПм);

– СУД System measuring instruments:

a) attitude sensors that determine directions in space base on various physical principles (ИКВ, "Курс", СГ);
b) attitude rate sensors (БДУС-I, БДУС-II, БДУС-III);
c) accelerometer, measuring acceleration along the spacecraft longitudinal axis;

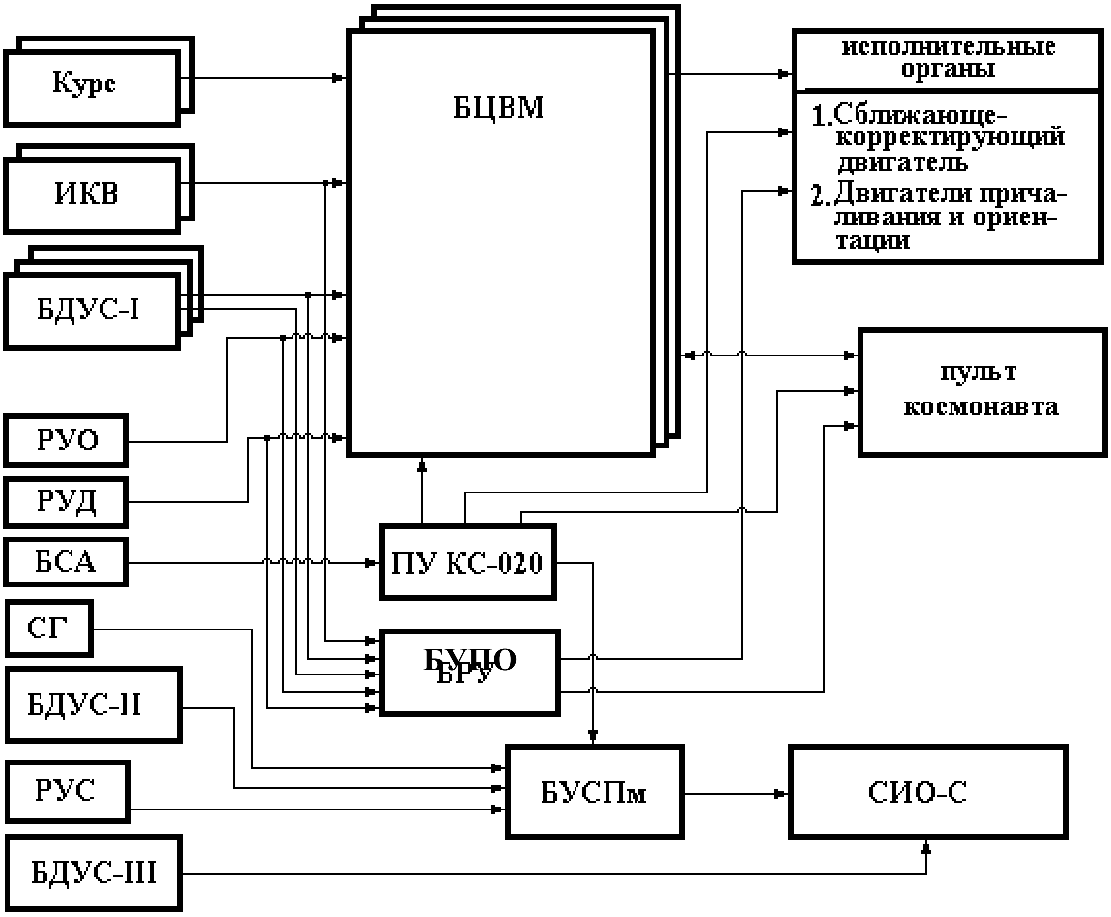


Fig. 1. (СУД System Block Diagram)

1. Onboard Digital Computer Complex. 2. Thrusters. 3. Orbital Maneuver Engine. 4. Berthing/Attitude Control Thrusters. 5. Cosmonaut Panel. 6. Descent Reaction Control System. 7. Descent Control Unit. 8. Special Programming/Computing Unit. 9. БУПО - Manual Control Unit. 10. Attitude Rate Sensor Units. 11. Descent Control Handle. 12. Free Gyro. 13. String Accelerometer Unit. 14. Translation Hand Controller. 15. Rotation Hand Controller. 16.Infrared Vertical Sensors.17. "Kurs" Rendezvous Radar System.

– комбинированная двигательная установка (КДУ) (Combined Propulsion System):
  - сближающе-корректирующий двигатель (СКД) (Orbital Maneuver Engine);
  - двигатели причаливания и ориентации (ДПО) (Berthing / Attitude Control Thrusters);

– система исполнительных органов спуска (СИО-С) (Descent Reaction Control System);

– СУД System crew display aids (ПК СА Cosmonaut Panel, other displays);

– manual motion control aids:
  - ручка управления ориентацией (РУО) (Rotation Hand Controller);
  - ручка управления движением (РУД) (Translation Hand Controller);
  - ручка управления спуском (РУС) (Descent Control Handle);
  - визуальная система космонавта (ВСК-4) (Cosmonaut Visual System).

Note: A new software version, the MO-17, has been adopted for the СУД System management which has brought about the following major updates:

- *algorithms for remote part of rendezvous/approach procedure have been revised as related to the target point approach guidance technique;*

- *a new program has been introduced for fire monitoring of the translational ДПО thrusters using the signal of the сигнализатор давления в камере сгорания (СДК) (Thruster Chamber Pressure Switch Sensor);*
- *the translational ДПО thruster test has been introduced into the СУД Test №1 procedure prior to berthing and prior to undocking;*
- *the undocking cyclogram has been revised for the spacecraft separation from the "tail" and "nadir" docking nodes of the ISS RS to ensure safety.*

1. *Revision of the Approach Control Programs*

A new translational ДПО test program specially developed for МО-17 version is included into the СУД Test №1, approach and undocking procedures.
In СУД Test №1 and undocking modes the program is initiated at the start of the БДУС Unit gyro spinning. While in approach mode the ДПО test program is started at the transfer to berthing mode.
The ДПО test program fires +X, -X, +Y, -Y, +Z, -Z thrusters during one БЦВК clock cycle the interval between fires being also one cycle.

An additional program, "ДПО +X Test", is implanted into МО-17 version. This program capable of checking up the "retrofire" ДПО thruster performance is initiated during berthing at the range of about 40 m and during undocking after the first ДПО +X separation burn is executed. For the ДПО +X test period the СУД System is transferred to the indicator mode. During the test ДПО +X thrusters are fired twice for the burn time of one БЦВК clock cycle.

One more test program is introduced into МО-17 version. It is the translational ДПО thruster fire monitoring program using the СДК (Chamber Pressure Switch Sensor). The program verifies if the data on the translational ДПО thruster actual fire from the СДК sensor and the data on the fire command being passed coincide. This monitoring is performed during СУД Test №1, during approach and during undocking. Whenever a mismatch is detected a failure warning signal is issued and the failed ДПО thruster identified. The spacecraft ДПО Subsystem manifolds are combined and in case of approach mode it is terminated and evasive maneuver mode initiated. In case of undocking the spacecraft continues its flight with ДПО sets combined.

2. *Undocking Program Update*

Now the full version of the nominal undocking cyclogram includes the following operations:

- *the БЦВК test immediately after the СУД System initiation;*
- *translational ДПО thruster test at the start of the БДУС gyro spinning;*
- *БДУС Unit test;*
- *СУД System operation in indicator mode up to 10 seconds after actual undocking;*
- *the preset coordinate system acquisition from the orbiter at the actual undocking;*
- *fire and 15 second burn of ДПО +X thrusters at 180 seconds after actual undocking;*
- *ДПО +X test;*
- *spacecraft rotational maneuver to the attitude defined by uplinked settings at the moment of 420 seconds after actual undocking (the target attitude presumably features spacecraft "+X" axis pointed to "nadir" and "-Y" / "+Z" bisector directed opposite to the orbital velocity vector);*
- *evasive maneuver second impulse at 550 seconds after actual undocking by means of ДПО "-Y" and "+Z" thruster burn for 30 seconds;*
- *СУД System switching off at the end of cyclogram.*

When undocking from the "tail" node of the ISS RS the second impulse is prohibited.

For manual redocking the БЦВК is initiated beforehand the БЦВК test, translational ДПО test and БДУС test being performed. When spacecraft undocks from the orbiter the coordinate system is acquired .
In case necessity arises to execute the spacecraft evasive maneuver from the orbiter automatically the crew must load special control flag (character) into the БЦВК.

3.15.1. СУД SYSTEM - ORBITAL FLIGHT (СУД-ОП)

Orbital flight phase is the flight portion from the moment of the spacecraft injection into orbit until the approach procedure initiation. The orbital flight phase includes the following dynamic modes:
- СУД System test #1 (revolution 2);
- Two burn maneuver (revolution 3 - 4);
- One burn maneuver (revolution 17).

The primary control circuit to function in the orbital flight phase as well as in the rendezvous and descent phases is the digital circuit. The analog control circuit is back-up for these flight phases.

DIGITAL CIRCUIT (ДК)

GENERAL INFORMATION ON THE SYSTEM

The СУД System digital control circuit ensures execution of the following dynamic modes and operations:

- automatic attitude configure(establishment) and attitude hold in the inertial coordinate system;
- automatic (manual) attitude configure and attitude hold in the orbital coordinate system;
- automatic attitude maneuver in any coordinate system base by programmed rotations for preset attitude angles;
- automatic execution of the Orbital Maneuver Engine burn cyclogram and the apparent velocity increment measurement during the burn;
- automatic and manual spacecraft attitude stabilization (hold) in the preset coordinate system during the Obital Maneuver Engine burn;
- automatic issuing of the engine cut-off command when the preset impulse value is reached;
- program/logic control of the operational modes;
- automatic System/equipment status monitoring, dynamic operation execution monitoring and System reconfiguration in case of equipment failure;
- data display to the crew on each dynamic mode execution procedure, on System parameters, on malfunctions and failures.

The digital circuit is built around a gimballess (platformless) inertial navigation system based on the БЦВК Computer Complex and the use of a three-component set of the absolute attitude rate sensors and a single-component set of string accelerometers (Fig. 1).

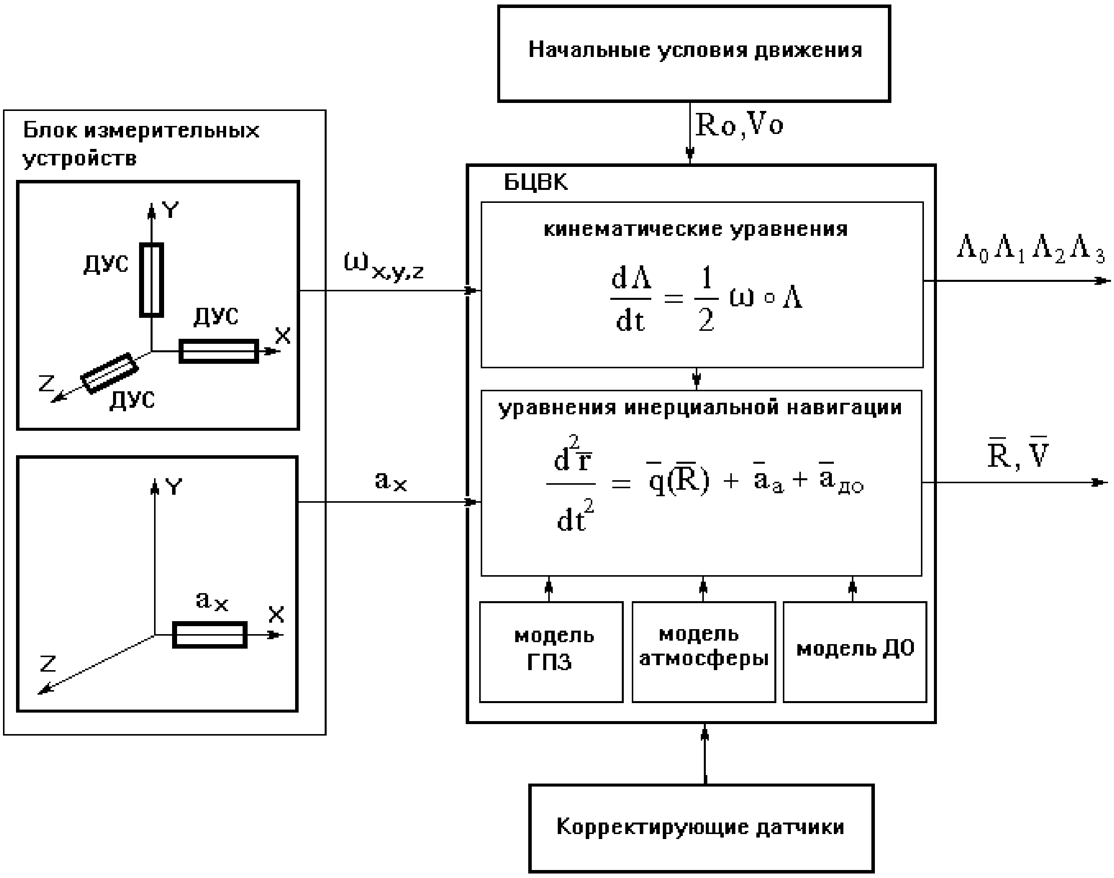


Fig. 1. (Digital Circuit Basics)

1. Initial conditions of motion. 2. Onboard Digital Computer Complex. 3. Kinematic equations. 4. Inertial Navigation equations. 5. Models. 6. Correction Sensors. 7. Measurement Instrument Set. 8. Attitude Rate Sensors. 9. Accelerometer.

SYSTEM COMPOSITION

The СУД System digital circuit for the orbital flight phase consists of (Fig. 2):

– БЦВК Onboard Computer Complex;

– set of sensor instruments (БДУС Rate Sensor Units, ИКВ IR Vertical Sensors, БСА Accelerometer Unit);

– actuating thrusters (e.g. КДУ Combined Propulsion System);

– Crew and ground control aids (РУО and РУД Hand Controllers, КСП-Л and ОВК Panels, БРВИ Manual Data Load Unit, ВКУ Monitor, ТСЭ Display, ВСК-4 Cosmonaut Visual System).

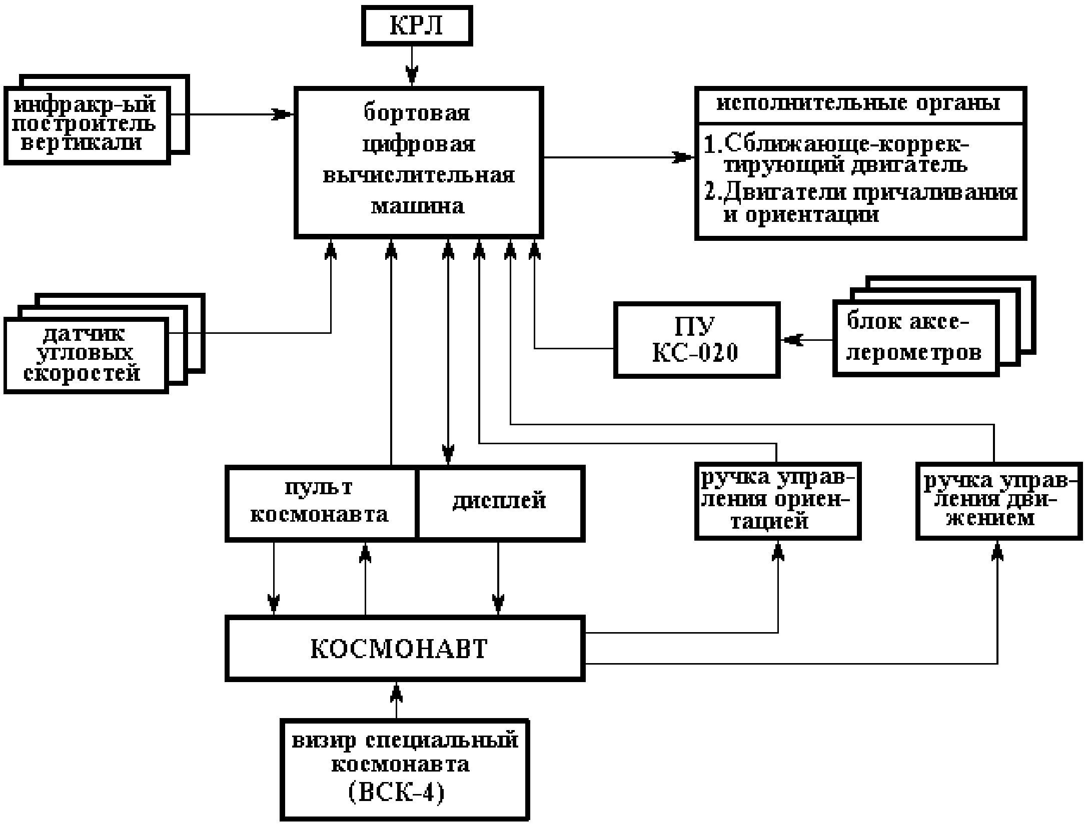


Fig. 2. (Digital Circuit Composition)

1. Onboard Computer Complex. 2. Actuating Thrusters: 1). Orbital Maneuver Engine 2). Berthing/Attitude Control Thrusters. 3. Accelerometer Unit. 4. Programming/Computing Unit. 5. Translation Hand Controller. 6. Rotation Hand Controller. 7. Cosmonaut Visual System. 8. Cosmonaut. 9. Display. 10. Cosmonaut Panel. 11. Attitude Rate Sensors. 12. Infrared Sensors. 13. Command Radio Link.

БДУС-1 Attitude Rate Sensor Unit is designed for measuring the absolute attitude rate vector projections on the spacecraft body axes.

ИКВ Infrared Sensor's function is to send to the БЦВК signals proportional to the spacecraft attitude deflection from the local vertical in roll and pitch The ИКВ sensitivity axis is directed along the spacecraft "-Y" axis.

БСА and ПУ КС-020. The БСА Accelerometer Unit has three string accelerometers for measuring linear acceleration acting along the spacecraft "+X" axis. The ПУ КС-020 Programming / Special Computing Unit is designed for processing the БСА signals corresponding to the spacecraft acceleration during engine burn.

БРВИ Manual Data Load Unit is designed for performing two tasks:
- to receive data from the Manual Data Load Panel Keyboard, process it and send it to the БЦВМ;
- to receive coded data from the БЦВМ and to send it to the Panel indicators.

РУО Rotation Hand Controller is for setting the spacecraft attitude rates around its X, Y, Z axes in manual attitude control modes.

РУД Translation Hand Controller is for manual issuing commands for the spacecraft center of mass translations along X, Y, Z axes.

==

PRINCIPAL ATTITUDE CONTROL MODES:

- OCK (Orbital Coordinate System) Mode;
- ИСКТ (Current Inertial Coordinate System) Mode;
- Programmed Attitude Maneuver Mode;
- Manual Attitude Control Mode.

OCK MODE

The basic OCK Orbital Coordinate System's origin is in the spacecraft center of mass (Fig. 3) and its axes are defined as follows:

- the OYo axis is directed along the radius vector connecting the Center of the Earth and the spacecraft center i. e. along the local vertical off the Earth;
- the OXo axis is perpendicular to the OY axis, it lies in the orbital plane and is directed forward along the spacecraft orbital heading;
- the OZo axis is perpendicular to the orbital plane and completes the right hand coordinate system.

It is a rotating coordinate system (the rotation rate being Wzo = - 0,067 °/sec).

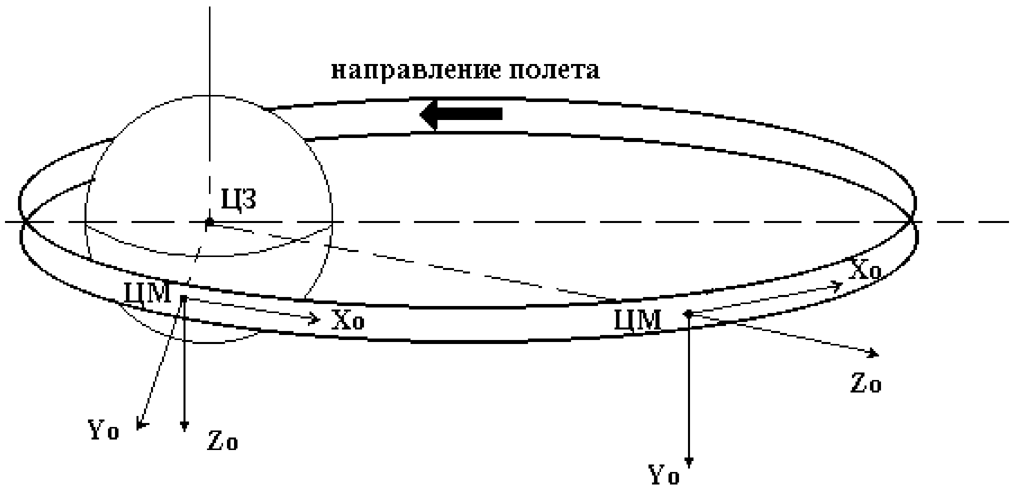


Fig. 3. (OCK Coordinate System)

1. Spacecraft orbital heading direction. (ЦМ – Centre of Mass, ЦЗ – Centre of Earth).

The spacecraft attitude establishment procedure in the OCK system can be conventionally subdivided into the following steps (Fig. 4):

1. The ИКВ Sensor switching on.

2. Searching the Earth.

3. Aligning the spacecraft along the local vertical in roll and pitch.

4. Establishing the spacecraft attitude in yaw.

5. Attitude hold in the OCK System.

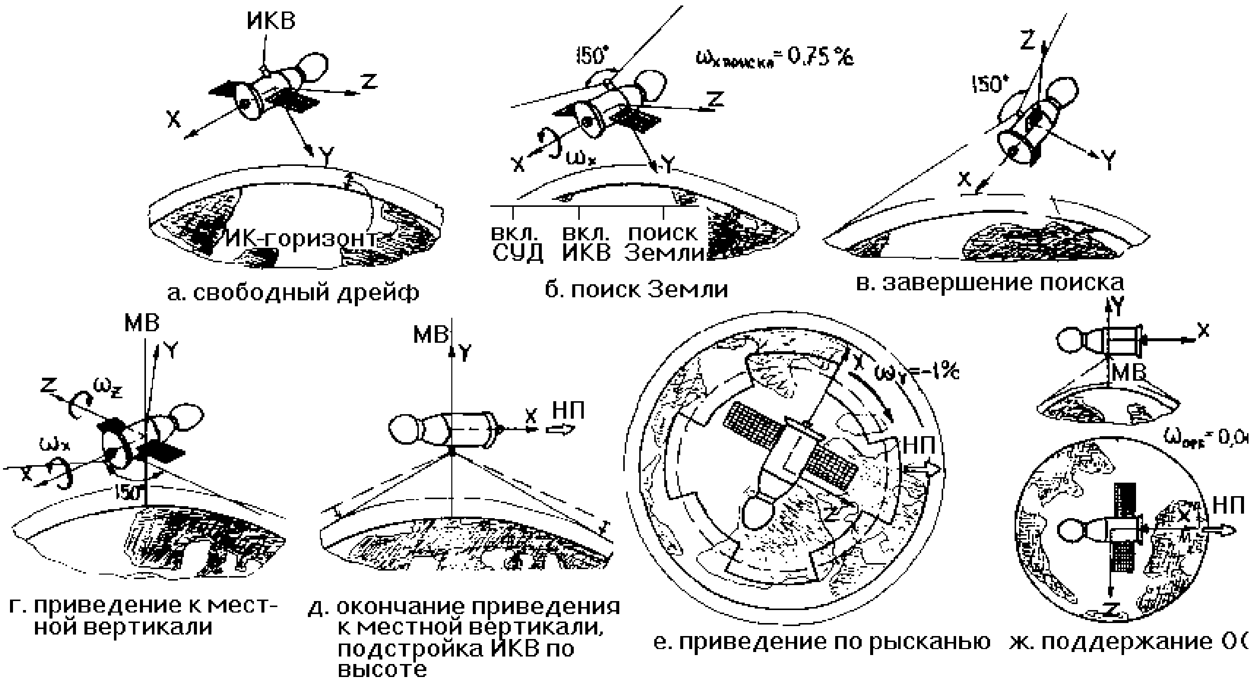


Fig. 4. (Establishing Attitude in OCK System)

а. Free Drift. 1.IR Vertical Sensor. 2. IR Horizon. **б**. Earth Search. **в**. Earth Search Completion. 3. Program Marks: СУД System ON, ИКВ Sensor ON, Earth Search. **г**. Alignment along the Local Vertical. 4. Local Vertical. **д**. Alignment Completion, ИКВ Sensor Adjustment in Altitude. 5. Spacecraft Flight Heading. **е**. Alignment in Yaw. **ж**. ОСК Attitude Hold.

РЕЖИМ ИНЕРЦИАЛЬНОЙ СИСТЕМЫ КООРДИНАТ ТЕКУЩЕЙ (ИСКТ) (CURRENT INERTIAL COORDINATE SYSTEM MODE)

In this mode the spacecraft's inertial attitude is held that was at the moment of the "Текущее положение" (Current Position) command issue from the КСП-Л.

PROGRAMMED ATTITUDE MANEUVER MODE

This mode is used for the spacecraft attitude maneuvers to any space angles as defined by the attitude maneuver quaternion.

MANUAL ATTITUDE CONTROL MODE

The Manual Attitude Control Mode (The РОДК Mode) is used for the spacecraft attitude control by means of the РУО Rotation Hand Controller and the ВСК-4 Cosmonaut Visual System. When in the РОДК mode by deflecting the РУО Controller from its neutral position the spacecraft attitude rates are set according to the characteristics chart shown in Fig. 5.

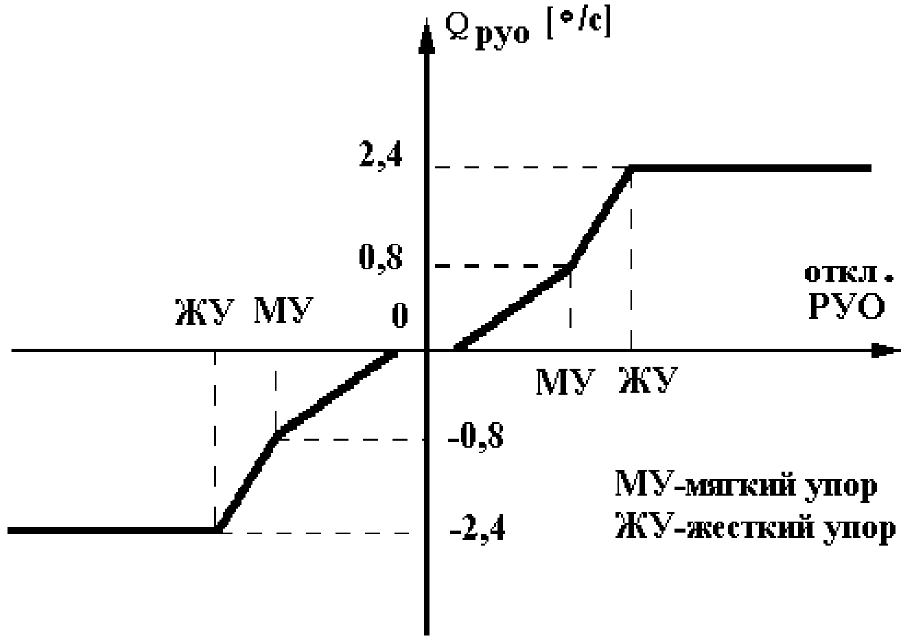


Fig. 5. (РУО Attitude Control Characteristics Chart)

1. Soft Stop. 2. Stiff Stop. 3. РУО Deflections. 4. Spacecraft Attitude Rates (°/sec).

PROGRAM/TIME CONTROL OF СУД SYSTEM

The СУД System control nominal version is automatic control using the гибкий временной цикл (ГВЦ) (Flexible Time Cycle). An example of the ГВЦ attitude maneuver procedure is shown in Fig. 6 (Step 2-6).

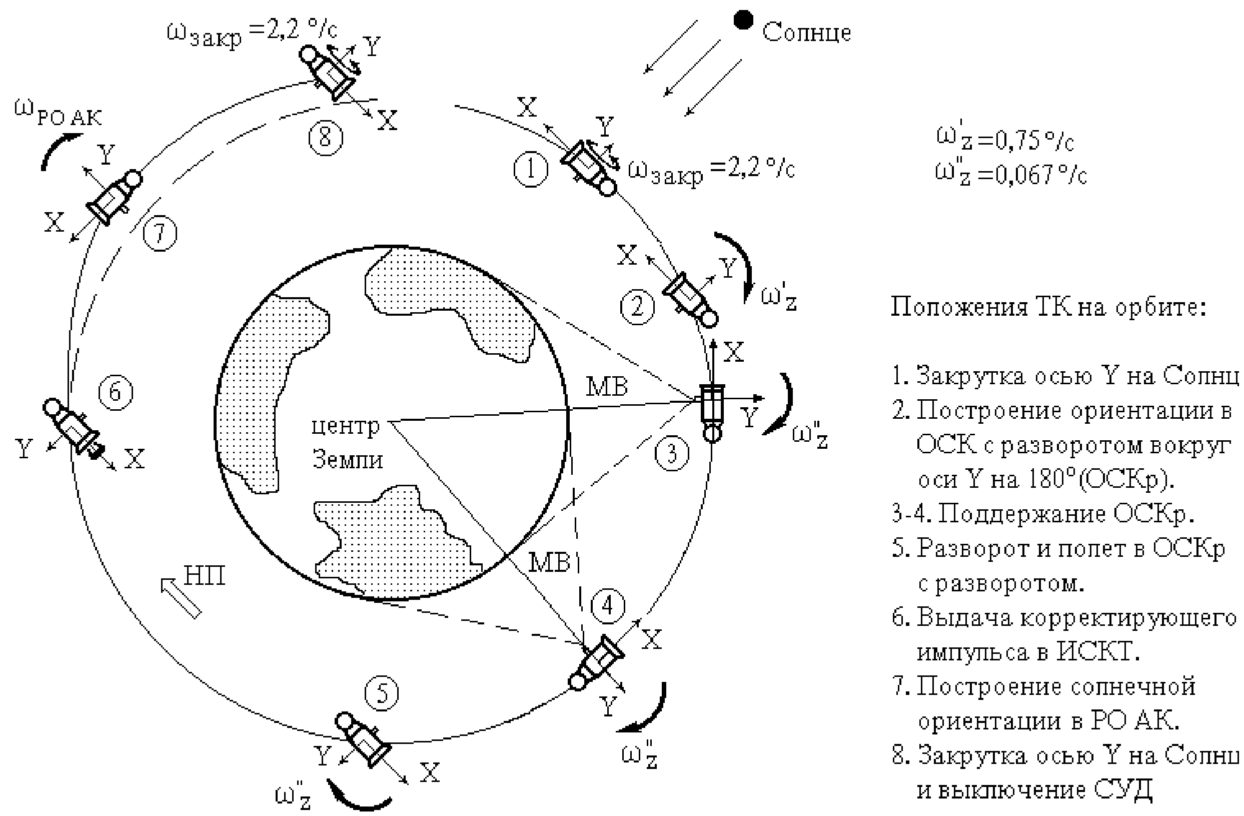


Fig. 6. (ГВЦ Maneuver Procedure)

0. Spacecraft positions in the orbit. 1. “Закрутка” (Solar barbecue rotation around Y axis). 2. Establishing the ОСК attitude with 180° attitude maneuver around Y axis (ОСКр Attitude). 3 - 4. ОСКр attitude hold. 5. Attitude maneuver around Z axis and flight in ОСКр attitude while maneuvering. 6. Orbital Maneuver Engine burn for orbit correction while in ИСКТ Attitude hold. 7. Establishing solar pointing (Y axis) attitude in РО АК Mode (manual attitude control / analog cxircuit). 8. “Закрутка” Solar barbecue and switching СУД System off. 9. Sun.

SYSTEM OPERATIONAL LIMITS AND CHARACTERISTICS

Time for establishing ОСК attitude does not exceed 15 min.
Accuracy of establishing attitude – 1,5°.
Propellant consumption for establishing attitude - Go < 1 kg.
Accuracy of attitude hold in the ИСКТ System is 1,1°/hr.
The programmed attitude maneuver attitude rate can take on the following values:

- in approach phase and in descent phase prior to separation – 3,5°/sec;
- if the preset attitude maneuver space angle is (Qпр)<36° - 0,3°/sec;
- in all other cases this value is chosen on the basis of the requirement that any attitude maneuver should be completed within 120 sec.

CREW OPERATION WITH THE SYSTEM

The crew realizes monitoring of all the dynamic modes and operations using the ПК СА and display formats as necessary.
Sequence of the СУД System commands to be monitored and their time ties are presented in the appropriate sections of the FDF.
When necessary the crew can realize the spacecraft manual control mode.

ANALOG CIRCUIT (АК)

GENERAL INFORMATION ON THE SYSTEM

The АК Analog Control Circuit is the СУД System back up circuit. As compared to the ДК Digital Circuit it fulfills a narrower scope of tasks which ensure accomplishment of the following critical flight operations when the ДК Circuit fails:

- the spacecraft manual approach to the orbital complex (at the range of no more than 5 km), berthing and docking;
- realization of the engine retrofire impulse for initiating the spacecraft descent from the orbit.

SYSTEM COMPOSITION

The АК block diagram is presented in Fig. 7.

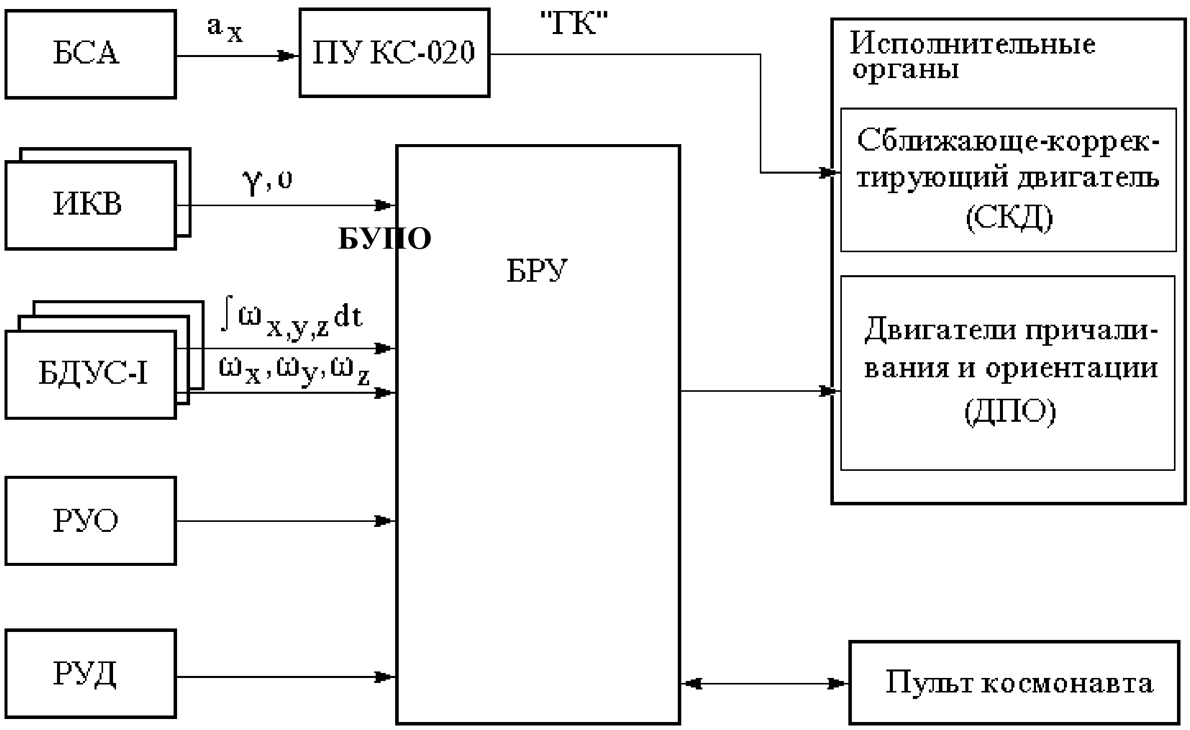


Fig. 7. (Analog Circuit Block Diagram)

1. String Accelerometer Unit. 2. Special Programming/Computing Unit. 3. СКД Engine Shut Off “Main” Command. 4. Actuating Thrusters. 5. СКД Orbital Maneuver Engine. 6. Berthing/Attitude Control Thrusters. 7. ПК СА Cosmonaut Panel. 8. Manual Control Unit. 9.Translation Hand Controller. 10. Rotation Hand Controller. 11. Attitude Rate Sensor Unit - I. 12. IR Vertical Sensor.

БЛОК УПРАВЛЕНИЯ ПРИЧАЛИВАНИЕМ И ОРИЕНТАЦИЕЙ (БУПО)
(BERTHING AND ATTITUDE CONTROL UNIT)

The БУПО Unit is a logic/converting device to be used only when the AK circuit is operative.
The БУПО functions are:

- summing and amplification of signals coming from sensors and hand controllers;
- conversion of each control channel (roll, pitch, yaw) summed up signal into the form required for the СУД System actuating thruster operation.
- spacecraft attitude hold in all channels whenever the РУО hand controller is returned into neutral position while in manual attitude control modes.

The AK Circuit can operate in two modes:

– automatic mode;
– manual mode.

AK AUTOMATIC MODE

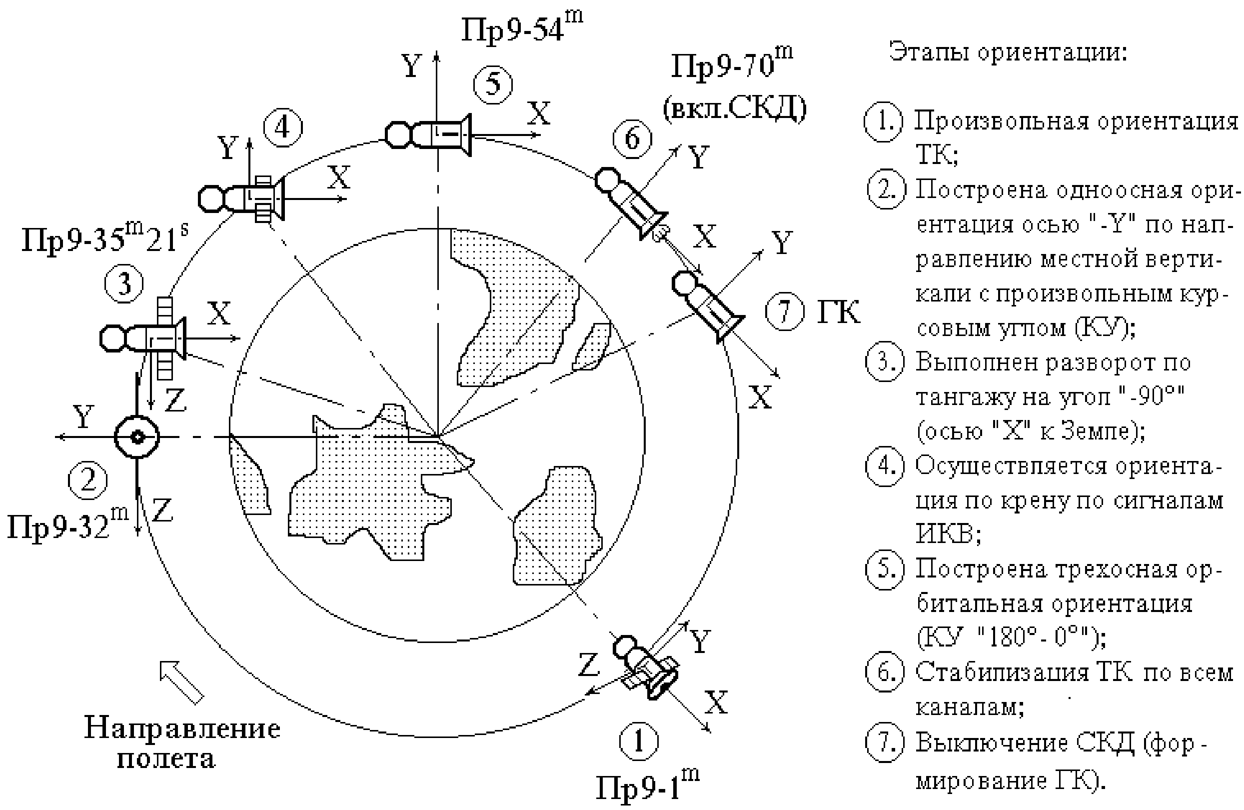


Fig. 8. Attitude Maneuver Steps in AK Automatic Mode

1. Spacecraft arbitrary attitude. 2. Single axis attitude established: "-Y" axis is aligned with the local vertical with the arbitrary heading angle. 3. Pitch 90° rotation maneuver executed, X axis now pointing to the Earth. 4. Attitude control in roll being executed using the ИКВ Sensor signals. 5. Three axis orbital attitude established (the spacecraft heading angle is "180°-0°"). 6. The СКД Orbital Maneuver Engine is fired and the spacecraft attitude is being stabilized (held) in all axes. 7. The СКД Engine shut off (the ГК "Main" command issue). 8. Flight direction. 9. Time marks of the Пр. 9 program.

AK MANUAL MODE

In this mode the following operations are fulfilled:

- establishing orbital attitude using the ВСК-4 instrument;
- establishing one-axis Solar attitude and initiating the "Закрутка" barbecue rotation;
- spacecraft three-axis attitude hold during the СКД Engine burn;
- manual berthing and docking to the Orbital Complex.

The spacecraft actual attitude data is acquired by the crew by means of the ВСК-4 Visual System and the ВКУ Display.

SYSTEM OPERATIONAL LIMITS AND CHARACTERISTICS

The РУО Controller characteristics chart while in the AK manual mode is shown in Fig. 9.

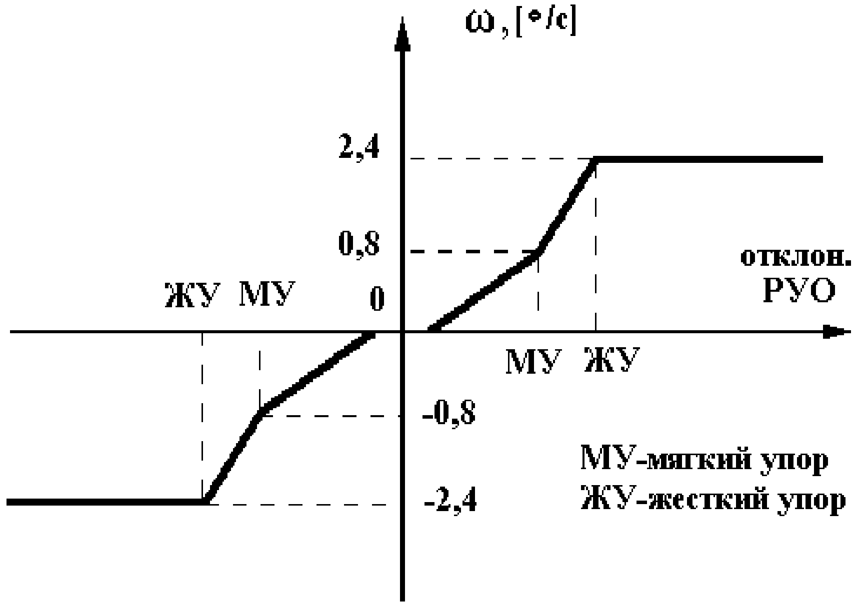


Fig. 9. (РУО Attitude Control Characteristics in the AK Manual Mode)

1. Soft Stop. 2. Stiff Stop. 3. РУО Deflections. 4. Spacecraft Attitude Rates (°/sec).

CREW OPERATION WITH THE SYSTEM

In order to make the AK operative the crew will issue the “Выбор АК” command from the КСП-Л.

The AK manual mode is selected by the crew by issuing either the “РО АК” command from the КСП-Л or the “РО” command from the РУС Handle.

Manual berthing mode is set by the “РУД” command from the КСП-Л. In this mode the cosmonaut operates both РУО and РУД Hand Controllers

Using the РУО Controller and ВСК-4 monitoring the spacecraft attitude relative to the Station is maintained.

3.15.2. СУД SYSTEM - RENDEZVOUS (СУД-СБ)

GENERAL INFORMATION ON THE SYSTEM

In the rendezvous flight phase the СУД System function is to fulfill the following tasks:

- the spacecraft optimal trajectory selection for the Mir station or ISS rendezvous to minimize propellant consumption;
- arranging the spacecraft motion along the rendezvous trajectory selected;
- ensuring automatic or manual spacecraft fly around to the specified station docking assembly, station keeping and berthing with the spacecraft/station relative motion parameters appropriate for the docking mechanism nominal operation;
- providing for automatic СУД System status monitoring during the rendezvous procedure and the control circuit automatic reconfiguration in case of equipment failure;
- crew data display on the rendezvous procedure execution, spacecraft/station relative motion parameters and the spacecraft СУД System faults;
- ensuring the spacecraft automatic or manual escape from the uncontrolled impact with the station.

In the rendezvous phase the station flies along the known orbit and maintains preset attitude hold for the best Solar illumination of the nominal docking assembly. The spacecraft must travel to the station proximity and execute soft docking. As the station cannot maintain responsive attitude relative to the spacecraft the latter after the station proximity approach must fly around the station to the preset docking assembly, establish attitude accurate enough relative to it and execute berthing and docking.

The rendezvous phase consists of two flight portions:

- дальний участок (ДУ) (Remote Approach) where the СУД System provides for the optimal rendezvous trajectory selection to bring the spacecraft to the orbital proximity area and the spacecraft motion control on that trajectory, the spacecraft guidance in this flight portion being based on free trajectory method;
- ближний участок (БУ) (Proximity Approach) where the СУД System provides for the spacecraft center of mass motion and attitude control while it flies to the selected docking assembly and ensures soft contact at docking, the parallel guidance method being used in this flight portion.

In the proximity approach flight portion the СУД can operate in:

- automatic mode;
- semiautomatic mode;
- manual mode;
- combined mode.

SYSTEM COMPOSITION

The СУД System composition and structure in the rendezvous flight phase is shown in Fig. 1.

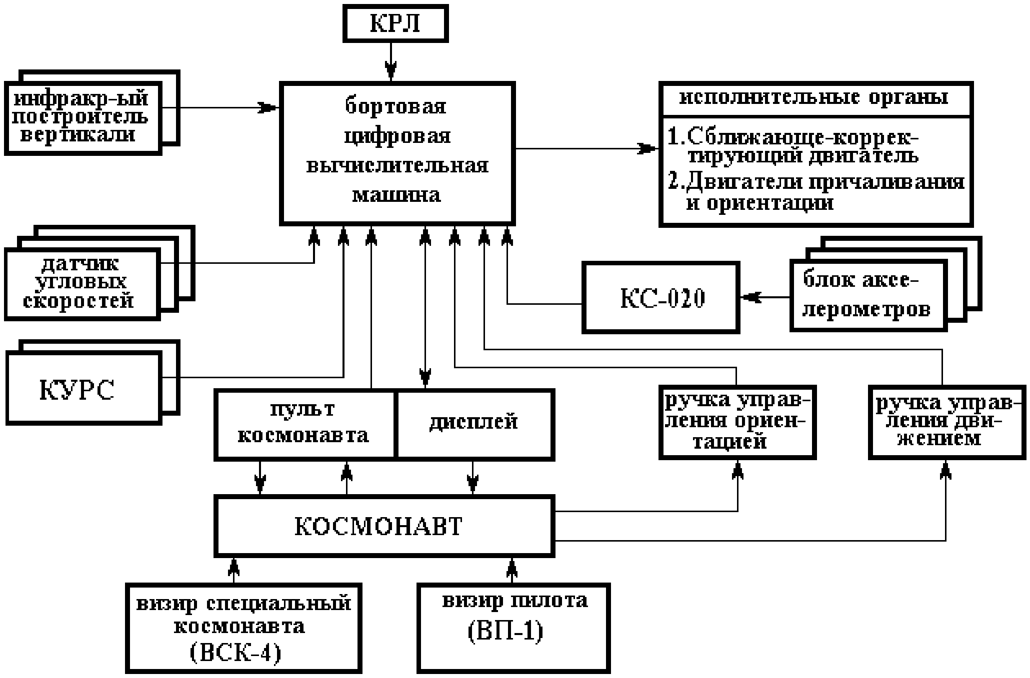


Fig. 1. (СУД Configuration in Rendezvous Phase)

1. Command Radio Link. 2. Actuating Thrusters. 3. Orbital Maneuver Engine. 4. Berthing/Attitude Control Thrusters. 5. Accelerometer Unit. 6. Special Programming/Computing Unit. 7. Rotation Hand Controller. 8. Translation Hand Controller. 9. Pilot Visor. 10. Cosmonaut Visual System. 11. Cosmonaut. 12. Display. 13. Cosmonaut Panel. 14. “Kurs” Radio Communication System. 15. Attitude Rate Sensor. 16. IR Vertical Sensor. 17. Onboard Computer Complex.

APPROACH CYCLOGRAM

The rendezvous phase consists of two flight portions:

- Дальний участок (ДУ) (Remote Approach) where the СУД System provides for the optimal rendezvous trajectory selection to bring the spacecraft to the orbiter proximity area and the spacecraft motion control while on that trajectory, the spacecraft guidance in this flight portion being based on the free trajectories to the extended target point technique;
- Ближний участок (БУ) (Proximity Approach) where the СУД System provides for the spacecraft center of mass motion and attitude control while it flies to the selected docking node and ensures soft contact at docking, the parallel guidance technique being used in this flight portion.

The cyclogram of the spacecraft approach to the station is shown in Fig. 2.

On the second day of the flight two orbits (revolutions) prior to the estimated time of the spacecraft/station contact The MCC-M uplinks and loads into the БЦВМ Computer memory the state vector containing data on the spacecraft and station orbit parameters estimated for a certain To moment. The spacecraft establishes attitude in the OCKp coordinate system for the engine posigrade burn.

At the To moment computation of the spacecraft/ station relative motion parameters is started and corre c-tion impulse values are calculated to be applied to the spacecraft center of mass.

One minute prior to the first impulse burn estimated time tскд 1 the spacecraft is rotated relative to the OCKp system to align the thrust vector with the computed ΔV скд 1 vector. At the tскд 1 time moment the orbital maneuver engine is fired and the ΔV скд 1 impulse is applied. After the engine is cut off the spacecraft is rotated back in the OCKp system and the OCKp attitude hold is maintained.

At the T1 moment the “Kurs” radar rendezvous system is switched on and tested. When the tests are over the target search is executed which is completed by the target acquisition and the СНЦ signal issue. From this moment on the “Kurs” system generates line of sight direction data (pitch and yaw angles) and sends it to the БЦВК Onboard Computer Complex.

At the range of 186 km the spacecraft attitude in the ЛСК (Radial Coordinate System) is established.

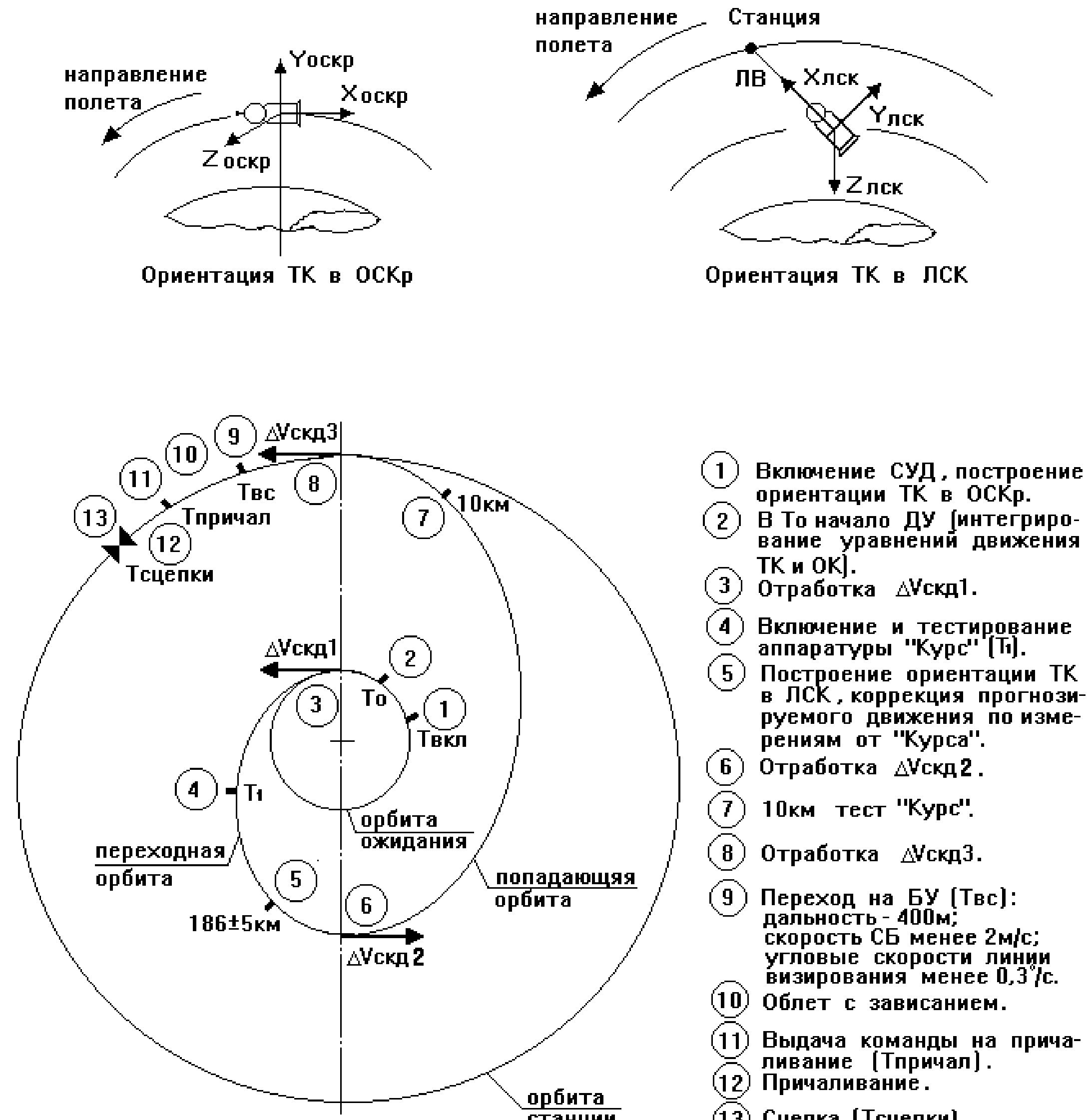


Fig. 2. (Spacecraft to Station Approach Cyclogram)

1. СУД System switching on and establishing the spacecraft attitude in OCKp coordinate system. 2. Starting point for the Remote Approach and for the equation of spacecraft/station motion solving procedure. 3. First impulse burn - ΔV скд 1. 4. “Kurs” equipment switching on and testing. 5. Establishing the spacecraft attitude in the ЛСК (Radial Coordinate System), correcting the motion parameters estimated on the basis of the “Kurs” System measurements. 6. Second impulse burn - ΔV скд 2. 7. “Kurs” test at 10 km range. 8. Third impulse burn - ΔV скд 3. 9. Transition to the Proximity Approach: range is 400 m, range rate is < 2 m/sec, line of sight angular rates are < 0.3°/sec. 10. Fly around and station keeping. 11. Berthing initiation command issue. 12. Berthing. 13. Latching. 14. Flight direction 15. Station. 16. Line of sight. 17. Spacecraft attitude in the ЛСК coordinate system. 18. Spacecraft attitude in the OCKp coordinate system. 19. Waiting orbit. 20. Transfer orbit. 21. Target hit orbit. 22. Station orbit.

The ЛСК coordinate system is as follows (Fig. 2):
- the ЛСК system origin is in the spacecraft center of mass;
- the X axis is aligned with the ЛВ (line of sight);
- the Y axis is perpendicular to the X axis and lies in the orbital plane;
- the Z axis complete the ЛСК to the right hand system.

The "Kurs" equipment acquires the target and sends the following data to the БЦВК:
- the line of sight direction (pitch "u" and yaw "h" angles);
- relative range "ρ";
- range rate "ρ'".

For the purpose of ensuring safety the spacecraft approach with ISS is directed to the extended target point which is on the orbiter ОСК Coordinate System Z axis at the range of 1 km. The СУД System provides for the spacecraft motion along the target point trajectory by generating corrective lateral impulse to the spacecraft center of mass approximately 80 minutes prior to the moment of transfer to Proximity Approach portion.

One minute prior to precalculated time tскд бок of the lateral impulse burn the spacecraft attitude maneuver is performed relative to the ОСКр Coordinate System in order to match the СКД thrust vector with the corrective impulse ΔVскд бок vector. So at the moment of tскд бок the СКД Engine is fired and burns for ΔVскд бок impulse. When the Engine is cut off the spacecraft is rotated back relative to the ОСКр Coordinate System with subsequent attitude hold in that System.

After the DV скд бок impulse burn the spacecraft flies along the internal transfer orbit to the target point.

The БЦВК compares measured the relative motion parameters with the calculated and gives corrections to the calculated parameters. The calculated value correction with the measured value is called "filtration".

At the moment of tскд2 the СКД is fired to produce the second corrective impulse ΔVскд2. One minute before the СКД is fired The spacecraft is rotated to match the СКД Engine thrust vector with the calculated ΔVскд2 vector. When the СКД burn is terminated the spacecraft is attitude maneuvered back relative to the ЛСК Coordinate System and then the СУД System executes the spacecraft attitude hold in the ЛСК System. After the ΔVскд2 impulse burn the spacecraft flies along the final trajectory to the target point.

At the relative range of ρ=15 km the "Kurs" Radar Rendezvous System reduced test is conducted.

At the range of ρ=3-5 km the СКД is fired for the ΔVскд3 maneuver impulse which is preceded by spacecraft attitude maneuver relative to the ЛСК System and is followed after the СКД cut off by the spacecraft rotation back in the ЛСК System.

After the ΔVскд3 maneuver the extended target point is removed to the docking node X axis at the range of 300 m from the node. That will require another СКД burn for the ΔVскд4 corrective maneuver impulse.

After that the berthing/attitude control thrusters can fire for the spacecraft motion parameter correction to meet the requirements of the transition to the Proximity Approach flight portion. These requirements include:

$$\rho < 400 \text{ m};$$
$$|\rho'| < 2 \text{ m/sec};$$
$$|\Omega^{ЛВ}| < 0{,}3°/\text{sec}.$$

When these requirements are fulfilled the spacecraft flies around the station to the preset docking assembly, station keeps and berths to the station.

After the spacecraft and the station docking mechanisms are latched the spacecraft СУД System is switched off automatically.

SYSTEM OPERATIONAL LIMITS AND CHARACTERISTICS

Automatic approach mode start range - not more than 900 km.

Accuracy of the spacecraft attitude establishment in the ЛСК coordinate system - not worse 1,5°.

Station keeping range - 100-200 m.

Impact velocity at contact – 0,35-0,1 m/sec.

Angular misalignment between spacecraft and station at contact - not more than 4°.

CREW OPERATION WITH THE SYSTEM

At the preset time the crew monitors the СУД System switching on and the approach cyclogram execution using the ПК СА Panel and the ВКУ Display data.

On the ground's instruction the crew issues command for berthing.

In case of an off-nominal situation the crew activity will be in accordance with the Flight Data File and the ground's instructions.

3.16. СИСТЕМА УПРАВЛЕНИЯ СПУСКОМ (СУС) (DESCENT CONTROL SYSTEM)

GENERAL INFORMATION ON THE SYSTEM

The СУС System is designed for the safe crew return to the nominal landing area.

SYSTEM COMPOSITION

The descent control circuit ensures the preset flight range counted from the moment of the СКД Engine firing and stabilization of the spacecraft longitudinal axis attitude relative to the incoming air flow throughout the descent flight phase until the Основная парашютная система (ОСП) (Primary Parachute System) is deployed.
The System's primary operation mode is the automatically controlled descent mode (АУС).

The Back Up modes are:
- Manually Controlled Descent mode (РУС);
- Ballistic Descent mode (БС);
- Back Up Ballistic Descent mode (БСР).

The descent control circuit hardware composition is shown in Fig. 1.

Блок автоматики спуска (БАСП) (Descent Automatic Equipment Unit) is designed for reception and logical processing of the input commands, commutation of the СУС System unit power buses, control command issue into the СУС System and data supply to the ПК СА indicators.

Блок струнных акселерометров (БСА) (String Accelerometer Unit) is designed for measuring the СА Module longitudinal acceleration in the atmosphere portion of the descent phase.

Специализированная вычислительная машина (КС-020) (Specialized Computer) computes and sends to the СУД System:
- signal of the apparent velocity Vs;
- programmed roll angle $\gamma_{пр.}$

The КС-020 Unit is switched on automatically on the "Разделение" (Separation) command (on the actual separation of the spacecraft modules).

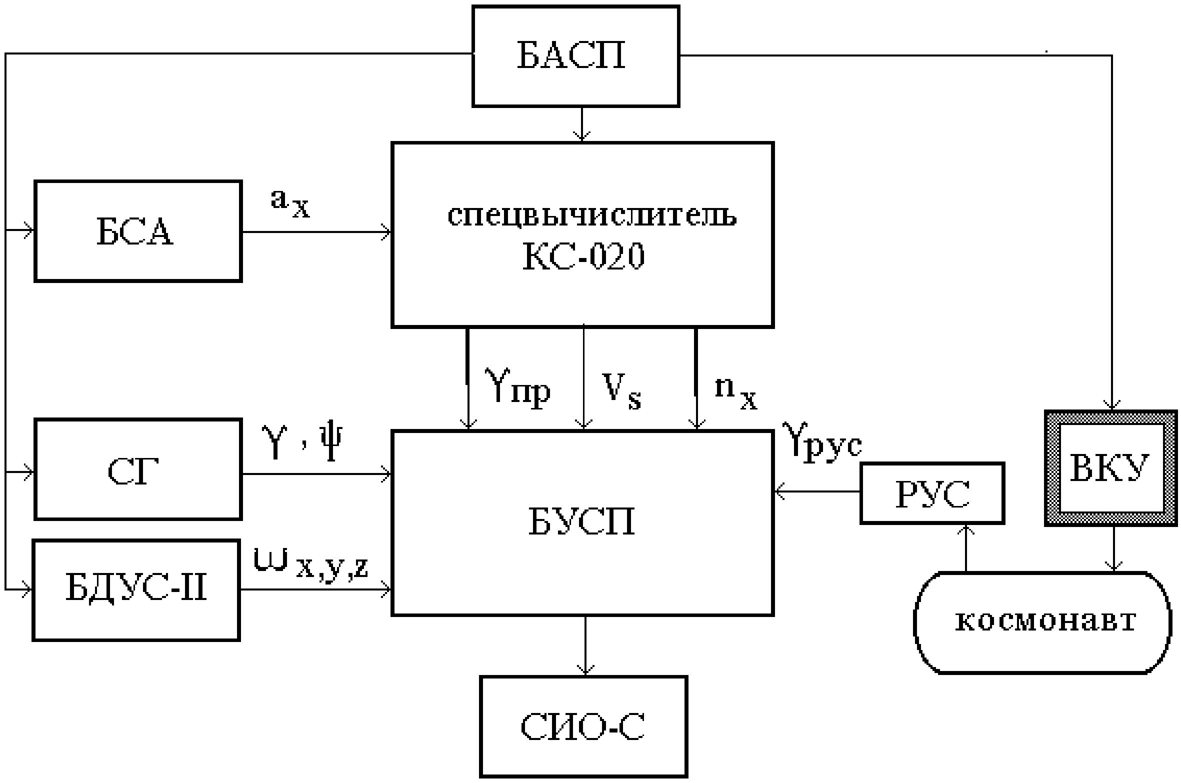


Fig. 1. (Descent Control Circuit Block Diagram)

1. Attitude Rate Sensor Unit. 2. Free Gyro. 3. String Accelerometer Unit. 4. Descent Automatic Equipment Unit. 5. Specialized Computer. 6. Descent Control Unit. 7. Descent Control Handle. 8. Display Unit. 9. Cosmonaut. 10. Descent Reaction Control System.

Блок управления спуском (БУСП) (Descent Control Unit) is designed for the Descent Reaction Control System (СИО-С) thruster ignition/shut off on signals coming from the КС-020, СГ, РУС, БДУС-II.

Ручка управления спуском (РУС) (Descent Control Handle) is designed for generating control signals $\gamma_{рус}$ to adjust the descent trajectory and for issuing main commands while configuring descent.

Свободный гироскоп (СГ) (Free Gyro) fulfills the following tasks:

- issues signals proportional to the CA angles about Xv and Yv axes;
- generates caution/warning signals when the roll and yaw angles reach the threshold values for the Control System transfer to the БС mode.

Блок датчиков угловых скоростей (БДУС-II) (Attitude Rate Sensor Unit) is designed for measuring attitude rates in three mutually perpendicular Velocity Coordinate System Xv, Yv, Zv.

АВТОМАТИЧЕСКИЙ УПРАВЛЯЕМЫЙ СПУСК (АУС) (AUTOMATICALLY CONTROLLED DESCENT)

The АУС is the СУС System primary operational mode. In this mode the descent is executed by setting the programmed roll angle which is calculated on the results of comparison of the descent actual time $t^{Ф}$ and the descent programmed time $t^{ПР}$ which is set as a function of the apparent velocity Vs:

$$t^{ПР}=t^{ПР}(Vs)$$

The crew monitors the descent procedure by the ВКУ Display data (Fig. 2).

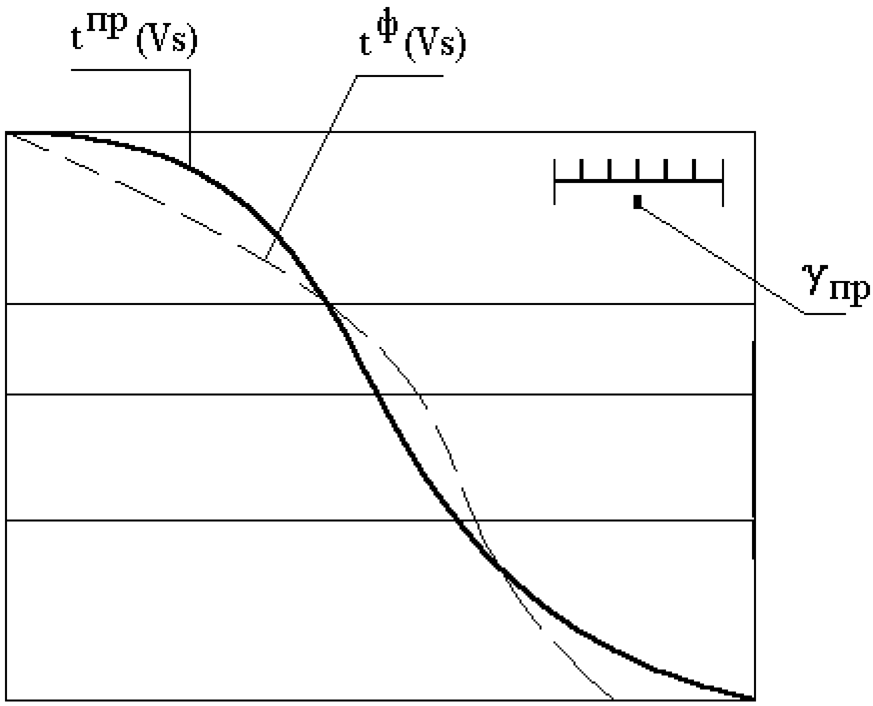


Fig. 2. (ВКУ Display Format for АУС Mode)

РУЧНОЙ УПРАВЛЯЕМЫЙ СПУСК (РУС) (MANUALLY CONTROLLED DESCENT)

The Manually Controlled Descent mode is a back up for the АУС mode and is used when the reentry conditions are not nominal or the spacecraft stabilization during the СКД engine burn is degraded or some specific failures of the СУС System equipment occur.
The descent control is executed by the crew using the Ручка управления спуском (РУС) (Descent Control Handle) which when deflected produces roll control signal γ.рус.

БАЛЛИСТИЧЕСКИЙ СПУСК (БС) (BALLISTIC DESCENT) and БАЛЛИСТИЧЕСКИЙ СПУСК РЕЗЕРВНЫЙ (БСР) (BACK UP BALLISTIC DESCENT)

The БС mode is executed by maintaining the СА roll rate (wx=+13 °/s) and simultaneously damping rotational oscillations about the spacecraft lateral axes when the АУС and РУС modes are impossible. In the БС mode the crew monitors the descent procedure by the ВКУ Display data (Fig. 3).

The БСР mode is initiated by the crew when the БС mode is impossible. The БСР mode is realized by an independent control circuit operation. In the БСР mode the СА roll rate wx=18°/s is maintained. The БСР mode descent is not monitored by the crew.

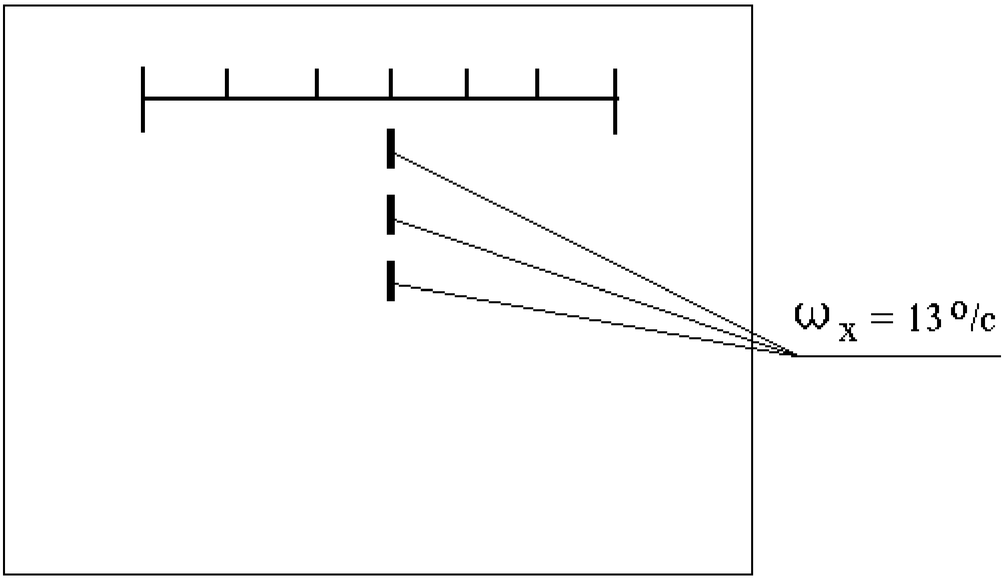


Fig 3. (ВКУ Display Format in БС Mode)

NOMINAL DESCENT PROCEDURE

The descent execution nominal version is single flexible cycle descent. The cyclogram of this descent is shown in Fig. 4.

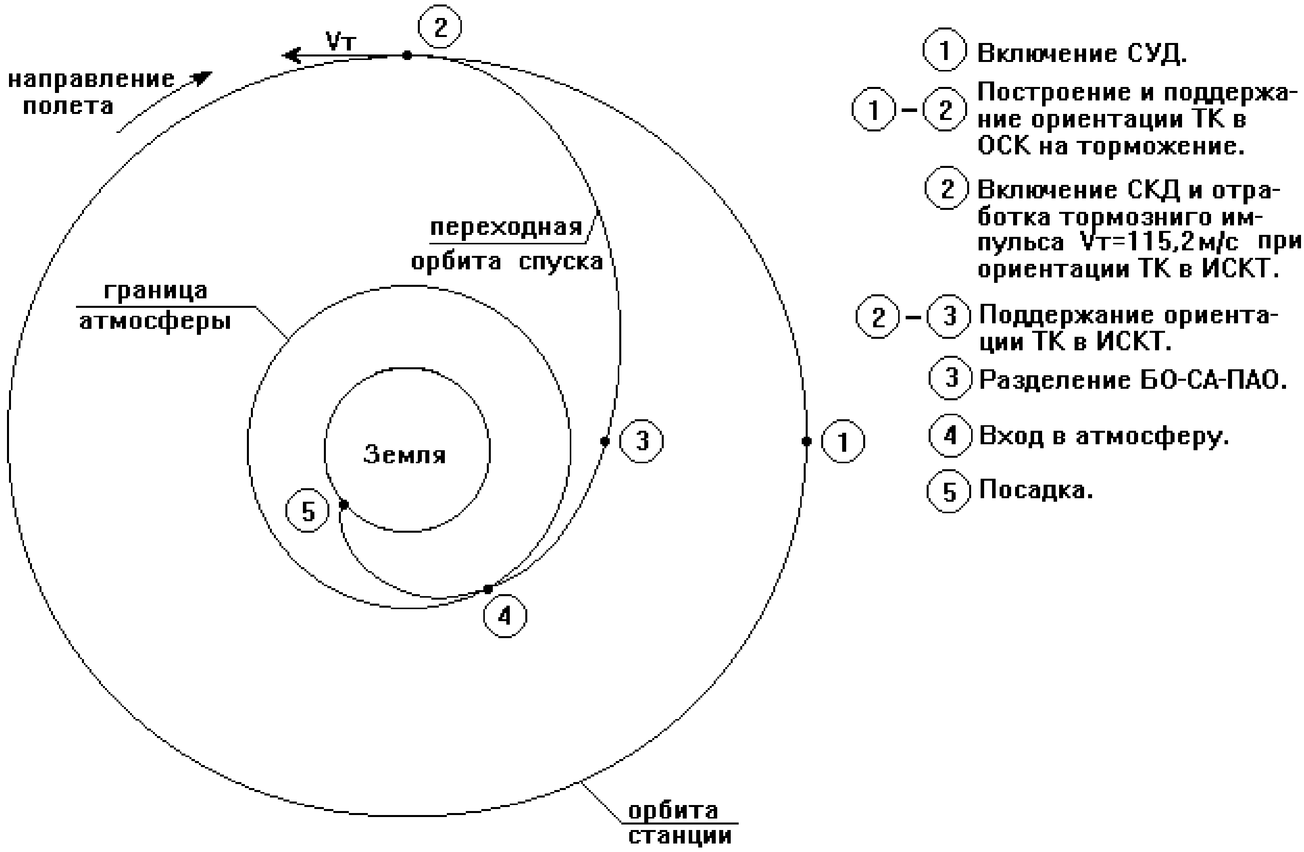


Fig. 4. (Nominal Descent Cyclogram)

1. СУД switching on. 1.-2. Spacecraft attitude establishment for retrofire in the ОСК and attitude hold. 2. СКД ignition for the burn time necessary to achieve the retrofire impulse $V_т$=115,2 m/s while the spacecraft is in the ИСКТ attitude. 2. Spacecraft attitude hold in the ИСКТ. 3. БО/СА/ПАО separation. 4. Atmosphere reentry. 5. Landing. 6. Flight heading. 7. Descent transfer orbit. 8. Station orbit. 9. Atmosphere boundary. 10. Earth.

SYSTEM OPERATIONAL LIMITS AND CHARACTERISTICS

The СУС System ensures the СА Module descent to landing within the nominal landing area the landing point deviation from the calculated point being:

- in the АУС mode - 30 km;
- in the РУС mode - 60 km;
- in the БС mode - 75 km.

The РУС mode cannot correct the СУС System СА stabilization circuit.

CREW OPERATION WITH THE SYSTEM

The СУС operation starts in the moment of the СКД Engine retrofire ignition and ends at the moment of the Primary Parachute System deployment. The crew monitors the process of the СУС configuring for operation and the descent procedure using indicator lights and display formats on the ПК СА.
In case the АУС mode cannot be executed the crew makes the decision to transfer to any of the back up modes (РУС, БС, БСР). There is no transfer back capability.

3.17. КОМБИНИРОВАННАЯ ДВИГАТЕЛЬНАЯ УСТАНОВКА (КДУ) (COMBINED PROPULSION SYSTEM)

GENERAL INFORMATION ON THE SYSTEM

The КДУ System is designed for generating thrust force along the spacecraft principal axes (X, Y, Z) and control moments about these axes.
The КДУ uses displacement (pressurization) propellant supply to the liquid bipropellant thrusters. The propellants used are: nitrogen tetroxide as the oxidizer and unsymmetrical dimethylhydrazine as the fuel.

The КДУ units are located in the AO and the ПхО Modules. The thruster location layout is shown in Fig. 1.

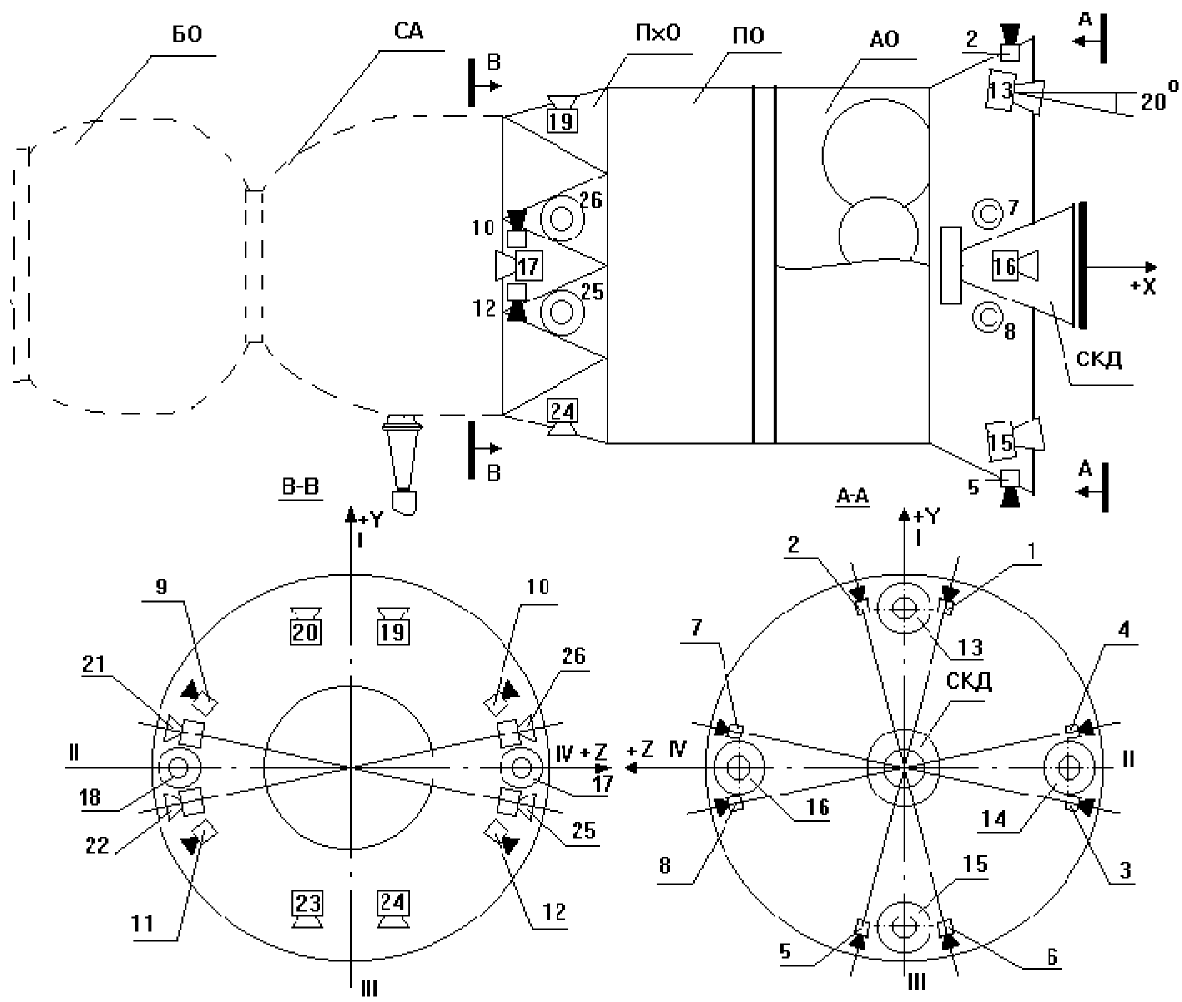


Fig. 1. (КДУ Thruster Location Layout)

SYSTEM COMPOSITION

The КДУ consists of:
- displacement pneumatic (pressurization) subsystem;
- propellant supply subsystem;
- сближающе-корректирующий двигатель (СКД) (Orbital Maneuver Engine);
- двигатели причаливания и ориентации (ДПО) (Berthing/Attitude Control Thrusters).

The КДУ System structurally consists of the Базовый Блок (ББ) (Basic Unit) and the Подсистема двигателей причаливания и ориентации (ДПО) (Berthing/Attitude Control Thruster Subsystem).

The ББ includes:
- Displacement Pneumatic Pressurization System;
- Propellant System which ensures propellant supply to the Orbital Maneuver Engine;
- Сближающе-корректирующий двигатель (СКД) (Orbital Maneuver Engine).

The ДПО Subsystem includes:
- Propellant System which ensures propellant supply to the ДПО thrusters;
- Двигатели причаливания и ориентации (ДПО) (Berthing/Attitude Control Thrusters).

The КДУ pneumatic/hydraulic circuit diagram is shown in Fig. 2

The Displacement Pneumatic Pressurization System is designed for:
- high pressure gas (Helium) stowage;
- creating operational pressure in the propellant tank ullages;
- actuation control of the СКД Engine line valves.

The Displacement Pneumatic Pressurization System includes:

КДУ Elements	Section 1	Section 2
Шар-баллоны (ШБ) (Spherical Bottles)	ШБ1, ШБ2	ШБ3, ШБ4
Электропневмоклапаны наддува (Electro-Pneumatic Pressurization Valves)	ЭПКН1	ЭПКН2
Датчики давления газа в ШБ (Spherical Bottle Gas Pressure Sensors)	ДШБ1	ДШБ2
Редукторы низкого давления (Pressure Reducing Valves)	РД1	РД2
Предохранительные клапаны (Pressure Relief Valves)	КПН1, КП1	КПН2, КП2
Обратные клапаны (Check Valves)	КО1, КО3, КО4	КО2, КО5, КО6
Электропневмоклапаны пуска СКД (Engine Start Electro-Pneumatic Valves)	П1, ПД1, Др1	П2, ПД2, Др2
Сигнализаторы давления газа за редуктором (Low Pressure (Post-Reducer)Switch Sensors)	СДР1	СДР2
Телеметрические датчики давления газа за редукторами РД1, РД2 (Low Pressure (Post-Reducer) Telemetry Sensors)	ДН1	ДН2
ПК1 - пироклапан объединения секций по высокому давлению (Squib -Operated Valve for Combining High Pressure Pipelines of Two Sections)		
ДрД - дренажный электропневмоклапан пуска СКД (Engine Start Electro-Pneumatic Drain Valve)		
ПК2 - пироклапан объединения секций по низкому давлению (Squi]-Operated Valve for Combining Low Pressure Pipelines of Two Sections)		
КПД -предохранительный клапан дренажный (Drainage/Pressure Releif Valve)		

The Propellant System is designed for:
- stowage of the propellant components;
- propellant supply to the СКД Engine and ДПО thrusters.

There are two sections in the Propellant System which include:

КДУ Elements	Section 1	Section 2
Топливные баки с окислителем и горючим (Oxidizer & Fuel Tanks)	БО1, БГ1	БО2, БГ2
Компенсаторы температурных расширений топлива (Propellant Thermal Expansion Compensators)	КТ1, КТ2	КТ3, КТ4
Датчики давления компонентов топлива в баках (Propellant Component Pressure Sensors in Tanks)	ДБО1, ДБГ1	ДБО2, ДБГ2
Электрогидроклапаны подачи топлива к ДПО (Pro-	ЭКО1, ЭКГ1	ЭКО2, ЭКГ2

pellant-to-ДПО Supply Electro-Hydraulic Valves)		
Датчики расхода топлива через ДПО (ДПО Propellant Flow Rate Sensors)	ДРО2, ДРГ2	ДРО3, ДРГ3
Гидроклапаны с пневмоуправлением предварительного пуска СКД (Pneumatically Operated Hydraulic Valves for СКД Pre-Start)	К1, К2	К3, К4
Телеметрические датчики давления компонентов топлива в магистралях ДПО (ДПО Pipeline Propellant Component Pressure Telemetry Sensors)	ДСГ1, ДСО1	ДСГ2, ДСО2
К5,К6-гидроклапаны окончательного пуска СКД (Hydraulic Valves for СКД Final Start)		
ДРО1, ДРГ1-датчики расхода компонентов топлива через СКД (СКД Propellant Component Flow Rate Sensors)		
СДО, СДГ-сигнализаторы давления компонентов топлива в магистралях СКД (СКД Pipeline Propellant Component Pressure Switch Sensors)		
ПК3, ПК4-пироклапаны объединения топливных магистралей (Squib-Operated Valves for Combining Propellant Pipelines)		
ЭКО3, ЭКГ3-электрогидроклапаны объединения топливных коллекторов (Electro-Hydraulic Valves for Combining Propellant Manifolds)		

The Orbital Maneuver Engine is a liquid propellant rocket engine and is used for generating spacecraft orbit adjustment and retrofire thrust impulses.
The Engine is gimbal-mounted and is capable of being deflected by electric motors within -5° up to +5° for thrust vector control in pitch and yaw.

<u>The ДПО Berthing/Attitude Control Thrusters</u> are liquid propellant rocket thrusters and are designed for rotating the spacecraft about its center of mass and translating the spacecraft center of mass along its main axes.

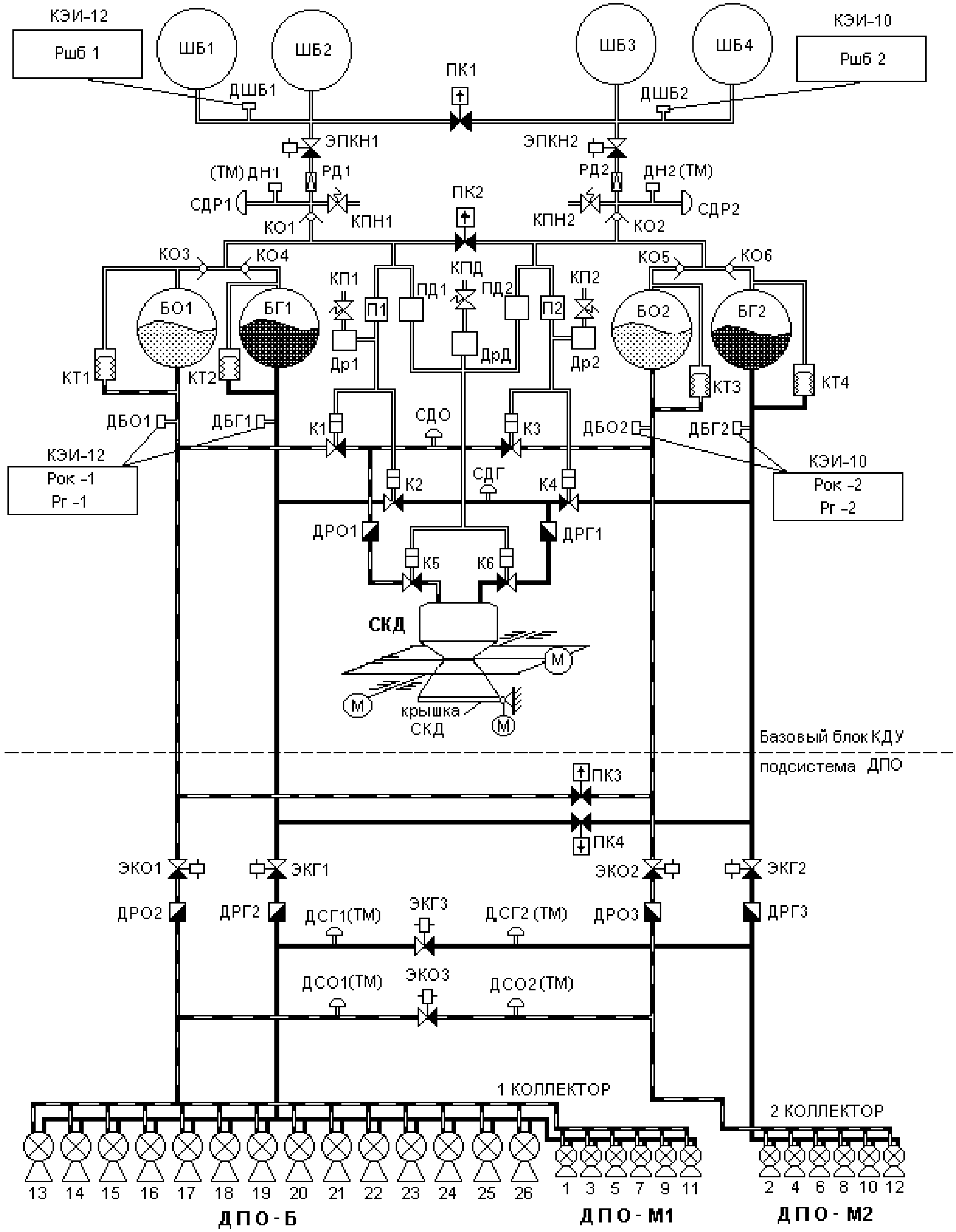


Fig. 2. КДУ Functional Block Diagram

1. КЭИ-12 - Combined Electronic Indicator Key 12; 2. КЭИ-10 - Combined Electronic Indicator Key 10; 3. Ршб 1 - Pressure in Section 1 Spherical Bottles (1 & 2); 4. ШБ1 - Spherical Bottle 1; 5. ШБ2 - Spherical Bottle 2; 6. ШБ3 - Spherical Bottle 3; 7. ШБ4 - Spherical Bottle 4; 8. Ршб 2 - Pressure in Section 2 Spherical Bottles (3 & 4); 9. ДШБ1 - Section 1 Spherical Bottle Pressure Sensor; 10. ПК 1 - Squib -Operated Valve for Combining High Pressure Pipelines of Two Sections; 11. ДШБ2 - Section 2 Spherical Bottle Pressure Sensor; 12. ЭПКН1- Section 1 Electro-Pneumatic Pressurization Valve; 13. ЭПКН2 - Section 2 Electro-Pneumatic Pressurization Valve; 14. (ТМ)ДН1 - Section 1 Low Pressure Sensor (Telemetry); 15.

РД1 - Section 1 Reducing Valve; 16. РД2 - Section 2 Reducing Valve; 17. ДН2(ТМ) - Section 2 Low Pressure Sensor (Telemetry); 18. СДР1 - Section 1 Low Pressure Switch Sensor; 19. ПК2 - Squib -Operated Valve for Combining Low Pressure Pipelines of Two Sections; 20. СДР2 - Section 2 Low Pressure Switch Sensor; 21. КО1 - Check Valve 1; 22. КПН1 - Purge Pressure Relief Valve 1; 23. КПН2 - Purge Pressure Relief Valve 2; 24. КО2 - Check Valve 2; 25. КО3 - Check Valve 3; 26. КО4 - Check Valve 4; 27. КО5 - Check Valve 5; 28. КО6 - Check Valve 6; 29. БО1 - Oxidizer Tank 1; 30. БГ1 Fuel Tank 1; 31. КП1 - Pressure Relief Valve 1; 32. П1 - Start Valve 1; 33. ПД1 - Drainage Start Valve 1; 34. КПД - Drainage Pressure Relief Valve; 35. ПД2 - Drainage Start Valve 2; 36. КП2 - Pressure Relief Valve 2; 37. П2 - Start Valve 2; 38. БО2 - Oxidizer Tank 2; 39. БГ2 - Fuel Tank 2; 40. КТ1 - Propellant Thermal Expansion Compensator 1; 41. КТ2 - Propellant Thermal Expansion Compensator 2; 42. Др1 - Drainage Valve 1; 43. ДрД - Engine Start Electro-Pneumatic Drain Valve; 44. Др2 - Drainage Valve 2; 45. КТ3 - Propellant Thermal Expansion Compensator 3; 46. КТ4 - Propellant Thermal Expansion Compensator 4; 47. ДБО1 - Oxidizer Tank 1 Pressure Sensor; 48. ДБГ1 - Fuel Tank 1 Pressure Sensor; 49. К1 - Engine Pre-Start (Oxidizer Supply) Valve 1; 50. СДО - Oxidizer Pressure Switch Sensor; 51. К3; - Engine Pre-Start (Oxidizer Supply) Valve 3. 52. ДБО2 - Oxidizer Tank 2 Pressure Sensor; 53. ДБГ2 - - Fuel Tank 2 Pressure Sensor; 54. КЭИ-12 - Combined Electronic Indicator Key 12; 55. Рок-1, Рг-1 - Section 1 Oxidizer, Fuel Pressure; 56. К2 - Engine Pre-Start (Fuel Supply) Valve 2; 57. СДГ - Fuel Pressure Switch Sensor; 58. К4 - Engine Pre-Start (Fuel Supply) Valve 4; 59. КЭИ-10 - Combined Electronic Indicator Key 10; 60. Рок-2, Рг-2 - Section 2 Oxidizer, Fuel Pressure; 61. ДРО1 - Oxidizer Flow Rate Sensor 1; 62. ДРГ1 - Fuel Flow Rate Sensor 1; 63. К5 - Engine Final Start (Oxidizer Supply) Valve 5; 64. К6 - Engine Final Start (Fuel Supply) Valve 6; 65. СКД - Orbital Maneuver Engine; 66. «М» - Engine Thrust Vector Control Gimbal Motors; 67. «М»- Engine Nozzle Cover Motor; 68. Крышка СКД - Engine Nozzle Cover; 69. Базовый блок КДУ - Propulsion System Basic Unit; 70. Подсистема ДПО - Berthing/Attitude Control Thruster Subsystem; 71. ПК3 - Squib-Operated Valve 3 for Combining Oxidizer Pipelines; 72. ПК4 - Squib-Operated Valve 4 for Combining Fuel Pipelines; 73. ЭКО1 - Oxidizer-to-ДПО Supply Electro-Hydraulic Valve 1; 74. ЭКГ1 - Fuel-to-ДПО Supply Electro-Hydraulic Valve 1; 75. ЭКО2 - Oxidizer-to-ДПО Supply Electro-Hydraulic Valve 2; 76. ЭКГ2 - Fuel-to-ДПО Supply Electro-Hydraulic Valve 2; 77. ДРО2 - Oxidizer Flow Rate Sensor 2; 78. ДРГ2 - Fuel Flow Rate Sensor 2; 79. ДСГ1(ТМ) - Fuel Pressure Switch Sensor 1 (Telemetry); 80. ЭКГ3 Fuel Manifold Combining Electro-Hydraulic Valve 3; 81. ДСГ2(ТМ) - Fuel Pressure Switch Sensor 2 (Telemetry); 82. ДРО3 - Oxidizer Flow Rate Sensor 3; 83. ДРГ3 - Fuel Flow Rate Sensor 3; 84. ДСО1(ТМ) - Oxidizer Pressure Switch Sensor 1 (Telemetry); 85. ЭКО3 - Oxidizer Manifold Combining Electro-Hydraulic Valve 3; 86. ДСО2(ТМ) - Oxidizer Pressure Switch Sensor 2 (Telemetry); 87. 1 коллектор - Manifold 1; 88. 2 коллектор - Manifold 2; 89. ДПО -Б - Higher Thrust ДПО Thrusters; 90. ДПО -М1 - Lower Thrust ДПО Thrusters in Manifold 1; 91. ДПО-М2 - Lower Thrust ДПО Thrusters in Manifold 2.

There are 26 ДПО thrusters: 12 lower thrust ДПО-М thrusters (1-12, Fig.1) and 14 higher thrust ДПО-Б thrusters (13-26, Fig.2).

Propellant is supplied to the thrusters via two manifolds:

- the first manifold feeds the propellant components to all the ДПО-Б thrusters and to six ДПО-М (ДПО-М1) thrusters;
- the second manifold feeds the propellant components to the other six ДПО-М (ДПО-М2) thrusters.

The first and the second manifolds are initially separated from each other by means of the ЭКО3 and the ЭКГ3 valves.
The first manifold is connected to the first propellant stowage tank section and the second manifold is connected to the second propellant tank section.

The ДПО thrusters are arranged into clusters, which are installed in the АО and the ПхО Modules in the spacecraft planes I, II, III and IV.
The ДПО-М1 and the ДПО-М2 thrusters are only used for the spacecraft attitude control and the ДПО-Б thrusters are used both for the attitude control and for the spacecraft approach and berthing to the station.

On the "КО" (Контакт отделения) (Separation Contact) command the КДУ stowage tanks of the two sections are for the first time pressurized and the two ДПО manifolds are filled with the propellant components.

КДУ PROPULSION SYSTEM CONTROL

The СКД (ДПО-Бт) is (are) ignited on the ОК-29 "ВКЛЮЧЕНИЕ СКД" (СКД Ignite) generalized command and is (are) shut off on the ОК-30 "ОТКЛЮЧЕНИЕ СКД" (СКД Shut Off) generalized command.

The КДУ control electrological diagram is shown in Fig. 3.

ДПО Operation

When the control signal comes from the СУД System the valves of appropriate ДПО thrusters are opened. The oxidizer and fuel enter the thruster combustion chamber and when mixed ignite. The combustion products (high temperature gases) exhaust through the thruster nozzle (jet) thus generating reactive thrust.

СКД Operation

On the “ВКЛЮЧЕНИЕ СКД” (СКД Ignite) (ОК-29) command the СКД starting hydraulic valves are opened providing for the propellant component flow from the stowage tanks to the СКД combustion chamber to self-ignite and to generate reactive thrust by the combustion product exhausting through the chamber nozzle. On the “ОТКЛЮЧЕНИЕ СКД” (СКД Shut Off) (ОК-30) command the hydraulic valves are closed to shut off the component flow to the СКД chamber. The СКД Engine burn is terminated.
Prior to the nominal descent execution the two pressurization subsystem sections and the two propellant stowage tank sections are connected to each other and the “ОБЪЕДИНЕНИЕ СЕКЦИЙ КДУ” (КДУ Section Connect) command is issued to configure the СКД Engine and the ДПО thruster operation as fed by the two sections simultaneously.

In case of the СКД failure there is a capability to fire four ДПО-Б thrusters simultaneously to fulfill the necessary retrofire impulse, called ДПО-Бт.

SYSTEM OPERATIONAL LIMITS AND CHARACTERISTICS

#	Technical Characteristics	Values
1	Propellant Total Charge Capacity	440 - 892 kg
2	Pressurization Gas Spherical Bottle Operational Pressure	350 - 30 kgf/cm2
3	Propellant Stowage Tank Admissable Pressure for the Thruster Operation	14 - 22 kgf/cm2
4	СДР Caution/Warning Sensor Actuation Pressure	24±1,5 kgf/cm2
5	СДД (СДО, СДГ) Caution/Warning Sensor actuation Pressure	12±0,5 kgf/cm2
6	Oxidizer to Fuel Ratio	1,85
7	СКД Cover Opening/Closing Time	15 – 25 sec

Table 1. КДУ Thruster Characteristics

Parameter	СКД	ДПО-Б	ДПО-М
Thrust, kgf	300±30	13,3	2,7
Total Component FlowRate, g/s	1070	55	11

Table 2. КДУ Parameter Values in Various Flight Phases (Monitored by КЭИ)

Flight Phase (Portion)	Parameters to be monitored by КЭИ (Allowable Values)	
	Ршб1 (КЭИ), Ршб2 (КЭИ) kgf/cm2	Р.о (КЭИ), Р.г (КЭИ) kgf/cm2
Prior to КП (Lift Off Contact)	300 - 350	0 - 1
After First Pressurization	250 - 280	14 - 22
Orbital Flight: – during СКД burn – during ДПО burn	 decreases decreases	 14 - 22 14 - 22

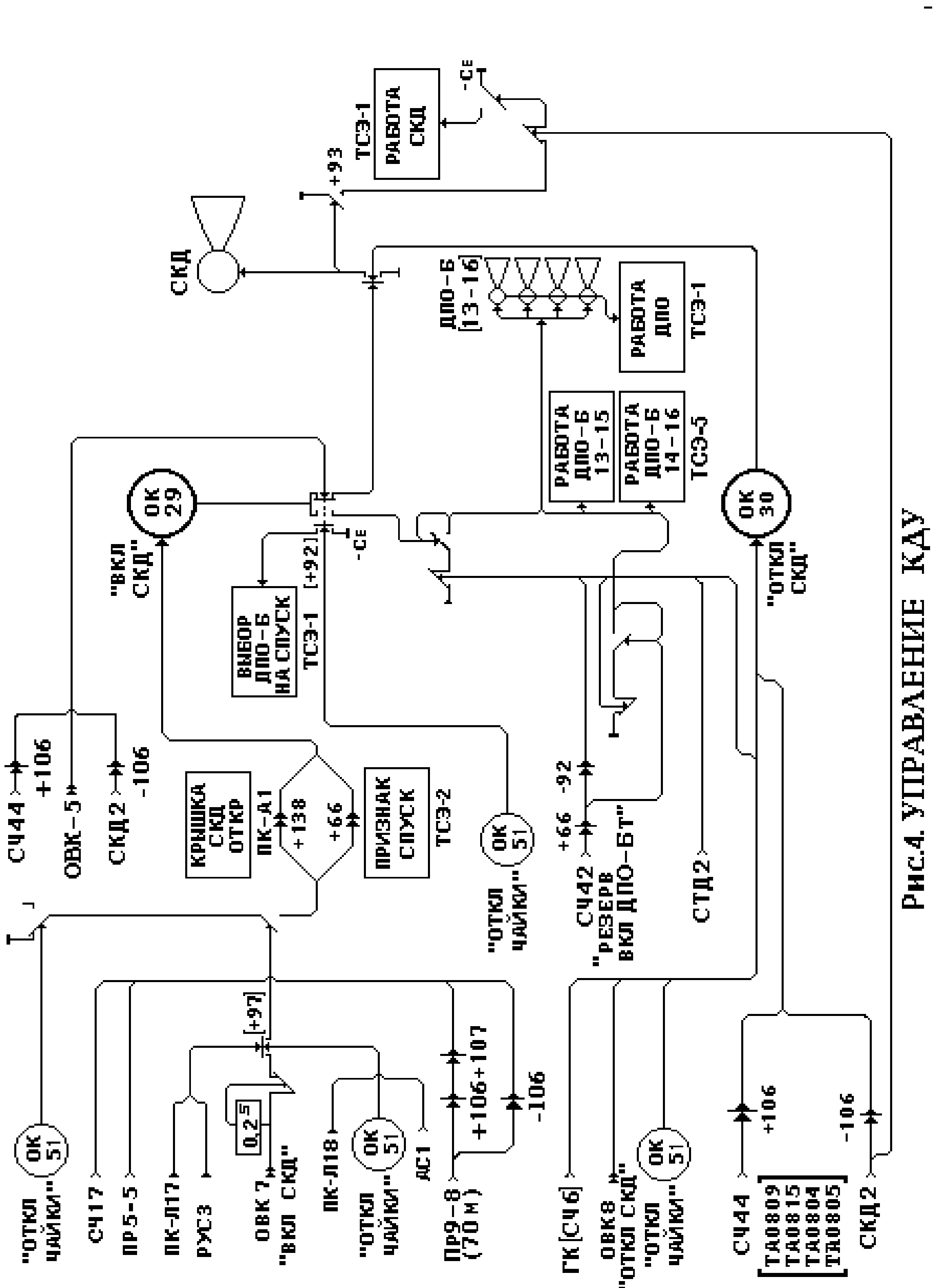


Fig. 4. КДУ Control

CREW OPERATION WITH THE SYSTEM

Prior to executing dynamic modes the crew configures the КДУ for the operation according to the FDF procedures:

– selection of the pressurization subsystem section, the propellant tank section and the ДПО set;
– monitoring the КДУ parameter values and the СИРТ Propellant Quantity Meter data.

When in a dynamic mode the crew monitors the procedure of the ДПО thruster and the СКД engine ignition, burn and shut off by the spacecraft behavior, indicator lights, display formats, КДУ parameter displayed by the КЭИ and the СИРТ.

In case of one of the pressurization subsystem sections failure or one of the propellant stowage tank sections failure the crew has the capability to transfer to the other (operative) КДУ sections.

In case of a failure in the selected ДПО thruster set during the spacecraft attitude establishment (maneuver) the crew has the capability of selecting the operative ДПО set using the ПК CA Panel.

3.18. СИСТЕМА ИСПОЛНИТЕЛЬНЫХ ОРГАНОВ СПУСКА (СИО -С) (DESCENT REACTION CONTROL SYSTEM)

GENERAL INFORMATION ON THE SYSTEM

The СИО-С System is designed for generating control moments around the CA Module body axes during its descent from the orbit to the Earth.
The СИО-С principle of operation is that of a propulsion system with the displacement (pressurization) liquid monopropellant supply to the thrusters. The monopropellantused is high concentration Hydrogene peroxide.

SYSTEM COMPOSITION

The СИО-С System consists of:
- displacement (pressurization) subsystem;
- monopropellant supply subsystem;
- управляющие реактивные микродвигатели (УРМД) (Reaction Control Microthrusters).

The СИО-С System pneumatic/hydraulic diagram is shown in Fig. 1.

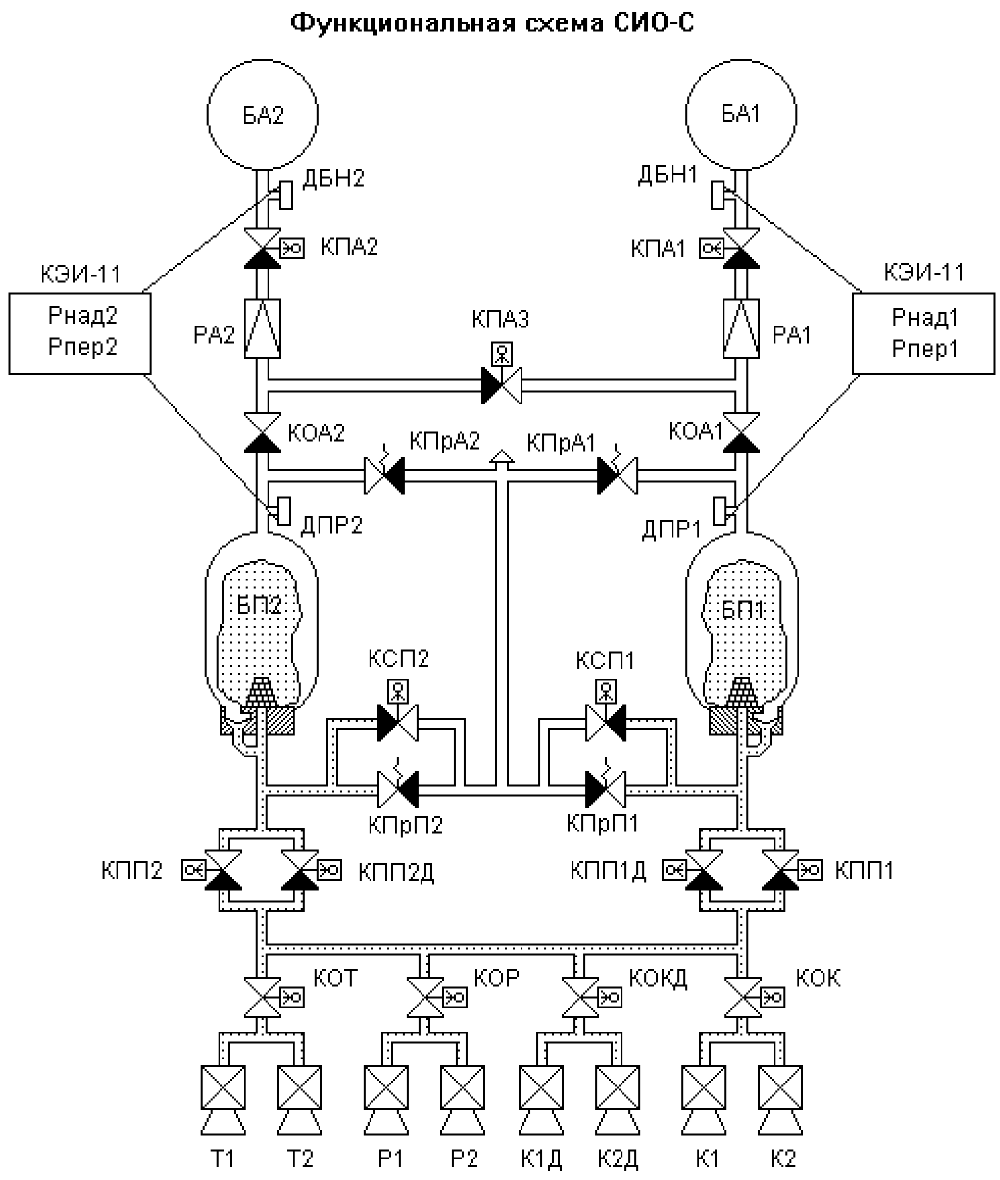


Fig. 1. СИО-С System Functional Block Diagram

Fig. 1 СИО-С System Functional Block Diagram

1. БА2 - Nitrogen Bottle 2; 2. БА1 - Nitrogen Bottle 1; 3. ДБН2 - Nitrogen Pressure Sensor 2; 4. ДБН1 - Nitrogen Pressure Sensor 1; 5. КПА2 - Nitrogen Purge Squib Valve 2; 6. КПА1 - Nitrogen Purge Squib Valve 1; 7. КЭИ-11 - Combined Electronic Indicator Key 11; 8. КЭИ-11 - Combined Electronic Indicator Key 11; 9. Рнад2, Рпер2 - Section 2 Nitrogen Purge, Peroxide Pressure; 10. РА2 - Nitrogen Pressure Reducer 2; 11. КПА3 - Squib Valve for Combining Low Pressure Nitrogen Sections; 12. РА1 - Nitrogen Pressure Reducer 1; 13. Рнад1, Рпер1 - Section 1 Nitrogen Purge, Peroxide Pressure; 14. КОА2 - Check Valve 2; 15. КПрА2 - Nitrogen Pressure Relief Valve 2; 16. ШС - Drain Outlet; 17. КПрА1 - Nitrogen Pressure Relief Valve 1; 18. КОА1 - Check Valve 1; 19. ДПР2 - Peroxide Pressure Sensor 2; 20. ДПР1 - Peroxide Pressure Sensor 1; 21. БП2 - Peroxide Tank 2; 22. БП1 - Peroxide Tank 1; 23. КСП2 - Peroxide Drain Valve 2; 24. КСП1 - Peroxide Drain Valve 1; 25. КПрП2 - Peroxide Pressure Relief Valve 2; 26. КПрП1 - Peroxide Pressure Relief Valve 1; 27. КПП2 - Squib-Operated Start Valve 2; 28. КПП2Д - Additional Squib-Operated Start Valve 2; 29. КПП1Д - Additional Squib-Operated Start Valve 1; 30. КПП1 - Squib-Operated Start Valve 1; 31. КОТ - Cut-Off Squib Valve for Pitch Thrusters; 32. КОР - Cut-Off Squib Valve for Yaw Thrusters; 33. КОКД - Cut-Off Squib Valve for Additional Roll Thrusters; 34. КОК - Cut-Off Squib Valve for Roll Thrusters; 35. Т1 - Pitch Thruster 1; 36. Т2 - Pitch Thruster 2; 37. Р1 - Yaw Thruster 1; 38. Р2 - Yaw Thruster 2; 39. К1Д - Additional Roll Thruster 1; 40. К2Д - Additional Roll Thruster 2; 41. К1 - Roll Thruster 1; 42. К2 - Roll Thruster 2.

The Displacement Pneumatic (Pressurization) System is designed for:

- pressurizing gas (Nitrogen) high pressure stowage;
- raising pressure to the necessary level in stowage tank ullages.

The Displacement System consists of two sections each one including (Table 1):

Table 1.

PNEUMATIC SYSTEM ELEMENTS	SECTION 1	SECTION 2
баллон с азотом (Nitrogen Bottle)	БА1	БА2
датчик давления азота наддува (Nitrogen Pressure Sensor)	ДБН1	ДБН2
пироклапан пуска азота (Nitrogen Purge Squib Valve)	КПА1	КПА2
редуктор низкого давления (Pressure Reducer)	РА1	РА2
обратный клапан (Check Valve)	КОА1	КОА2
клапан предохранительный (Pressure Relief Valve)	КПрА1	КПрА2
датчик давления перекиси водорода (Hydrogen Peroxide Pressure Sensor)	ДПР1	ДПР2
КПА3 - пироклапан объединения секций азота низкого давления (Squib Valve for Combining Low Pressure Nitrogen Sections}		

The Propellant System is designed for:

- the Hydrogen Peroxide stowage;
- the Peroxide (monopropellant) supply to the inputs of the управляющие реактивные микродвигатели (УРМД) (Reaction Control Miro-Thrusters).

The Propellant Supply System consists of two sections including the following elements (Table 2):

Table 2.

PROPELLANT SYSTEM ELEMENTS	SECTION 1	SECTION 2
топливный бак (бак перекиси) (Monopropellant (Peroxide) Tank)	БП1	БП2
пусковой пироклапан (Squib-Operated Start Valve)	КПП1	КПП2
пусковой пироклапан дополнительный (Additional Squib-Operated Start Valve)	КПП1Д	КПП2Д
пироклапан слива перекиси (Peroxide Drain Squib Valve)	КСП1	КСП2
клапан предохранительный перекиси (Peroxide Pressure Relief Valve)	КПрП1	КПрП2
ШС - штуцер слива (Drain Outlet)		
КОТ, КОР, КОК, КОКД - пироклапаны отсечные двигателей по каналам тангажа, рыскания, крена, крена дополнительный (Cut-Off Squib Valves for Pitch, Yaw, Roll and Additional Roll Thrusters)		

Управляющие реактивные микродвигатели (УРМД) (Reaction Control Micro-Thrusters) are designed for generating control moments (+Mx, -Mx, +My, -My, +Mz, -Mz) about the CA Module center of mass.

There are 8 УРМД thrusters in the СИО-С System (Fig.2):

- T1, T2 (pitch channel),
- P1, P2 (yaw channel),
- K1, K1Д; K2, K2Д (roll channel, K1Д and K2Д are additional roll control thrusters).

Each УРМД thruster includes управляющий электрогидроклапан (УЭГК) (Electro-Hydraulic Control Valve), reactor and nozzle.

All the СИО-С equipment articles except cut-off squib valves and thrusters are structurally combined in the Пневмогидроагрегат (ПГА) (Pneumatic/Hydraulic Unit) which is mounted in a special container beyond the pressurized CA Module sheath (Fig. 2).

The KOT, KOP, KOK and KOKД squib-actuated valves are located beside corresponding УРМД thrusters.

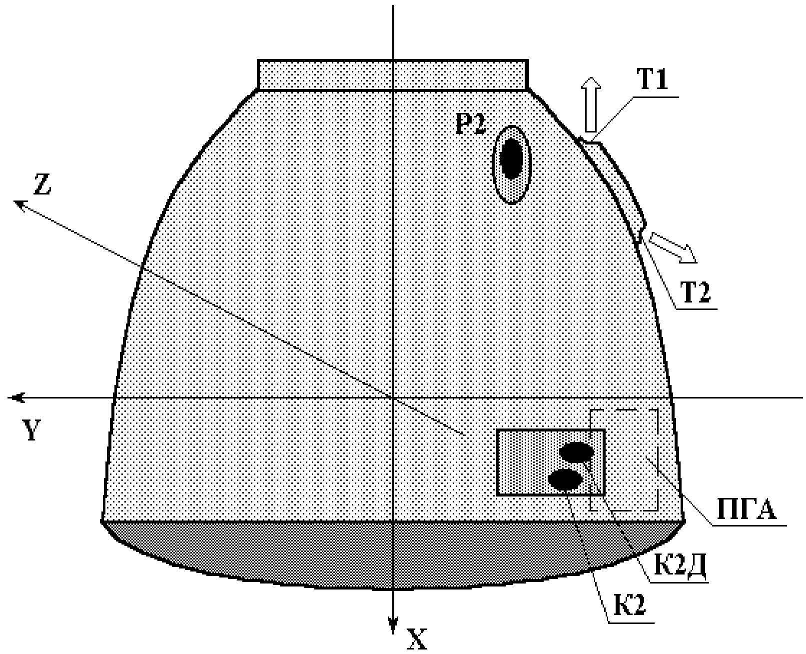


Fig. 2. (СИО-С Thruster Location)

The СИО-С System starts operating after the CA Module separation.

The system is configured into the operational state 14 seconds prior to the module separation. While configuring the system appropriate cartridge activated valves are opened feeding the Hydrogene peroxide to the УРМД.

From the module separation moment up to the CA bottom shield jettison moment the СИО-С operates under the СУС System command control.
At the parachuting portion of the flight until landing the СИО-С System operates under the система приземления (СП) (Landing System) command control.
When there are control signals from the СУС or СП Systems valves of appropriate УРМД thrusters are opened. The Hydrogene peroxide enters the catalyst reactor where the peroxide decomposition reaction is realized producing gaseous oxygen and water vapor. The decomposition products are exhausted through the jet generating the thrust.

On the "ОТСТРЕЛ ЛОБОВОЙ ТЕПЛОЗАЩИТЫ" (Bottom Shield Jettison) all УРМД thruster valves are opened and all the peroxide residuals are drained out.

SYSTEM OPERATIONAL LIMITS AND CHARACTERISTICS

#	Technical Characteristics	Values
1	Monopropellant Charge Capacity	29,6-31,4 kg
2	Nitrogen Stowage Pressure Range (P.над1.,P.над2)	270-350 atm
3	Peroxide Stowage Tank Pressure Range	1,5-4,5 atm
4	Peroxide Allowable Pressure for Thruster Operation (P.пер1, P.пер2)	15-18 atm
5	System Readiness for Operation Time after Opening Nitrogen and Peroxide Starting Valve Opening	not more than 10 sec
6	System Operativeness Time since Filling Moment	195 days

CREW OPERATION WITH THE SYSTEM

The crew all along the flight time until the module separation moment monitors the СИО-С parameters by the КЭИ data (P.над1, P.над2, P.пер1, P.пер2).

During the System operation it is monitored and controlled automatically.

3.19. КОМПЛЕКС СРЕДСТВ ПОСАДКИ (КСП) (LANDING AID COMPLEX)

КСП System Purpose and Composition

The Soyuz spacecraft КСП Complex is designed for the crew safe landing in the CA Module during nominal descent and in case of the Launch Vehicle failure at the launch site and in the orbit injection phase.

The КСП consists of:
1. Основная парашютная система (ОСП) (Primary Parachute System).
2. Запасная парашютная система (ЗСП) (Back Up Parachute System).
3. Двигатели мягкой посадки (ДМП) (Soft Landing Thrusters).
4. Cosmonaut Operation Seat.
5. Автоматика КСП (АКСП) (КСП Automatic Equipment).

ОСП System

The ОСП System consists of three parachutes: the вытяжной парашют (ВП) (Pilot Parachute), the тормозной парашют (ТП) (Brake Parachute) and the основной парашют (ОП) (Main Parachute). The ОСП System ensures landing of the CA Module weighing 2800 - 3100 kg at the velocity of 6.5 m/s. The System is located in a pressurized container inside the CA Module.
The ВП Parachute ensures the ТП Parachute deployment and consists of two canopies connected in series. The ВП Parachute is brought into action compulsorily - when the ОСП System container cap is jettisoned.
The ТП Parachute ensures CA descent velocity decrease from 230 m/s down to 90 m/s and the ОП Parachute deployment.
The ОП Parachute ensures the CA Module landing at the velocity of 6 - 7 m/s. The ОП Parachute consists of the 1000 square meter canopy and the harness system.

ЗСП System

The ЗСП System consists of three parachutes: the ВП Parachute, the ТП Parachute and the ОП Parachute. The ЗСП System ensures the CA Module landing in case of the ОСП System failure. The landing velocity with the ЗСП is 9.5 m/s. The system is located in a pressurized container inside the CA Module.
The ВП Parachute ensures the ТП Parachute deployment and consists of two canopies connected in series. The ВП Parachute is deployed compulsorily - when the ЗСП System container cap is jettisoned.
The ТП Parachute ensures the CA Module descent velocity decrease and the ОП Parachute deployment.
The ОП Parachute ensures the CA Module landing at the velocity of 10 m/s. It consists of the 590 square meter canopy and the harness system.

ДМП Soft Landing Thrusters

The six ДМП thrusters are located at the CA bottom. Their purpose is to decrease the CA descent vertical velocity down to 2 m/s. When parachuting with the ОСП System six/four ДМП thrusters are ignited and when with the ЗСП system six ДМП thrusters are fired.

Cosmonaut Operation Seat

The "Казбек У" shock absorbing seat is the cosmonaut work station and ensures crew member endurance to high G loads during launch/injection and CA module landing. There are three seats installed in the CA Module. Each one has two operational positions: unarmed position (throughout the flight time) and armed position (prior to landing).

АКСП Automatic Equipment

The АКСП consists of barostatic and time mechanisms and the Гамма-лучевой высотомер (ГЛВ) (Gamma Ray Altimeter). The barostatic and time mechanisms operating according to their settings issue commands for sequential parachute deployment and for the execution of pre-landing operations in the CA. The АКСП units are located at the CA Module bottom.
The purpose of the ГЛВ Altimeter is to issue the landing event signal at the altitude of 15 m (ТСЭ-4 “ПОСАДКА” (Landing) light goes ON) and the command for the ДМП thruster ignition at the altitude of 0.8 m.

КСП Operation

There are four КСП operation modes:
- Nominal mode (descent with the ОСП) (Fig.1);
- Back up mode (descent with the ЗСП) (Fig.1);
- First emergency program;
- Second emergency program.

Nominal Mode (Landing with ОСП)

While descending from the orbit after the retrofire burn the “РАЗДЕЛЕНИЕ” (Separation) generalized command comes from the СУБК System on which the СА separates from the adjacent modules (БО and ПАО). The separation command also arms the АКСП Equipment. If it does not arm automatically the crew will duplicate it manually by issuing Ф1 “АСП” command on the КСП-П. When the descent altitude is as low as 10.5 km the АКСП issues the command for the ОСП container cover jettison which results in the ВП Parachute deployment and sequentially the ТП Parachute deployment. Then the ballistic descent mode (БС) is initiated the СА Module being rotated about its longitudinal axis at the rate of 13°/s. In 16.5 s the ТП Parachute is jettisoned pulling out the ОП Parachute by its connector link The СА is descending with unsymmetrical harness connection to the ОП parachute.
Between the altitudes of 6.5 km and 5.5 km the АКСП measures the СА vertical descent rate with the parachute (if the descent rate is greater than 18 m/s the “АВАРИЯ” (ОСП System Failure) command is issued and the ЗСП System is deployed).

When the altitude reaches 5.5 km the АКСП gets down to the pre-landing operations:
- bottom thermal shield jettison;
- switching off the “БС” mode of the СУС System;
- СА/environment pressure equalization;
- jettison of the СА window covers;
- transfer to the СА symmetrical harness connection to the ОП Parachute;
- the seat shock absorber arming.

At the descent final portion following the ГЛВ Altimeter commands:
- at the altitude of 15 m the audio signal is switched On and the “ПОСАДКА”(Landing) light illuminates (ТСЭ-4);
- at the altitude of 0.8 m 4 ДМП thrusters are fired;
- manual ОП rope jettison inhibit is removed;
- The система дыхательной вентиляции (ДВ) (Breathing Ventilation System) is put to operation.

When landing onto the firm ground the Commander jettisons only one parachute rope. When the spacecraft lands onto the water surface he jettisons the parachute completely.

Landing with ЗСП (in Case of ОСП Failure)

At the altitude of 6.5 - 5.5 km the ОСП operational status is analysed. The descent rate greater than 18 m/s is the ОСП failure indication. The АКСП generates the “АВАРИЯ” (ОСП System Failure) command and brings the ЗСП system into operation.

On the “АВАРИЯ” command the following is accomplished:
- the ОСП System ОП Parachute release;
- the ЗСП System container cover jettison;
- the ЗСП System ВП Parachute and the ТП Parachute deployment;
- the “БС” mode initiation;
- the ТП Parachute jettison and the ОП Parachute deployment;

After that the pre-landing operations are executed.

Pre-Landing Operations

At the altitude of 10 m the “ПОСАДКА” (Landing) (ТСЭ-4) light goes On and the audio signal is switched On. At the altitude of 0.8 m six ДМП thrusters are fired.
When landing onto the firm ground the Commander jettisons only one parachute rope. When the spacecraft lands onto the water surface he jettisons the parachute completely.

Fig.1. (Descent with ОСП, Descent with ЗСП)

Descent with ОСП

Flag	Altitude	АСП Operation
SEPARATION (АСП arming)	130 km	АСП pre-operational initiation ("АСП" КСП Ф1)
<u>:: 00</u> (P= 133 mm Hg)	10,5 km	ББР-1 (Barometric Relay Unit) actuation ПВМ1-1,2,3 (Program/Timing Mechanism) start ОСП container cover jettison ("БС" ТСЭ-4)
:: 16,5	8,5 km	Jettison of ТП Brake parachute of ОСП ("ВВОД ОСП" ТСЭ-5)
:: 19,5	7,2 km	ПВМ1-1,2,3 stop ОСП full development
<u>:: 00</u> (P= 335 mm Hg)	6,5 km	ББР-2 actuation ПВМ1-1,2,3 start Breathing orifice circuit configuring Time base counting t.базы=55 s Statoscope circuit configuring (P.настр.=54 mm Hg)
:: 55	5,5 km	
:: 58		Bottom shield jettison ГЛВ circuit configuring Opening БАРД (Automatic Pressure Control Unit) valves Window cover jettison
:: 63		ОСП rope rearrangement (transfer from unsymmetrical to symmetrical harness)
:: 67		Seat shock absorber arming Pressurizing the ВЕ (Displacement Cavity) of ОСП Air release from the high pressure bottle for pressurizing the ВЕ of ЗСП in the СА
:: 70		ГЛВ and УД (Impact Sensor) energizing
H= 20-10 m		"ПОСАДКА" light ON (ТСЭ-4)
:: 85		ПВМ1-1,2,3 stop
H= 1,5 m	0,8-1,5 m	Fire (4 thrusters) Breathing orifice opening
H= 0 m		Landing contact

Descent with ЗСП

Flag	Altitude	АСП Operation
P= 54 mm Hg during 55 s (V.осп>18 m/s)		БР-2 (Barometric Relay Unit) actuation ПВМ1-1,2,3 (Program/Timing Mechanism) start
<u>:: 00</u>	5,5 km	Jettison of the ОСП ropes
:: 02		ЗСП container cover jettison
:: 13	4 km	Jettison of ТП Brake parachute of ЗСП ("ВВОД ЗСП" ТСЭ-5)
:: 27	3,5 km	Bottom shield jettison ГЛВ circuit configuring Opening БАРД (Automatic Pressure Control Unit) valves Window cover jettison
:: 30		ЗСП rope rearrangement
:: 36		Seat shock absorber arming ЗСП parachute ВЕ displacement cavity pressurization Air release from the high pressure bottle for pressurizing ВЕ of ОСП in the СА
:: 39		ГЛВ and УД (Impact Sensor) energizing
H= 20-10 m		"ПОСАДКА" light ON (ТСЭ-4)
H= 1,5 m	0,8-1,5 m	ДМП fire (6 thrusters) Breathing orifice opening
H= 0 m		Landing contact

Fig.1.

3.20. СИСТЕМА АВАРИЙНОГО СПАСЕНИЯ (САС) (LAUNCH ESCAPE SYSTEM)

CAC SYSTEM PURPOSE AND COMPOSITION

The CAC System is designed for bringing the crew modules away from the failed Launch Vehicle and providing conditions for guarantied operation of the landing aids while at the launch site and in the orbit injection phase.

The system is fully automatic. In case of the Launch Vehicle failure the “АВАРИЯ НОСИТЕЛЯ” (Launch Vehicle Failure) red light illuminates (ТСЭ-3) and also the Central Light goes ON and the intermittent audio signal sounds.
Having received these signals the crew reports to the Launch Control and prepares to withstand the accelerations associated with the launch escape procedures.

General CAC System design is shown in Fig.1.

The CAC System consists of:
- CAC Propulsion System;
- Aerodynamic Cap covering the crew modules;
- CAC Automatic Equipment.

Двигательная установка САС (ДУ САС) (CAC Propulsion System)
The ДУ CAC is an active aid which enables the spacecraft rescued part to escape in case of the Launch Vehicle failure both at the launch site and in the orbit injection phase.

The ДУ CAC consists of:
- Центральный ракетный двигатель (ЦРД) (Central Rocket Engine);
- Four Управляющие ракетные двигатели (УРД) (Attitude Control Rocket Thrusters);
- Ракетные двигатели разделения (РДР) (Separation Rocket Thrusters).

The ЦРД engine is designed for the spacecraft crew module (БО-СА) escape from the failed Launch Vehicle and climb up to the altitude necessary for the parachute system operation in case of emergency at the launch site or in launch vicinity conditions.
The УРД thrusters are designed for executing the preset spacecraft crew module escape trajectory in case of emergency at the launch site or in the vicinity of the launch site.
The РДР thrusters are designed for executing the evasive trajectory of the CAC System after its nominal jettison in the spacecraft orbit injection phase. The РДР thrusters are also used to take the Cap+БО cluster away from the CA at the climb portion of the spacecraft rescued part launch escape trajectory.

Apart from the ДУ CAC Propulsion System the following thrusters are located on the Aerodynamic Cap:
- Ракетные двигатели головного обтекателя (РДГ) (Cap Thrusters);
- Двигатели сброса створок (ДСС) (Section Jettison Thrusters).

The РДГ thrusters are designed for raising the climb altitude of the spacecraft rescued part in case of emergency in launch vicinity conditions and also for taking the rescued part away in the orbit injection phase after the ЦРД nominal jettison and prior to the Cap jettison.
The ДСС thrusters are designed for taking the Cap sections away from the spacecraft during its nominal jettison procedure in the orbit injection phase.

Crew Module Aerodynamic Cap
The Crew Module Aerodynamic Cap is the structural base for the escaping crew modules.

CAC System Automatic Equipment
The CAC Automatic Equipment is designed for joint operation with the spacecraft and the Launch Vehicle systems in generating signals and executing commands for the crew module escape from the failed Launch Vehicle in case of emergency at the launch site or in the orbit injection flight phase.

CAC SYSTEM OPERATIONAL PROCEDURE

The CAC System total operational period is subdivided into six portions:
1. From the moment of the “Взведение САС” (CAC arming) command for configuring the CAC System for operation up to the “КП” (контакт подъема - Lift-Off Contact).

2. From the “КП” up to 20 seconds of flight elapsed time.
3. From the FET 20 s up to the ДУ САС jettison programmed time.
4. From the ДУ САС programmed jettison up to the Cap (ГО) jettison.
5. From the ГО programmed jettison up to the “ПО” (предварительное отделение – preliminary separation) command.
6. From the “ПО” command up to the Launch Vehicle 3rd stage Propulsion System Shut Off command.

First Portion Procedure

In this CAC System operational period portion the emergency signal can be issued only by the Launch Director via the КРЛ system from the Launch Control vault.
On receiving the “Авария” (Emergency) signal the following commands are issued:

- for the spacecraft separation at the СА-ПАО interface;
- for the ЦРД engine 1 - 2 chamber ignition.

In 1,8 s after the “Авария” signal is issued the УРД thrusters are fired under the program control which depends on the wind direction and the location of the launch facilities.
In 4 s after the “Авария” the РДГ thrusters are fired.
At the escape trajectory peak the CAC Automatic Equipment issues commands:

- for the ВСК jettison;
- for the СА / БО separation.

After the ВСК jettison the a РДР thruster is fired and carries the Cap+БО cluster away from the CA so as to prevent their collision. At the preset time moment the parachute system is put to operation and follows a reduced time program.

Second Portion Procedure

This portion features low flight altitudes. So the failed Launch Vehicle Propulsion System is not cut off to carry the Launch Vehicle away from the launch facilities as far as possible. The parachute system operates under the control of reduced time programs.

Third Portion Procedure

When the “Авария” signal arrives the following commands are issued:

1. The Launch Vehicle Propulsion System emergency ignition;
2. Execution of all the commands according to the First portion program of the CAC operation with exceptions:
   - only the first ЦРД chamber is ignited (the altitude clearance is sufficient for the КСП complex operation;
   - the РДГ is not fired (altitude sufficient for the КСП operation);
   - only one УРД thruster is burnt, the one located in plane II.

At the preset moment the КСП Complex is put to operation.

Fourth Portion Procedure

This portion’s peculiar feature consists in using the РДГ thrusters as active aid for the crew module escape. On the “Авария” signal the spacecraft is separated at the СА-ПАО interface and two РДГ thrusters are ignited. In 0,32 s after the “Авария” command the second РДГ thruster group is ignited to take the crew modules away from the failed Launch Vehicle trajectory. According to the preset program the CAC automatic equipment issues commands for the ВСК jettison and for the СА I БО separation.
At the preset moment the КСП Complex is put to operation following the nominal time program.

Fifth Portion Procedure

There are no active aids used in this portion for the crew module evasive maneuver away from the failed Launch Vehicle. So the nominal spacecraft separation aids are employed. On the “Авария” signal the CAC automatic equipment issues commands for the Launch Vehicle Propulsion System emergency cut off and for the spacecraft crew module nominal separation. The КСП operation follows the nominal time program.

Sixth Portion Procedure

It is this portion’s peculiarity, that in case of emergency separation the spacecraft injection to off-nominal orbits is possible. So based on the long duration (>30 min) crew life support requirement for the off-nominal orbit flight the crew rescue is executed within the integrated spacecraft. On the “Авария” signal the CAC automatic equipment translate command for the spacecraft nominal separation from the Launch

Vehicle 3rd stage. The separation is accomplished followed by the spacecraft descent. The integrated spacecraft separation is executed nominally at the atmosphere reentry. The spacecraft landing aids operate on the nominal program.

Fig. 1. CAC System Diagram

1. Stabilizer.

2. I-III, II-IV - Stabilization Planes.

3. View A:

БГ - Balance Weight;
УРД - Attitude Control Thrusters;
РДР - Separation Thrusters;
ДУ САС - CAC Propulsion System;
ЦРД - Central Rocket Engine;
ГО - Aerodynamic Cap;
ДСС - Section Jettison Thrusters;
ВО - Upper Support;
РДГ - Cap Thrusters;
БО - Habitable (Crew Resting) Module;
СА - Descent Module;
НО - Lower Support;
ВСК - Cosmonaut Visual System.

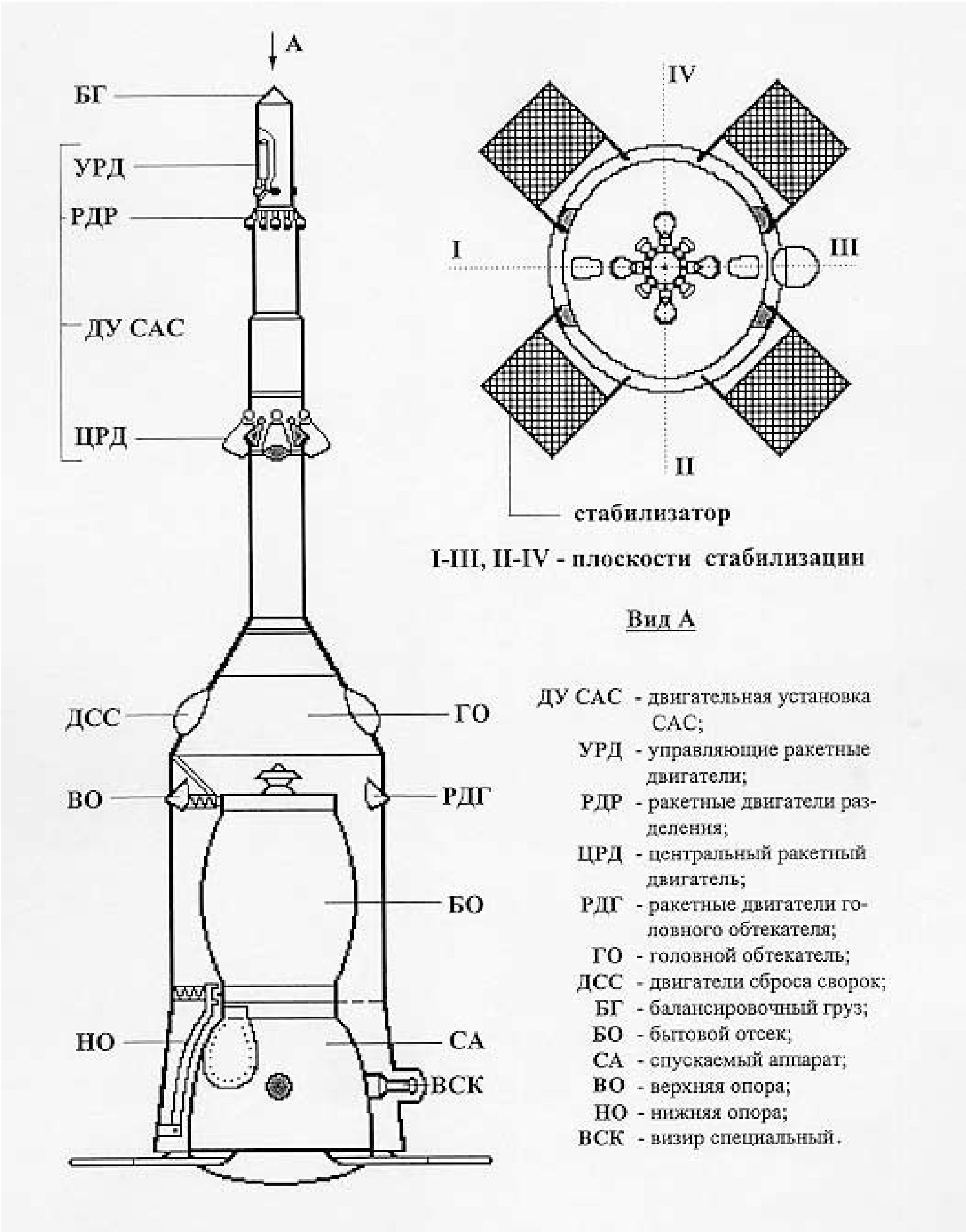


Fig. 1. CAC System Diagram.

3.21. НОСИМЫЙ АВАРИЙНЫЙ ЗАПАС (НАЗ) (POST LANDING SURVIVAL KIT)

НАЗ PURPOSE

The "Granat 6" НАЗ is designed for the Soyuz spacecraft crew life support at the off nominal landing site during not less than 3 days.

НАЗ COMPOSITION

The НАЗ Kit is made up of the following component groups:

1. Emergency radio and illumination aids;
2. Camp outfit;
3. Water/Meals group;
4. Weapon;
5. Medical Aid Kit;
6. Individual buoyancy aids;
7. Thermal protection garment.

The НАЗ components are stowed in three units and 13 soft packs and are located in the CA Module.

Unit 1

The Unit 1 bag is made of orange capron. In the bag there are: potable water canister, crew checklist for off-nominal solid ground landing/water splashdown and a polyethylene flask. At the bag side in the pocket there is a mouthpiece for water drinking.
The 6 liter canister is made of Aluminium alloy and has two orifices: the greater one and the smaller one. The smaller orifice is used for inserting the mouthpiece and is covered with a thread plug. The greater orifice makes it easier to fill the canister with water, snow or ice to be melted and is covered with a coupling connector and a coupling nut. The crew checklist is put into a polyethylene bag and soldered. The soft polyethylene flask in tissue jacket is used for water stowage under the garment in cold weather.

Unit 2

The Unit 2 bag is made of rubberized tissue of orange color and has two pressure tight sections. In the upper section there are food rations and salt. In the lower section there are the medical aid kit and camp outfit articles. The medical aid kit contains medicines and dressing material. The medical kit composition and usage instruction data are on the label sticked to the kit cover inner part. The camp outfit includes: fishing tackle, dry fuel, wind resistant matches, needles/threads, wire saw (3 pcs.). The medical cloak (3 pcs.) can also be used for precipitation/overcooling/overheating protection and for water collection. To provide for the crew meals there are three meal a day food rations for each crewman in the НАЗ Kit.

Unit 3

The unit is composed of two pressure tight bags connected to each other and to the raft which is laced up above. In the lower bag there is the emergency radio set with cables and power supply sources, signal/illumination aids, a lantern, light filters, a whetstone for sharpening knives, sticky plasters, a measuring glass and packets for vomit excreta. In the upper bag there are weapon, a machete knife in casing, the Air Force graded multi-tool knife and cartridges in bandoliers. The raft purpose is to provide for the Unit 3 positive buoyancy.

The emergency VHF band radio set purpose is to enable the off-nominally landed crew to communicate with the Search/Rescue Service planes and helicopters and to direct them to the crew actual position in the area. The radio set can operate in two modes: "Связь" (Communication) and "Маяк" (Beacon). The radio set is equipped with three power sources.

The weapon is a three barrel pistol ("ТП-82" make). It is designed for light/audio signaling, hunting/game shooting and defense for beast-of-prey. For the upper two smooth-bore barrel shooting 12,5 mm cartridges are used, for the lower rifled barrel 5,45 mm bullet cartridges are to be used. The machete knife in casing can be used as a butt for the weapon. For giving light signals light signaling aids are used.
There are hydraulic combination suits (3 pcs stowed in one soft package) which are individual survival aids in case of the CA water surface splashdown. The suits have two eye-loops each to enable the crewman to be lifted from the water surface on board the hovering helicopter.

The thermal protection garment (3 sets, each stowed in 4 soft packages) is designed for the crew protection on the ground at the temperatures of down to -50 ° C and at the wind speed of up to 10 m/s. The set can be worn together with the underwear, flight suit and the hydro-suit. It consists of: combination suit, jacket, high boots, helmet, cap, fur socks and wool gloves.

4. SYSTEMS' OPERATIONAL LIMITS AND CHARACTERISTICS

Soyuz Spacecraft Main Technical Characteristics

#	Characteristics	Values
1	Launch weight	7000 kg
2	Total spacecraft body length	7000 mm
3	Maximal diameter	2720 mm
4	Solar battery wing span	10700 mm
5	Solar battery area	10,4 sq. M
6	Diameter of habitable modules	2200 mm
7	Volume of habitable modules (for gas content)	10 cu. M
8	CA module weight (crew ingressed)	2100 kg
9	Payload: – payload injected into orbit – payload returned to the Earth	 50 kg 50 kg
10	Propulsion System: – Propellant total charge capacity – СКД thrust – ДПО-Б thrust – ДПО-М thrust – СКД propellant flow rate – ДПО propellant flow rate – Propellant consumption for 1 m/s increment	 840 kg 300 kgf 13,8 kgf 2,5 kgf 1 kg/s 0,4 kg/s 2 kg
11	Power Supply System: – voltage – buffer battery capacity – back up battery capacity – CA battery capacity – solar battery current	 27 V 340 A/h 280 A/h 120 A/h 22 A
12	Landing System: – rated landing point hit accuracy – parachuting descent rate (primary parachute) – parachuting descent rate (back up parachute) – landing contact vertical velocity (parachute + soft landing thrusters)	 ±30 km 6,7 m/s 9,8 m/s 2 m/s

Soyuz Spacecraft Orbit Injection Flight Phase Parameters

#	Parameter	Time t, s	Velocity V, m/s	Altitude H, km	Range L, km	Acceleration N.x1, g
1	Lift Off Contact	0	0	0	0	0
2	Lift	8	29	0,1	0	1,4
3	Pitch Mnvr	20	81	0,8	0	1,5
4	Ram (Q)max	65	455	11,1	16	2,2
5	St I Cut Off (ГК I)	118,03	1560	41,5	39	3,5
6	ДУ САС Jettison	121,23	1670	45,4	41	3,5
7	Cap (ГО) Jettison	156,31	1900	85	109	1,25
8	St II Cut Off (ГК II)	285,05	3680	168	418	2,46
9	Tail Flare (ХО) jettison	305,78	3809	176	500	1,0
10	St III Cut OFF (ГК III)	526,13	7492	208	1600	3,25
11	Sepacecraft/LV Separation	529,43		208	1640	0

КДУ Propulsion System Operational Limits and Characteristics

#	Technical Characteristics	Values
1	Propellant Total Charge Capacity	440 - 892 kg
2	Pressurization Gas Spherical Bottle Operational Pressure	350 - 30 kgf/cm2
3	Propellant Stowage Tank Admissable Pressure for the Thruster Operation	14 - 22 kgf/cm2
4	СДР Caution/Warning Sensor Actuation Pressure	24±1,5 kgf/cm2
5	СДД (СДО, СДГ) Caution/Warning Sensor actuation Pressure	12±0,5 kgf/cm2

6	Oxidizer to Fuel Ratio	1,85
7	СКД Cover Opening/Closing Time	15 - 25 sec

СИОС Descent Reaction Control System Operational Limits and Characteristics

#	Technical Characteristics	Values
1	Monopropellant Charge Capacity	29,6-31,4 kg
2	Nitrogen Stowage Pressure Range (Р.над1.,Р.над2)	270-350 atm
3	Peroxide Stowage Tank Pressure Range	1,5-4,5 atm
4	Peroxide Allowable Pressure for Thruster Operation (Р.пер1, Р.пер2)	15-18 atm
5	System Readiness for Operation Time after Opening Nitrogen and Peroxide Starting Valve Opening	not more than 10 sec
6	System Operativeness Time since Filling Moment	195 days

ССВП Docking/Internal Transfer System Operational Limits and Characteristics

#	Technical Characteristics	Values
1	Berthing parameters at the moment of contact: – Longitudinal approach speed Vx – Lateral approach speeds Vy, z – Roll angle mutual error – Pitch and Yaw angle mutual error – Relative angular rates	 0,1 ÷ 0,35 m/s < 0,1 m/s ± 10 degrees ± 7 degrees ± 0,6 degrees/s
2	Excentricity (Central aiming error)	± 340 mm
3	Maximal ПСМ Drive force at Rod retraction	1500 kg
4	CM Rod extension time	6 ± 9,5 min
5	CM Rod Head Latch extension/retraction time	2 ± 3 min
6	Maximal МГС force at structural Ring latching	20 tons
7	Maximal МГС force at structural Ring latching when АСА and ПСА Hooks are closed simultaneously	40 tons
8	МГС Hooks opening and closing time	3 ± 5 min
9	Total force of the four spring pushers at separation	300 kg
10	Spacecraft/station separation velocity at pusher action	0,15 m/s
11	Transfer Hatch diameter	800 mm
12	System weight	200 kg
13	АСА Assembly service life	5 dockings/ undockings
14	ПСА Assembly service life	20 dockings/ undockings

СОТР Thermal Conditions Control System Operational Limits and Characteristics

#	Technical Characteristics	Values
1	Air temperature in habitable modules	+18 ÷ +25°C
2	Instrument/assembly temperature in their location area	+0 ÷ +40°C
3	Air relative humidity	< 75%
4	Air speed in the habitation area	0,1 ÷ 0,8 m/s
5	Air speed in the instrument area	0,05 ÷ 1,5 m/s
6	Gas temperature in the ПО Module	0 ÷40°C
7	Operational pressure in all hydraulic loops	0,5 ÷2,0 kg/cm^2
8	СТР System service life	4500 hrs

СЭП Power Supply System Operational Limits and Characteristics

#	Technical Characteristics	Values
1	Onboard bus D.C. energy	< 85 A
2	Onboard network voltage	23 ÷ 34 V
3	ББ capacity guaranteed	340 A/h
4	ББ service life	100 discharge/ charge cycles
5	РБ capacity guaranteed for the first discharge (service life is two discharge/charge cycles)	280 A/h

6	СА Battery capacity guaranteed (after 180 day stowage)	100 A/h
7	СБ current/voltage when in Sun Orientation with accuracynot worse than ± 10 degrees	26 A 34 V

СКГС (Interface Pressurization Control) System Operational Limits and Characteristics

#	Technical Characteristics	Values
1	МВ Vacuum Pressure Gauge measurement range	1 ÷ 960 mm of Hg
2	МВ measurement error	< 2 mm of Hg
3	КЭИ Indicator measurement range	1 ÷ 1000 mm of Hg
4	КЭИ measurement error	<95 mm of Hg
5	БП Volume	250 l
6	МП Volume	2,5 l
7	Pressure feed to БП: - from БО - from ОБ	 < 1 min < 30 min

ТВС Television System Operational Limits and Characteristics

#	Technical Characteristics	Values
1	TV image color (Display)	black & white
2	Exterior TV camera field of view (ШУ mode)	64x50°
3	Exterior TV camera field of view (УУ mode)	13,50x10,20°
4	СА module TV camera field of view	60x50°
5	TV camera maximal allowable continuous operation time	1 hr 30 min
6	TV camera warm up time	30 s
7	TV transmitter max. allowable continuous operation time	30 hrs
8	TV transmitter warm up time	120 s
9	TV frame dimension format (w/h)	4/3
10	Decomposition method	every other line
11	Line scan frequency	625 Hz
12	Frame scan frequency	25 Hz

БР-9ЦУ Equipment (СБИ System) Operational Limits and Characteristics

#	Technical Characteristics	Values
1	Total weight	95 kg
2	Maximal data rate	25600 1/sec
3	ЛК channel sampling rate	50 Hz
4	Number of channels	8
5	Number of ЛК channels	64
6	ЗУ memory capacity	6 M words
7	Telemetry frame capacity	512 words
8	Word capacity	8 bits
9	Service life	1500 hrs

Мир-3-А1 Equipment Operational Limits and Characteristics

#	Technical Characteristics	Values
1	Total weight	18,5 kg
2	Maximal data rate	6000 1/sec
3	Channel sampling frequency	31,25 Hz
4	Number of analog channels	64
5	Number of digital (signal) channels	128
6	Continuous operation time	76 minutes
7	Service life	50 hrs

ВСК-4 System Operational Limits and Characteristics

#	Technical Characteristics	Values
1	Central system field of view angle	15°
2	Central system magnification	(0,7 – 0,1)
3	Central system lens aperture diameter - not less than	77 mm
4	Visor axis angle relative to central system axis	0 and 84°

5	Field of view angle of each peripheral system visor tube: – in radial direction – in tangential direction	 14° 30°
6	Peripheral system magnification	(0,09-0,01)
7	Peripheral system lens aperture diameter - not less	60 mm
8	Power supply voltage	27^{+7}_{-4} V
9	Power consumption	15 W

ВНУК-К System Operational Limits and Characteristics

#	Technical Characteristics	Values
1	Objective relative aperture	1:1,8
2	Objective focal distance	36 mm
3	Field of view angle: - with ВСК-4 - in autonomous mode	 12, 20° 37°
4	Brightness gain : - with ВСК-4 - in autonomous mode	 600 900
5	Grid rotation	20+1

ВП-2 System Operational Limits and Characteristics

#	Technical Characteristics	Values
1	Field of view angle	10°
2	Magnification	1
3	Output aperture diameter	18 mm
4	Output aperture offset from the instrument axis	110 mm
5	Power Supply Voltage	27 V

ЛПР-1 Operational Limits and Characteristics

#	Technical Characteristics	Values
1	Ranges to be measured through the window	145-6000 m
2	Measurement error	±10 m
3	Visor field of view angle	6,7°
4	Warm up time for measurement	5 s
5	Time for measurement data display in the left ocular	4±1 s
6	ЛПР service life (single battery powered)	300 measurements
7	Continuous operation time	5 hrs

СОГС Atmosphere Revitalization System Operational Limits and Characteristics

#	Technical Characteristics	Values
1	Operational time with 2/3 man crew	4,2 days
2	Total pressure in habitable modules	450-970 mm Hg
3	O_2 average consumption by one man	25 l/hr
4	CO_2 averege excretion by one man	20 l/hr
5	Carbon dioxide partial pressure	<10 mm Hg
6	Oxygen partial pressure	140-310 mm Hg
7	Water vapor partial pressure	<15 mm Hg
8	Injurious additives	not to exceed specified values
9	БОА Unit purification cartridge service life	60 man-hr
10	Regenerator service life (AT 20° C)	51 man-hr
11	Air flow rate through БОА primary fan	180 l/min
12	Air flow rate through БОА back up fan	120 l/min
13	P.CO_2 for purification cartridge replacement	10 mm Hg
14	БОА fan power	7,5 W
15	ГА Gas Analyzer warm up time	1 hr

ГА Gas Analyzer Operational Limit and Characteristics

#	Parameters	P.O2	P.CO2	P.H2O
1	Range (mm Hg)	0(80) - 350	0 - 25	0 - 35
2	Error (mm Hg)	± 12	± 1,5	± 2
3	Control command to the O2 Supply Valve: (mm Hg) - ОТКР ЭПК-РД - ЗАКР ЭПК-РД	 160 185	 - -	 - -
4	Emergency Signal (mm Hg)	≤ 120	≥ 20	

ДСД Caution/Warning Pressure Sensor Operational Limits and Characteristics

#	Technical Characteristics	Values
1	ДСД pressure range number	2
2	ДСД pressure range I	420-690 mm Hg
3	ДСД pressure range II	720-990 mm Hg
4	Interval between setting points	30 mm Hg
5	Number of ДСД setting points	20
6	ДСД actuation error	±20 mm Hg

СПГС Gas Mixture Supply Aids Operational Limits and Characteristics

#	Technical Characteristics	Values
1	O2 supply pressure to space suits	4,2 atm
2	O2 supply flow rate	23,5 l/min
3	Crew life support time in case of CA depressurization	125 min
4	Crew life support time using O2 from ПхО tanks	90 min
5	Crew life support time using O2 from CA tank	35 min
6	O2 supply flow rate through ЭПК-РД in CA for 4.2 days	6 l/min
7	Total O2 consumption for space suit tests	up to 240 l
8	Volume capacity of ПхО O2 stowage tank (4 pcs)	20 l
9	ПхО O2 stowage tank pressure	220 atm
10	Volume capacity of O2 stowage tank in CA (1 pc)	12 l
11	CA O2 stowage tank pressure	230 atm
12	Excess gas maximal pressure in CA	<950 mm Hg
13	Pressure range maintained after БАРД actuation	740-870 mm Hg
14	PO2 pressure in depressurized CA	≤ 10 mm Hg
15	CA/environment pressure equalization altitude	5,5 km
16	Ca O2 stowage tank pressure prior to landing	10 atm
17	CA total pressure increase rate at ЭПК-РД actuation	1 mm Hg/min
18	CA total pressure decrease rate at БАРД actuation	40 mm Hg/s

СВО Water Supply System Operational Limits and Characteristics

#	Technical Characteristics	Values
1	Stowage tank capacity	20 l
2	Feed tank capacity	0,85 l
3	Stowage time in stowage tank	360 days
4	Stowage time in feed tank	120 days
5	Silver content in water	0,2 mg/l
6	Rated daily water consumption by a crew member	1,7 l
7	Water charge in stowage tank for 3 man crew	19,7 l
8	Water charge in stowage tank for 2 man crew	12 l

АСУ Waste Management System Operational Limits and Characteristics

#	Technical Characteristics	Values
1	АСУ service life	12,6 man-days
2	АСУ collector capacity	10,8 l
3	Fan air flow rate	250±30 l/min
4	Rated one man daily urine excretion	1,2 l

«Sokol-KB-2» Space Suit Operational Limits and Characteristics

#	Technical Characteristics	Values

1	Time for crew stay in suit: ventilation ON, helmet open, gloves doffed (nominal operation) in 3-6 hr cycles	20 hrs
2	Time for crew stay in suit: ventilation ON, helmet open, gloves doffed (emergency operation) incl. 30 hr continuous operation	50 hrs
3	Time for crew stay in suit: ventilation ON, helmet closed, gloves donned	1 yr
4	Time for crew stay in suit: ventilation OFF, helmet open, gloves donned	1 hr
5	Life support time in case of CA depressurization	125 min
6	Life support time in case of CA depressurization using ПхО O2 stowage tanks (pre-separation)	90 min
7	Life support time in case of CA depressurization using CA O2 stowage tank (post-separation)	35 min

СУД Motion Control System Operational Limits and Characteristics

#	Technical Characteristics	Values
1	Time for establishing attitude in ОСК	<15 min
2	ОСК attitude establishment accuracy	1,5^{o}
3	Propellant consumption for ОСК attitude establishment	<1 kg
4	Attitude hold accuracy in ИСКТ	1,1^{o}/hr
5	Programmed rotation maneuver attitude rates: – in approach and in descent prior to separation – if the preset space angle for rotation maneuver is less than 36^{o}	 3,5^{o}/s 0,3^{o}/s
6	Time for programmed rotation maneuver execution	<120 s
7	Spacecraft automatic approach mode initiation range	<900 km
8	ЛСК attitude establishment accuracy	<1,5^{o}
9	Spacecraft station keeping range	100-200 m
10	Range rate (impact velocity) at contact	0,35-0,1 m/s
11	Spacecraft/Orbiter angular misalignment at contact	<4^{o}
12	Landing accuracy in АУС mode	30 km
13	Landing accuracy in РУС mode	60 km
14	Landing accuracy in БС mode	75 km

КСП Landing Aid Complex Operational Limits and Characteristics

#	Technical Characteristics	Values
1	Descent rate with pilot parachute (ВП)	230 m/s
2	Descent rate with brake parachute (ТП)	90 m/s
3	Descent rate with primary parachute (ОСП)	6,5 m/s
4	Descent rate with back up parachute (ЗСП)	9,5 m/s
5	ОСП parachute canopy area	1000 sq m
6	ЗСП parachute canopy area	590 sq m
7	Number of ДМП thrusters at CA bottom	6 pcs
8	Descent rate after ДМП thruster fire	2 m/s
9	Number of ДМП thrusters fired in descent with ОСП	6/4 thrusters
10	Number of ДМП thrusters fired in descent with ЗСП	6 thrusters

5. FLIGHT DATA FILE REVIEW

5.1. SOYUZ FLIGHT DATA FILE GENERAL CONCEPT

The Soyuz spacecraft flight data file (as of November 1997, Edition № 76/18) includes 5 type onboard checklist books:
- «Nominal Modes» book (one book for each crew member);
- «Back Up Modes» book (one book for Commander and one for Flight Engineer);
- «Off-Nominal Situations» book (one book for each crew member);
- «Reference Materials» book (one book for the crew);
- «Flight Plan» book (one for the crew).

There are 10 books onboard spacecraft for 3-man crew and 8 books for 2-man crew.

In the «Nominal Modes» book nominal flight operations are described successively in conformity with the nominal flight plan from pre-launch procedures up to descent and post landing crew operations. In describing the majority of operations two data presentation forms are used: block form and detailed form. The block form gives the crew a general outline of the operation to be performed, and the detailed form enables the crew to monitor step by step the status change in the spacecraft displays and controls while executing the operation.
To facilitate registering data transmitted from the MCC special underlined blank spaces are provided in the FDF.
In detailed nominal operation cyclograms references are made as necessary to other FDF books indicating the page where the necessary back up operation, off-nominal situation or reference data are presented.
In the «Back Up Modes» book back up operations is described successively in accordance with the nominal flight plan. The data presentation forms are identical to those of the nominal operation description.
The crew refers to the «Off-Nominal Situations» book as necessary either following reference in the «Nominal Modes» and «Back Up Modes» or on the results of the spacec raft system status monitoring.
The «Reference Materials» book is a collection of brief descriptions of all the spacecraft systems including their main technical performance data, block-diagrams and information on the status of the spacecraft systems and controls in various flight phases.
In the «Flight Plan» book every spacecraft flight day is briefly described in conformity with nominal and back up flight plan options.
Conventional notations/symbols used in the Soyuz spacecraft Flight Data File as well as adopted abbreviations/acronyms are presented in the beginning of each book (ref. Section 5.7).
The FDF is issued for the Soyuz spacecraft specific series: there are even and odd issue numbers (according to the spacecraft sequence number)

Note:
Revision of the Soyuz spacecraft flight data file composition is planned for June 1999.
The Soyuz spacecraft FDF (as of June 1999, Edition 204/205) will include 6 type books:
- *«Launch/Injection. Descent» book (pre-launch operations; launch/injection; spacecraft depreservation; transfer hatch closing; pre-undocking operations; undocking; nominal and urgent descent; additional retrofire maneuver in case of the СКД Engine failure in descent phase; post-landing crew operations);*
- *«Orbital Flight» book (СУД Test №1; Transfer to БО; Maneuvers №1 and №2; automatic approach, berthing, docking; interface pressurization test; transfer hatch opening; spacecraft preservation; operations in docked configuration; СУД Test №2; redocking);*
- *«Off-Nominal Situations» book (depressurization and fire in the СА and БО; envisaged off-nominal situations in selected spacecraft systems; crew operations most frequently performed in spacecraft);*
- *"Back-Up Modes" book (not revised)*
- *«Reference Materials» book (not revised);*
- *«Flight Plan» book (not revised).*

5.2. «NOMINAL MODES» BOOK

The «Nominal Modes» book is the principal checklist for the Soyuz spacecraft control and contains complete description of the crew nominal operations while executing the spacecraft flight plan in all the flight phases.
In this book data is presented in conformity with the flight plan execution for 2-man and 3-man crew options. In the 2-man option the Cosmonaut-Researcher's operations are performed by either

Commander or Flight Engineer depending on their actual location at the moment the Cosmonaut-Researcher's activity is required.
The checklist data contents and the form of its presentation are designed so as to be used by specially taught and trained crews.
The «Nominal Modes» book is issued for a specific series of spacecraft to fulfill identical tasks.
The book can be updated based both on the spacecraft system modifications and on the crew procedure development in simulation facilities.

When preparing for a dynamic mode execution the crew as authorized by the ground can take pages out of other FDF sections and insert them into the nominal cyclogram provided that the nominal cyclogram procedure should not be violated.

The «Nominal Modes» book contents are as follows:

1. General instructions.
   - 1.1 Crew responsibilities in executing the flight plan.
   - 1.2 Functional duty distribution among the crew members.
   - 1.3 Realizing in flight communication.
   - 1.4 Crew operation with the БЧК Onboard Clock.
     - 1.4.1 БЧК time synchronization.
     - 1.4.2 БЧК correction.
     - 1.4.3 Entering the ОП (Announcement) time.
     - 1.4.4. Crew operation with the Stop-Watch.
   - 1.5 «Globe» correction.

2. Pre-launch procedures.
   - 2.1 Crew ingress and the spacecraft preliminary inspection.
   - 2.2 Closing the СА/БО hatch door.
   - 2.3 СА equipment test and initiation.
   - 2.4 System status test.
   - 2.5 Communication test.
   - 2.6 ДСД sensor performance check.
   - 2.7 Space suit pressurization test.

3. Orbit injection phase.
   - 3.1 Spacecraft system status monitoring and pressurization tests of the СА, БО and ПО modules after КО.
   - 3.2 Descent: ДК circuit + Пр.5 program + АУС mode (in case of СА, ПО depressurization in the orbit injection phase).

4. ВИПШ (Docking Rod -to-initial position mode)

5. СУД system test № 1 («Kurs» system and ДК circuit test)

6. TV system test.

7. Crew transfer to БО module.

8. Opening СА/БО hatch door.

9. Space suit doffing, drying and stowage.

10. Purification cartridge replacement.

11. Regenerator preparation and switching ON.

12. Spacecraft system in-flight monitoring.
    - 12.1 Oxygen pressurization of the СА/БО modules.

13. Maneuver № 1.
    - 13.1 First (two-impulse) maneuver.
    - 13.2 preparation an d test of approach control/monitoring aids in the БО module.
    - 13.3 Second (single-impulse) maneuver + РУО-2 test.

14. Configuring approach/
    14.1 Crew duties in the approach/berthing procedure.

15. Space suit donning.

16. Approach/berthing.

17. Docking and spacecraft pressurization test.

18. Interface pressurization test
    18.1 МП (Minor volume) pressurization.
    18.2 МП pressurization test.
    18.3 МВ (Vacuum Pressure Gauge) pressurization monitoring.
    18.4 БП (Greater Volume) test without pressurization.
    18.5 БП pressurization from spacecraft.
    18.6 БП pressurization from ОБ (Station Orbital Module) (on ground instruction).
    18.7 МП integrity test after БП pressurization.
    18.8 МП integrity test.

19. Spacecraft/ ОБ pressure equalization.
    19.1 Spacecraft/ОБ pressure equalization procedure.
    19.2 Spacecraft/ОБ urgent pressure equalization procedure.

20. Transfer hatch door opening and transfer to ОБ.

21. Spacecraft preservation.
    21.1 Individual equipment replacement.
    21.2 Cosmonaut support replacement.
    21.3 Cargo replacement.
    21.4 ПГ (Payload) from ОБ to spacecraft or from spacecraft to ОБ.

22. Spacecraft operations in docked configuration.
    22.1 Transfer to combined power supply mode.
    22.2 ББ (Buffer battery) and (if necessary) РБ (Back up battery) refreshening charging.
    22.3 ББ and РБ refreshening charging termination (СЭП preservation).
    22.4 Transfer to autonomous power supply mode.
    22.5 Airflow vent of ВСК-4.

23. Spacecraft monitoring in docked configuration.
    23.1 System monitoring.
    23.2 МП integrity monitoring in docked configuration.

24. СУД System test № 2 (in docked configuration)

25. Returnable equipment packing.

26. Spacecraft depreservation.

27. Closing of transfer hatch doors.
    27.1 Preparation for closing ОБ/СУ(Docking assembly) and СУ/БО hatch doors.
    27.2 СУ/БО and ОБ/СУ hatch door automatic closing.
    27.3 ОБ/СУ and СУ/БО hatch door manual closing.

28. Transfer hatch pressurization test.

29. Preparation for redocking.

30. Redocking.

31. Preparation for undocking (for descent in case of docking failure).

32. Pressurization test of СА/БО hatch.

33. Undocking without picture taking.

34. Descent.
    - 34.1 БРВИ (Manual Data Load Unit) modes in descent
        - 34.1.1 Time synchronization mode.
    - 34.2 Descent № 2 ГЦ(Flexible Cycle)+ СКД (Orbital Maneuver Engine) +БО Module.

35. Post landing crew activities.
    - 35.1 Solid ground landing.
    - 35.2 Water surface splashdown.
        - 35.2.1 Floating CA egress.
    - 35.3 Rapping communication code.
    - 35.4 Post egress crew procedures.
    - 35.5 Post landing radio communication.
    - 35.6 Post landing communication regulations.
        - 35.6.1 Solid ground landing.
        - 35.6.2 Water surface splashdown.

36. Form 2. «Globe» correction.

37. Form 03 TK. Spacecraft system monitoring.

38. Tables and charts for range determination.

5.3. «BACK UP MODES» BOOK

The «Back Up Modes» book is a checklist for the back up mode execution. The back up modes are executed on Главная оперативная группа управления (ГОГУ) (Main Operative Control Group) (MSS) instruction.
A back up operation is the onboard system control, monitoring or maintenance activities envisaged to be accomplished to ensure the mission task fulfillment in case of necessity.

The «Back Up Modes» book contents are as follows:

1. General instructions.
    - 1.1. Crew responsibilities in executing the flight plan.
    - 1.2. Functional duty distribution among the crew members.

2. Urgent orbit rise.
    - 2.1. Urgent orbit rise using ГЦ (Flexible cycle).
    - 2.2. Urgent orbit rise with «Kurs» System test.

3. Maneuvers.
    - 3.1. Additional single-impulse maneuver.
    - 3.2. Additional maneuver №2 (two impulse, coarse mode).
    - 3.3. Additional maneuver №2a (single impulse, coarse mode).
    - 3.4. Additional maneuver №2б (single impulse, preceded by attitude maneuver).
    - 3.5. Additional maneuver №2в (single impulse, no preliminary attitude maneuver).
    - 3.6. Maneuver №3. Two pulse, PO manual attitude control in ДК digital circuit, according to ГЦ Flexible cycle with CO Solar barbecue mode.
    - 3.7. Maneuver with PO manual attitude control in AK analog circuit.

4. Back up approach modes.
    - 4.1 Preparing for approach.

4.2 Crew duties in approach/berthing procedure.
4.3 Back up approach/berthing mode with V.5 and V.6.
4.4 Approach/berthing without measurements using cupola («-X» axis).
4.5 Ballistic precision approach.

5. Elements of attitude control modes.
5.1 Configuring systems and «Chaika» СУД System switching on.
5.2 ОСК (Orbital coordinate system attitude establishment).
5.3 ИСК (Inertial coordinate system attitude establishment).
5.4 Attitude maneuver - rotation to a preset space angle.
5.5 СО+Закрутка (Solar attitude establishment and barbecue rotation).
5.6 СОиЗ in РО manual attitude control in АК analog circuit.
5.7 РО АК manual attitude control in analog circuit.
5.8 РО ДК (manual attitude control in digital circuit) starting from ОСК (ИСКт) attitude.
5.9 РО ДК manual attitude control in digital circuit.
5.10 Manual maneuver using ВП-1 through cupola in РО ДК to retrofire attitude.

6. Spacecraft/Orbiter Docked Cluster Back Up Attitude Control Modes.
6.1 Spacecraft(Cluster) attitude rate damping in РО АК.
6.2 Cluster barbecue rotation using Cluster aids: Spacecraft + Orbiter Core Module + Specialized Module + Cargo Transport Vehicle.
6.3 ТП + РУМИ Cluster mode: Spacecraft + Core Module + Specialized Module.

7. Redocking back up modes.
7.1 Redocking in automatic mode.

8. ССВП System back up modes.
8.1 Opening Orbital Module hooks.
8.2 Back up undocking.
8.3 СМ (Docking mechanism) jettison .

9. Back up descents.
9.1 Descent № 2 (ГЦ + ДПО-Бт thrusters)
9.2 Descent № 3 (ГЦ + РО ДК + СКД engine + БО)
9.3 Descent № 4 - АК circuit on Пр.9 program.

10. Undocking back up modes.
10.1 Undocking with picture taking.

11. БО Module jettison.

12. EVA
12.1 Spacecraft preparation for EVA.
12.2 Crew activities on EVA day.
12.2.1 Cdr and Flight Engineer activities.
12.2.2 Cosmonaut-Researcher activities.
12.3 Post EVA crew activities.
12.3.1 Cosmonaut-Researcher activities.
12.3.2 Cdr and Flight Engineer activities.
12.3.3 Crew activities when using БО as air lock.

5.4. «OFF NOMINAL SITUATIONS» BOOK

In the «Off Nominal Situations» book envisaged off nominal situations are presented both for the spacecraft as a whole and for its systems as well as the urgent descent procedure is described for the space suit being either doffed or depressurized as a consequence of some off nominal situations.

Besides for some situations of the spacecraft as a whole where the risk of the crew death is involved recommendations are given for the highest probability method to achieve crew survival.
The «Off Nominal Situations» book is designed for use by a specially taught and trained crews as their guide for off-nominal situation detection, diagnosis and elimination for the purpose of:

1. Ensuring flight safety.
2. Prevention of the off nominal situation further development.
3. Retaining the spacecraft system operability.
4. Ensuring the flight plan execution.

The crew will report all the off nominal situations and off-nominal deviation cases to the ground by codeless communication.

The principal order of the off-nominal situation presentation in the book is as follows:

1. Indication - data that tells the crew that there is an off-nominal situation with highest probability.
2. Crew activities - the off-nominal situation diagnosis and elimination.

The following term definitions are used in the «Off Nominal Situations» book:

1. *Off nominal situation*: a spacecraft equipment failure or an operative (non-operative) system parameter value deviation of its nominal status that could result in the nominal flight plan reconfiguration or in resorting to back up modes.
2. *Envisaged off nominal situation*: a situation which results from the equipment failure described in the FDF.
3. *Non-envisaged off nominal situation*: a situation which results from the equipment failure not described in the FDF.
4. *Nominal descent*: the descent on primary or back-up landing day to the nominal landing area from the primary or back up orbit revolution.
5. *Descent ahead of time*: the descent executed on the ground instructions ahead of the flight plan schedule to the nominal or back up landing area.
6. *Urgent descent*: the descent on the crew decision or the ground instructions from any orbit revolution using forms 23-14 if possible.

The contents of the «Off Nominal Situations» book are as follows:

1. General Instructions.

2. Depressurization.

3. Fire.
   - 3.1 Fire in БО.
   - 3.2 Fire in CA
   - 3.3 Crew transfer to CA using Изолирующий противогаз (ИПК) (Oxygen Breathing Gas Mask).

4. Off nominal situation at launch pad.

5. Off nominal situation in spacecraft systems.
   - 5.1. СУД (Motion Control System).
     - 5.1.1 Attitude control/maneuvers.
   - 5.2. КДУ (Combined Propulsion System).
   - 5.3. СИОС (Descent Reaction Control System).
   - 5.4. ССВП (Docking and Internal Transfer System)
     - 5.4.1. Docking.
   - 5.5. СКГС (Interface Pressurization Control Aids).
   - 5.6. СОГС (Atmosphere Revitalization System).
   - 5.7. СПГС (Gas Mixture Supply System).
   - 5.8. КСС (Survival Aid Complex).
   - 5.9. СОТР (Thermal Condition Control System).
   - 5.10. Water supply.

5.11. АСУ (Toilet).
5.12. Radio communication system.
5.13. TV system.
5.14. СЭП (Power Supply System).
5.15. СУБК (Onboard Complex Control System).

6. Urgent descents.
6.1 Preparation for urgent descent.
6.2 Urgent descent modes.
6.2.1. Descent ДК(Digital circuit) + Пр. 5 program+ БС (ballistic descent).
6.2.2. РО АК (manual attitude control in analog circuit) + БС.
6.2.3. ДК + Вкл. СКД с ПК (Orbital Maneuver Engine fire by crew command) + БС.
6.3 Post separation descent operations.

7. Operations frequently used (for reference).
7.1 СА/БО hatch door closing.
7.2 СА/БО hatch pressurization test.
7.3 Space suit donning.
7.4 Space suit pressurization test.

8. Radio communication forms.
8.1 Form 23-14. Ballistics data.

5.5. «REFERENCE MATERIALS» BOOK

The «Reference Materials» book is a supplementary flight data book and includes data on the design, operation logic, maintenance order and rules of the spacecraft systems, equipment and instruments which are under direct crew operation while executing the flight plan.

The book describes all versions of system usage modes and enables the crew to estimate the system status and performance in various flight phases. The scope of information on the system presented in the book depends on the system role in fulfilling
the flight objectives and generally includes the following data:

1. The system block diagram accompanied by the list of parameters displayed to the crew and commands issued by the crew from the ПК panel and ПВУ commands.
2. The system technical characteristics needed by the crew when analyzing the system actual performance.
3. Nominal status and nominal parameters of the system presented in order of the flight phase sequence.

The materials contents and their presentation form in the book are designed for the use of specially taught and trained crews capable of independent understanding and estimation of the situation onboard the spacecraft.

The «Reference Materials» book has the following contents:

1. General instructions

2. Motion Control System (СУД).
2.1. Technical characteristics.
2.1.1 CO Solar pointing and solar barbecue rotation mode.
2.1.2 ОСК attitude establishment using ИКВ (IR Vertical Sensor).
2.1.3 ОСК in РО manual attitude control using ВСК visual system.
2.1.4 Programmed attitude maneuver.
2.1.5 РУО Attitude control handle.
2.1.6 РУС Descent control handle.
2.1.7 Setting calculation (on the ground instruction).
2.1.7.1. Calculation of V (velocity increment) setting.

2.1.7.2. Calculation of t.гц1(2) setting.
2.1.8. РУО-2/КРУО (Rotation Hand Controller/RHC Commutator)and РУД-2/ КРУД (Translation Hand Controller/THC Commutator) connection chart in БО Module.
2.2. БРВИ Manual data entry unit.
2.2.1 БРВИ switching on.
2.2.2 БРВИ switching off.
2.2.3 БРВИ test.
2.2.4 Display test.
2.2.5 Display format setting.
2.2.6 System status monitoring data display program.
2.2.7 Current faults.
2.2.8 Forseen faults.
2.2.9 Urgent faults.
2.2.10 Instructions.
2.2.11 «Сервис СКД» (СКД Engine service data).
2.2.12 Entering АУС (Automatically Controlled Descent) first group (t)S setting.
2.2.13 Display of АУС first group setting.
2.2.14 Entering АУС second group (t.o, K) setting.
2.2.15 Display of АУС second group setting.
2.2.16 Entering РУС (Manual Controlled Descent) (S, K, N) setting.
2.2.17 «Предупреждение» (Warning)
2.2.18 «Командная информация» (Command data).
2.3. Control words.
2.4. Display formats.

3. Combined Propulsion System (КДУ).
3.1. Functional block diagram.
3.2. КДУ technical characteristics.
3.3. КДУ nominal status and parameters in various flight phases.

4. Descent Reaction Control System (СИОС).
4.1. СИОС technical characteristics.
4.2. СИОС nominal status and parameters in various flight phases.

5. Docking and Internal Transfer System (ССВП).
5.1. Functional block diagram.
5.2. ССВП technical characteristics.
5.3. ССВП nominal status in various flight phases.
5.4. ССВП operation mode elements.
5.4.1. Rod retraction.
5.4.2. Closing hooks.
5.4.3. Retraction of latches.
5.4.4. Extension of latches.
5.4.5. Monitoring of ОБ Module hook opening.
5.4.6. Opening of ОБ Module stops.
5.4.7. Manual closing of СУ/ОБ hatch door.
5.4.8. Dismounting of БО/СУ hatch door with СМ (Docking mechanism).
5.4.9. Dismounting of СМ.

6. Interface Pressurization Control Aids (СКГС).
6.1. Functional block diagram.
6.2. Technical characteristics.
6.3. СКГС nominal status and parameters in various flight modes.
6.4. СА/БО hatch door closing.
6.5. СА/БО hatch door opening.

7. Atmosphere Revitalization System (СОГС), Gas Mixture Supply Aids (СПГС), Survival Aid Complex (КСС).
    - 7.1 Functional block-diagram.
    - 7.2 СОГС technical characteristics.
    - 7.3 Space suit technical characteristics.
    - 7.4 СОГС operation modes in various flight phases.
    - 7.5 Purification cartridge replacement order and cartridge cap positions.
    - 7.6 СПГС and space suit nominal status and parameters in various operation modes.
    - 7.7 Space suit donning.
        - 7.7.1 Structural shell donning.
        - 7.7.2 Suit Donning.
        - 7.7.3 Donning of space suit with special glove.
    - 7.8 Space suit pressurization test.
    - 7.9 Space suit drying and stowage.

8. Thermal Condition Control System (СОТР)
    - 8.1 Functional block-diagram.
    - 8.2 Technical characteristics.
    - 8.3 Operation modes.
    - 8.4 Principle of crew operation with the PPB air flow regulator of XCA cooling/drying unit while air temperature adjusting.

9. Complex of Life Support Articles (СОЖ)
    - 9.1 Having meals.
    - 9.2 Water supply.
    - 9.3 АСУ Waste management system.
    - 9.4 Medical monitoring/
        - 9.4.1 Bracelet. Prevention of adverse flight factor effects in adaptation critical period.
        - 9.4.2 Motion sickness effect prevention using the ПША device.

10. Radio communication system.
    - 10.1 Functional block diagram.
    - 10.2 In flight communication procedures.
    - 10.3 Nominal status of transmitting/receiving aids in various flight phases.
    - 10.4 Tape recorder operation modes.
    - 10.5 Communication system operation.
    - 10.6 Operation in telegraph mode.
    - 10.7 Data radio exchange.

11. TV System.
    - 11.1. Functional Block diagram.
    - 11.2. Purpose and technical characteristics of TV system.
    - 11.3. Operation modes and functional diagrams.

12. Illumination.
    - 12.1. Control procedures.
    - 12.2. ФЭС Special electric lantern.

13. Power Supply System (СЭП)
    - 13.1. Functional block diagram.
    - 13.2. СЭП technical characteristics.
    - 13.3. СЭП nominal status and parameters in various flight phases.

14. Landing automatic equipment (АСП)
    - 14.1. Descent with primary parachute system (ОСП).

21.2. Safety measures.
21.3. Dismounting of K1-BKA-01 unit.
21.4. Dismounting of ПТС-250АТ-2.
21.5. Mounting of 2Ф4-ВКА.

5.6. «FLIGHT PLAN» BOOK

The «Flight Plan» book is a brief checklist for executing the Soyuz spacecraft flight and contains crew data on time and execution order for operations starting from the spacecraft orbit injection moment up to the spacecraft module separation in descent phase.
In the book operations are presented which the crew while following the nominal flight plan schedule as well as dynamic operation postponement scheme for several flight days fulfills.

The «Flight Plan» book contents are as follows:

1. Nominal Flight Plan.
   1.1 СТ20. Orbit injection. Tests. First maneuver.
   1.2. СТ21. Second maneuver.
   1.3. СТ22. Three impulse autonomous approach.
   1.4. СТ23. Redocking.
   1.5. СТ24. СУД System test № 2 in ОБ part configuration.
   1.6. СТ25. Undocking. Descent from the first orbit revolution in ГЦ БЦВК.

2. Dynamic Operation Postponement Scheme.
   2.1. Postponement scheme for dynamic operations in the first day.
   2.2. Postponement scheme for dynamic operations in the second day.
   2.3. Postponement scheme for dynamic operations in the third day.
   2.4. Postponement scheme for dynamic operations in the fourth day

5.7. CONVENTIONAL NOTATION/SYMBOLS IN SOYUZ SPACECRAFT FDF

The Soyuz spacecraft FDF notations/symbols are presented in Table 1.

Below a few examples are given to illustrate how the crew uses these notations/symbols (from Soyuz spacecraft FDF #76/18).

Example 1:
In «Nominal Modes» book on page 35 the operation of the ДСД Sensor actuation test is described. The crew puts the switch on the ДСД in the «720» position, the «СИГНАЛИЗАТОР-ВЫКЛ.» toggle switch - to the «СИГНАЛИЗАТОР» position, toggle switch to the «720-990» position (an example of using the conventional symbol №8). The increase of Р.НАСТР. results in illumination of the «ДАВЛЕНИЕ СА ПАДАЕТ» light on ТСЭ-3 indicator (Conventional symbol №1 is used to denote the light illumination). When the ДСД actuates the audio signal sounds and the ЦО Central Light blinks.(To indicate the ЦО blinking symbol №3 is used). Then the crew must write down the ДСД actuation pressure value - «Р.СРАБАТ» and report it to the ground. The place for this value registration in the FDF is denoted by symbol №33. Then the crew decreases the ДСД actuation pressure until the «ДАВЛЕНИЕ СА ПАДАЕТ» light on ТСЭ-3 goes off. (Symbol №2 is used to denote the light going off).

Example 2:
In the «Nominal Modes» book on page 48 the «ДК + Пр.5 + АУС» urgent descent cyclogram is described. When preparing to the operation the crew check the initial status of КСП and ТСЭ lights. The «СДД ОТКЛ» light must be off (symbol №2 is used) and the «2 СЕКЦИЯ НАДДУВА» and «2 СЕКЦИЯ КДУ» lights must illuminate (symbol № 1 is used). The tape recorder is switched on by the crew if it has not been on (symbol № 22 is used). The actions described in the frame are to be taken in case of the СА depressurization (symbol № 27 is used). At the time moment denoted «Т.Пр5» the crew initiates АПВУ program № 5 from the РУС handle which will illuminate the «УКОРОЧ ПРОГР СПУСКА» light on ТСЭ-2 (symbol № 1 is used). Beside the «Т.Пр5» inscription there is a straight line marking the space for writing down the program № 5 initiation Moscow time (symbol № 31 is used). One minute after program № 5 initiation The «Chaika» СУД System is powered automatically. The first minute of program № 5 is denoted by symbol № 20.

Example 3:
On page 61 of the «Nominal Modes» book the crew transfer to the БО Module after the spacecraft module pressurization test is described. To present the action sequence of the Commander in space suit ventilation switching off, disconnecting the space suit connectors and umbilicals symbol № 26 is used, the «Отстыковать шланги СК и разъемы Х3, Ш9» (Disconnect space suit hoses and X3, Ш9 connectors) instruction being presented by means of symbol № 7. The space for writing down the «Р.ТК(МВ)» value measured by means of the Vacuum Pressure Gauge is denoted by symbol № 32 and the space for writing down the «P.N2» nitrogen pressure calculated value - by symbol № 33. This is because the crew must report the P.N2 value to the ground in the next communication session and the P.TK(MB) value will be used by the crew throughout the flight. The off nominal situation which results in the urgent descent from the orbit (pressure decrease in the spacecraft of 2 mm Hg for the time period less than 10 minutes) is emphasized by means of symbol № 34. Notation № 28 is used for describing the crew procedure of switching off the БО Module atmosphere purification units and switching on the CA atmosphere purification units (operations at the end of page). On page 61 symbol № 29 is also used. For instance the КВД valve opening on the СКГС panel in the БО should only be executed by the crew after closing the РПВ-1 valve in the CA.

Example 4:
On page 15 of the «Off Nominal Situations» book crew procedures in case of the CA or БО depressurization are described. Here for emphasizing the actions to be executed simultaneously or with minimal interval between them symbol № 25 is used three times. On the same page the following graphical aid is used for emphasizing reference/caution information:

ВНИМАНИЕ! ЕСЛИ БЫЛО ЛОЖНОЕ СРАБАТЫВАНИЕ АРГУСА...

(ATTENTION! IN CASE OF «ARGUS» FALSE ACTUATION...)

Example 5:
In the «Off Nominal Situations» book on page 20 the crew activities in case of fire in the CA are described. Here symbol № 23 is used. The crew is instructed to obligatorily close the ЭПК-РД valve to shut off oxygen supply into the CA Module.

5.8. FDF IN-FLIGHT OPERATIONAL USE

Two months before the launch date (one month prior to the crew complex examination training session) the FDF set with the latest updates related to the forthcoming flight is transferred from the RSC «Energia» to the Gagarin Cosmonaut Training Center.
Three weeks prior to launch the Gagarin Center receives two sets of the Soyuz spacecraft FDF: one for the primary and one for the back up crew. During the pre-launch period which starts 14 to 10 days before the launch date the crew can introduce necessary marks and underline important positions in the FDF.
One or two days before the launch in Baikonur Launch Center the current ballistic data are introduced into the primary crew's FDF and writing aids (pens, pencils, erasers) are fixed to the FDF books. Thus prepared FDF is handed over to the RSC «Energia» representatives for stowing it onboard the spacecraft. The whole FDF set (except the Flight Engineer's «Back Up Modes» book and the «Flight Plan» book is stowed in the FDF container located in the CA Module and the Flight Engineer's «Back Up Modes» book and the «Flight Plan» book - in one of the payload containers in the БО Module.

After the crew ingress into the spacecraft 2,5 hours prior to launch time the cosmonauts get the «Nominal Modes» books from the FDF container and when necessary other books as well.
While the flight proceeds nominally the crew uses mainly the «Nominal Modes» booksreferring to other books when necessary. The crew is free to replace pages from one book to another if that makes the FDF use more convenient.

After the landing the FDF remains in the CA Module. If necessary it can be used by the crew and experts for analysis of specific flight situations and for preparing the crew post flight reports.

Table 1

Conventional Notation/Symbols in Soyuz Spacecraft FDF

1) □	Light illuminates and is on, does not go off
2) ■	Light goes off, stays off, does not illuminate
3) ◪	Light blinks
4) ⬓	Light is either on or off
5) ◨	Light changes status on the command issue (seldom used symbol)
6) ⟶	Connect
7) ⟵	Disconnect
8) ——	Reposition as instructed, transfer to
9) ↷	Clockwise
10) ↶	Anti-clockwise
11) ↷—	Clockwise until stop
12) —↶	Anti-clockwise until stop
13) ⌒	Adjust
14) 12:35:20	Hours, minutes, seconds
15) 12:35:	Hours, minutes
16) :35:20	Minutes, seconds
17) 03::	Hours
18) :05:	Minutes
19) ::08	Seconds
20) 10:Пр1	Tenth minute of Program 1
21) :01Пр12	First second of Program 12
22) /ВКЛ/	Execute action if it has not yet been executed
23) <u>ВКЛ</u>	Execute action obligatorily irrespective of whether it has been executed or not
24) | ВКЛ | ОТКЛ | ОТКР	Execute sequence of actions in strictly stated order
25) [ВКЛ ОТКЛ ОТКР]	Execute actions either simultaneously or sequentially with minimal interval
26) БИ : ВКЛ : ОТКЛ : ОТКР	Sequence of actions to be executed by the Flight Engineer
27) ВКЛ ОТКЛ ОТКР | ПРИ РАС-КОНСЕР-ВАЦИИ	Execute actions only at the indicated condition

28) ВКЛ БОА СА ОСН, РЕЗ БРУС	Execute in consecutive order several similar actions
29) ВКЛ... ─┴─┐ ВКЛ	Lower action is to be executed only after the upper action is executed
30) ::00 ОТКЛ :01: ОТКР	Execute action ОТКР (Open) 1 minute after action ОТКЛ (Switch Off)
31) __________	Space for registering current information uplinked from the ground
32)	Space for registering data necessary for subsequent crew operations or for post flight analysis
33) - - - - - - - - - - - - - - - - - -	Space for registering data necessary for current analysis
34)	Emphasis of references to off nominal operations or to actions in case of an off nominal situation

6. NOMINAL PROCEDURES

6.1. General Flight Program

The Soyuz manned spacecraft flight objective is:
- 2 - 3 man crew and payload delivery to Mir station or ISS;
- joint flight up to 180 days;
- crew and payload return to the Earth;
- return of the crew uncapable of using its nominal spacecraft from the orbital station to the ground.

The Soyuz spacecraft general flight program is shown in Fig. 1.

The Soyuz spacecraft is launched by Soyuz Launch Vehicle and injected into orbit the with the following parameters:
- inclination 51,6 degrees;
- period of revolution 88,44 minutes;
- maximal altitude of the orbit 240 km;
- minimal altitude of the orbit 200 km.

After the spacecraft injection into orbit the module pressurization test is conducted.
In the second revolution of the first flight day the following operations are accomplished: «Kurs» equipment test, ДК (Digital circuit) test, РУО (Rotation Hand Controller) test in АК (Analog circuit), accelerometer test, spacecraft solar pointing and Solar barbecue rotation.
In the third - fourth revolution two impulse interorbital transfer maneuver is executed.
In the 17-th revolution a single impulse maneuver is executed with the test of the back up РУО Controller set in the БО Module.
In revolution 33-34 three impulse autonomous spacecraft approach to the orbital station is executed which ends with berthing and docking in revolution 34 at the illuminated part of the orbit.
The approach/docking procedure is mainly monitored by the ground control tracking aids.
After the spacecraft and the orbital complex are docked and the hooks are closed the joint flight is begun with the capability of executing dynamic operations using spacecraft СУД and КДУ Systems including the docked cluster orbit correction, automatic and manual redocking from one docking node to another and СУД System tests.
3 - 4 days prior to the joint flight termination the pre-descent test of the СУД and the КДУ system is conducted. On the test results the decision is made on undocking and on descent mode selection.
In revolution 15 of the pre-descent day the spacecraft/station undocking is executed with the spacecraft attitude hold so as to align its «+X» axis along the velocity vector.
In revolution 16 of the pre-descent day the nominal descent cyclogram is initiated and the Orbital Maneuver Engine retrofire impulse is executed.
The spacecraft landing in the preset area is accomplished with the descent in the first revolution of the landing day.

6.2. Preparation for Launch

The pre-launch procedure starts with the Launch Vehicle installation with the spacecraft on the launch pad and ends with the launch.
Nominal preparation cycle at the launch complex is supposed to be completed in two days.
The following operations are executed at the launch complex:
- spacecraft radio system test for the joint operation with the ground radio complex;
- test of the onboard part of the command radio complex for the joint operation with the ground radio-command complex;
- test of the Launch Escape Complex readiness for launch;
- test of the onboard Launch Escape System as a part of the Launch Escape Complex;
- all system transfer into the flight configuration;
- spacecraft participation in the Launch Vehicle General Test.
- monitoring telemetry parameters of the spacecraft onboard system status;
- monitoring crew medical parameters after the spacecraft ingress;
- БО Module oxygen pressurization up to differential pressure of 0.1 atm for its integrity test;
- collection of launch readiness indications for the Launch Vehicle and the spacecraft;
- entering the Launch Escape System settings according to the flight schedule;
- Launch Vehicle/spacecraft lift off.

The spacecraft preparation for launch is conducted according to the launch complex technological plan.

The crew ingress into the spacecraft at the launch pad is scheduled for 2.5 hours prior to launch (using the ingress hatch in the БО Module. After the ingress the crew:

- conducts prelaunch inspection of the БО and СА equipment;
- connects hoses and connectors Х3, Ш9 to the space suits;
- switches on the suit ventilation;
- checks up the fastening system;
- establishes communication with the Launch Control;
- takes the cap off the СА purification cartridge;
- at T-2 hrs tests the СА/БО hatch door closing jointly with the launch team;
- positions the БЧК Onboard clock, СИРТ Propellant meter and ИНК Indicator into initial status;
- conducts checks and collection of all the equipment initial status;
- checks the radio communication system;
- switches on the ДСД Sensor/signalizer, checks its actuation and adjusts the indication pressure;
- fastens itself in the seats;
- conducts space suit pressurization test;
- monitors system parameters, total and partial pressures air temperature and humidity in the modules;
- writes down and transmits to the ground pressure and temperature in БО and СА.

6.3. Orbit Injection

The injection to orbit phase starts with the spacecraft launch (the «Контакт подъема» - Lift Off Contact command issue) and ends with the nominal spacecraft separation from the Launch Vehicle («Контакт отделения» - Separation Contact command issue). The injection flight phase duration is 530 seconds.
During the orbit injection phase all the constant operation system are switched on and also САС, СУС, КСС, and «Kvant» system are ready for operation (standby mode)in case of emergency flight abort.
Apart from that in the injection phase the crew status and the spacecraft status are constantly monitored using the crew reports and telemetry data coming from the РТС system (direct transmission mode) and «Клест-М» system (TV transmission mode from the СА).

The Launch Vehicle status is monitored by means of:

- visual status estimation within the visibility limits from the Launch Control shelter;
- telemetry data from the Launch Vehicle;
- crew flight procedure reports using the ПК СА display data and the Launch Vehicle control system indicators.

In the injection phase the crew must:

- conduct TV transmission (Transfer to the СА TV-camera 2 at 110-130 s after Launch);
- listen to the Launch Vehicle flight procedure data transmission;
- monitor the ГО Aerodynamic Cap jettison;
- monitor the КО command passing by the ИНК Indicator switching on and the indicator light status change;
- at the acceleration termination and transfer to weightlessness switch on the wrist watch Stop-Watch.

6.4. Orbital Flight (Maneuver)

The spacecraft orbital flight phase starts with the spacecraft separation from the Launch Vehicle Stage III («Separation Contact» command) and ends with the initiation of the autonomous approach mode (to the orbital complex) in the «Chaika-3» СУД System.

The following operations are executed in the orbital flight phase:

- post injection spacecraft structure and system operability and crew status monitoring;
- spacecraft system transfer to the initial position for approach and docking;
- phasing orbit shaping.

After the spacecraft is separated from the Launch Vehicle on the marks of program № 4 АПВУ the radar system antennae and Solar battery panels are deployed, constant operation systems are switched on and program №1 АПВУ is started for the communication equipment control. During communication sessions the spacecraft structure and system status and operability is monitored, crew medical status monitoring is conducted, spacecraft orbit radio tracking is accomplished, flight settings are entered into the БЦВК,

system operation is controlled and voice communication is conducted. The monitors the spacecraft/Launch Vehicle separation, onboard system status and operation by means of the ПК СА data and in 15 - 20 seconds after the separation switches off the СТД (Thermal Sensor System) isolating it from the actuation circuit.
During intervals between the dynamic operations the spacecraft is in passive rotation about «+Y» axis pointing to the Sun in order to charge up the СЭП System buffer batteries.
In the first revolution as a part of docking preparation the «ВИПШ» mode is executed (the docking mechanism rod is extended into the initial position). In the second revolution for the purpose of testing the operability of the СУД System automatic and manual control circuits as well as of the КДУ Propulsion System СУД System test № 1 is conducted, i. e. the СУД digital circuit test and РУО Attitude Hand Controller in РО АК mode. Tests are conducted on the second КДУ section. In the digital; circuit test procedure the two sets of the «Kurs» equipment, the two ИКВ Sensors and a selected set of the БДУС-I Sensor Unit.
In the second revolution on the results of the module pressurization test (the oxygen supply being terminated for the test period) the crew opens the СА/БО hatch door, checks the СА+БО volume pressurization using the Vacuum Pressure Gauge, doffs the space suits, switches on the БОА unit in the БО and switches off the БОА unit in the СА, periodically pumps out condensate.
On the results of the ВИПШ mode execution, the СУД and КДУ test the decision is made about further flight program.
Phasing orbit shaping maneuvers are executed on the БЦВК double «flexible» cycles:
- first maneuver (first and second impulses) - in revolutions 3 and 4;
- second maneuver (third impulse) -in revolution 17.

In the first maneuver the second КДУ section propellant is used and in the second maneuver - the first КДУ section propellant is utilized.
Nominally revolutions 6 - 11 (22 - 27) are scheduled for the crew resting.
In revolution 31 the crew dons the space suits, transfers to the СА, closes the СА/БО hatch door, leaves the atmosphere purification units in the БО in on position, connects hoses and connectors Х3, Ш9 of the space suits, switches on the space suit ventilation (the space suit pressurization is not tested), fastens themselves in the seats and conducts preparation for the approach to the orbital complex.
In revolution 33 on the БЦВК setting data command the autonomous approach mode is switched on.

6.5. Approach and Docking

The autonomous approach phase starts in revolution 33 and ends with the spacecraft station keeping at the range of 150 m from the orbital complex.
While executing the autonomous approach mode the crew is in the СА, in space suit donned and fastened to seats. The СА/БО hatch door is closed, the КСС is in standby mode.
At the range of 400 km the «Kurs» radar rendezvous system is switched on and the system performance test is conducted.
The approach and station keeping procedure is monitored by the ГОГУ Control Group (МСС) and by the crew:
- ГОГУ - by means of telemetry, TV and display data;
- Crew - by means of TV and display data, ВСК-4 image and the КСП and ТСЭ indicator light data.

In the radio communication zone of revolution 34 basing on the results of the approach procedure monitoring the ГОГУ gives GO to the crew for transfer to the berthing mode.
Nominally the spacecraft berthing is executed in automatic mode. While berthing the crew monitors visually the berthing parameters by means of TV and display data on the ВКУ device, ПК СА indications and the orbital complex image in the ВСК-4.
The crew uses the target on the orbital complex outer surface for monitoring visually the angular errors between the spacecraft and the orbital complex looking through the ВСК-4 visor.
The docking procedure starts with the contact of the rod head and the receiving cone and ends with the rod retraction up to the final position. The docking procedure is aimed at establishing rigid hermetically sealed interface and forming electrical and hydraulic communications between the spacecraft and the orbital complex.

The crew in space suits donned is in the СА and monitors the system status and the mode schedule execution.

6.6. Operations in Docked Configuration

The joint flight phase starts with the moment of the docking procedure termination and ends with the undocking command issue.
The following operations are accomplished in the joint flight phase:
- spacecraft and docking interface integrity check;
- transfer hatch opening;
- spacecraft preservation;
- spacecraft system monitoring in cluster (docked configuration);
- spacecraft depreservation;
- transfer hatch closing;
- preparation for undocking.

6.6.1. Spacecraft and Docking Interface Integrity Check

This operation is executed after the spacecraft/orbital complex docking or after the spacecraft redocking from one docking node to another.
The crew monitors pressure in minor and greater volumes by means of the Vacuum Pressure Gauge and pressure in the СА and БО by means of the КЭИ indicator and using the ККТ, ККС and КВД БО/СУ valves on the СКГС panel. On the monitoring time interval (45 - 60 minutes) expiration the crew equalizes pressure between the spacecraft and station volumes using the ККТ, КВД БО/СУ and КВД СУ/ОБ valves.

6.6.2. Transfer Hatch Opening

The hatches are opened after the integrity (pressurization) check of the docking interface between the spacecraft and station.
The hatches in the spacecraft and in the station are opened manually. For opening the БО/СУ and СУ/ОБ hatch doors a special handle with a stopper. The stopper is controlled by means of the lever which has two positions: operational and emergency. Prior to transfer to the station the crew sets a special plug onto the КСД СУ valve.
After the transfer hatches are opened the crew transfers to the station.

6.6.3. Spacecraft Preservation

The spacecraft preservation is executed in 1 - 2 revolutions after the hatch opening and the crew transfer to the station. The purpose of this operation is the service life saving of the spacecraft systems which are not planned to be used in the joint flight phase.
The crew executes the following main preservation operations:
- opens or closes appropriate valves of the СКГС, СПГС, and СОГС system;
- switches off the purification units in the БО and СА Modules;
- organizes air circulation in the spacecraft volume by means of the ВБО and ВСА fans and the ХСА СА and ХСА БО fans;
- lays supplementary air hoses through the open hatches for the air flow circulation from the station to the spacecraft;
- pumps out the condensate and executes the СОТР System preservation;
- executes the СЭП System transfer to the combined power supply mode (on the MCC instruction).

To conclude the preservation procedure the crew checks the status of indicator lights on the ТСЭ and КСП and switches off the panel and the СА illumination.

6.6.4. Spacecraft System Monitoring in Docked Configuration

While flying in the spacecraft/station docked cluster the crew acting on the MCC instruction executes operations for the autonomous or combined power supply mode transfer, for charging the buffer and the back up battery.
The spacecraft system monitoring is accomplished either independently or on the MCC instruction.
When the spacecraft system monitoring is accomplished in the cluster flight configuration the crew executes the following operations:
- switches on the СА illumination and the panel;
- checks up the light integrity on the ТСЭ and КСП;
- fills in the Ф.03ТК form comparing actual parameters with their nominal values;
- checks up the light status on the ТСЭ and КСП.

If any parameter deviates from its nominal value or if the light configuration differs from the FDF-indicated status the crew reports to the MCC.

6.6.5. Spacecraft Depreservation

The spacecraft depreservation is necessary to prepare it for undocking and descent or for redocking.
When preparing for undocking prior to nominal descent the depreservation is executed by the crew in the revolution 12 of the flight day.
The following depreservation operations are accomplished by the crew:

- switching on illumination and the panel in the CA;
- switching on the purification units in the БО and CA Modules;
- opening/closing appropriate valves of the СКГС, СПГС, and СОГС system;
- organizing nominal air circulation in the spacecraft volume by means of the ВБО and ВСА fans and the ХСА СА and ХСА БО fans;
- taking away supplementary air hoses and transferring them from the spacecraft to the the station;
- executing the СОТР System preservation and pumping out the condensate;
- executing the СЭП System transfer to the autonomous power supply mode (on the MCC instruction);
- checking the light status on the ТСЭ and КСП;
- executing the БЧК Clock and the ИНК Indicator correction.

If any parameter deviates from its nominal value or if the light configuration differs from the FDF-indicated status the crew reports to the MCC.

6.6.6. Transfer Hatch Closing

When preparing for undocking the crew executes the transfer hatch closing in revolution 13 of the flight day. As a rule this operation is accomplished in the MCC-indicated time during communication session.
In preparing for the ОБ/СУ and СУ/БО hatch door closing the crew switches on communication aids for MCC and intermodule communication and takes off the special plug from the КСД СУ valve.

There are two methods for the transfer hatch closing:

1) Automatic closing of the ОБ/СУ hatch door and manual closing of the БО/СУ hatch door (when there is no crew onboard the station).
2) Manual closing of the ОБ/СУ and the СУ/БО hatch doors (when there is a crew onboard the station).

To close the СУ/БО hatch door the crew checks up the rubber sealing and manually closes the ОБ/СУ hatch door until the stopper actuates. After that the crew executes manual closing of the ОБ/СУ hatch door and then closing of the БО/СУ hatch door using a special handle which is a part of the ССВП System instrument set.
When the two hatch doors are closed the crew checks up actuation of the hatch closing sensors.
After the spacecraft/station hatches are closed and prior to undocking in revolution 13 the pre-undocking transfer hatch pressurization test is conducted. The crew using the ПК СА opens the КСД СУ valve and monitors pressure in the СА, БО and ОБ Modules by means of the КЭИ Indicator. When the monitor time period (30 minutes) expires the crew starts preparation for undocking.

6.6.7. Preparation for Undocking

This operation is executed in revolution 14 of the flight day after the transfer hatch closing and their pressurization test.
Before the preparation for undocking the crew completes packing of the returnable equipment and dons the medical belts and the space suits.

When preparing for undocking the crew:

- switches off the ventilator and purification units in the БО Module;
- closes or opens appropriate valves of the СКГС, СПГС, СОГС Systems;
- manually pumps out the condensate;
- closes the БО protective grid;
- switchis on the air purification unit in the CA Module;
- closes the СА/БО hatch door;
- connects hoses and connectors of the space suits, switches on their ventilation.

The conclusive operations of the preparation for docking procedure are the space suit and the СА/БО hatch pressurization tests.
When testing the СА/БО hatch pressurization the crew closes the РПВ-1 cock and issues command for opening the КСД БО valve, then relives the БО pressure by 150 mm Hg. After that the crew monitors pressure in the СА and БО Modules for the time period of 25 minutes. If the СА pressure change is not more than for 25 mm Hg the crew opens the РПВ-1 and РПВ-2 cocks.

6.7. Undocking

The pre-descent undocking is scheduled for revolution 15 of the flight day. As a rule it is executed by the crew on the MCC instruction and under the MCC control during a communication session.
Prior to undocking the crew prepares for operation the РУО Controller, theВСК-4 Visual System switches on the tape recorder and the floodlight (when undocking in shadow) and switches on the ССВП System power. At the preset Т.РАССТЫК (T. Undock.) the crew issues command for undocking. In 3 - 4 minutes the crew monitors actual spacecraft/station undocking and moving from each other at the velocity of 0.12 - 0.15 m/s.
When concluding the post-undocking operations the crew switches off the ССВП System power.

6.8. Descent

6.8.1. Preparation for Descent

When preparing for the nominal descent the crew monitors (or enters when necessary) the control setting data for the descent execution. Nominally these data are entered into the БЦВК and into the СУС System via the КРЛ Uplink. Both the MCC and the crew monitor the correctness of the data entering procedure. The crew is authorized to change the setting data only on the MCC instruction.

6.8.2. Nominal Descent from Orbit

The nominal descent version is the descent with the use of the single flexible cycle - descent № 1 (ГЦ+СКД+БО).

The nominal descent procedure can be subdivided into two parts:
- descent before the module separation;
- descent after the module separation.

6.8.2.1. Descent Before Module Separation

From the undocking moment the spacecraft autonomous flight phase is started.
In the autonomous flight phase the crew must:
- monitor correctness of the descent setting data entering (БЦВК, СУС);
- maintain radio communication with the ГОГУ Group;
- Monitor the onboard system performance.

When executing the nominal descent the descent program starts with the ОСК attitude establishment and ends with the СА landing in preset site within the nominal landing area.

When descending before the module separation the crew:
- executes pre-descent system performance and status monitoring;
- monitors automatic initiation of the descent program and automatic orbital attitude establishment;
- checks the КДУ Propulsion System main parameters prior to the СКД Engine retrofire for the descent;
- monitors the СКД burn and its fulfilling the retrofire impulse;
- monitors the spacecraft main parameters after the СКД shut off;
- monitors pressure relief from the БО by means of the КЭИ Indicator;
- monitors preparation of the СУС System units;
- monitors spacecraft module separation in preset time.

6.8.2.2. Descent After Module Separation

When executing descent after the spacecraft module separation the crew:
- gives the "T.c." command at the СА preset atmosphere entry time;
- monitors the АУС automatic descent control circuit performance using «ТВ РУС» format of the ВКУ;

– monitors deployment of the ОСП primary parachute system at the altitude of 10 km;
– monitors the bottom shield jettison, oxygen relief from the CA stowage tank and the CA Module/environment pressure equalization;
– monitors the ОСП parachute rope rearrangement and arming of the seat shock absorbers;
– monitors the CA parachuting until the landing contact;

The descent trajectory after the module separation can be subdivided in three parts:

– Extra-atmosphere part which starts at the moment of separation Т.разд. (H=145 km) and ends with formation of the «lost» velocity value V.s=25.6 m/s (H=80 km) in the СУС System automatics. Formation of this value is considered the «atmosphere reentry» moment which is accompanied by the «ПЕРЕГРУЗКА» (overload, acceleration) light illumination on the ТСЭ-2.
– Atmosphere part which starts at the atmosphere reentry moment (V.s=25.6 m/s, H=80 km) and ends with the Primary parachute system deployment (H=10 km) which is accompanied by the «ВВОД ОСП» ("Input Deploy Prime Parashute") light illumination on the ТСЭ-5.
– Parachuting part starting with the Primary parachute system deployment (H=10 km) and ending with the landing contact when the «ПОСАДКА» (Landing) light illuminates on the ТСЭ-4.

6.9. Post Landing Operations

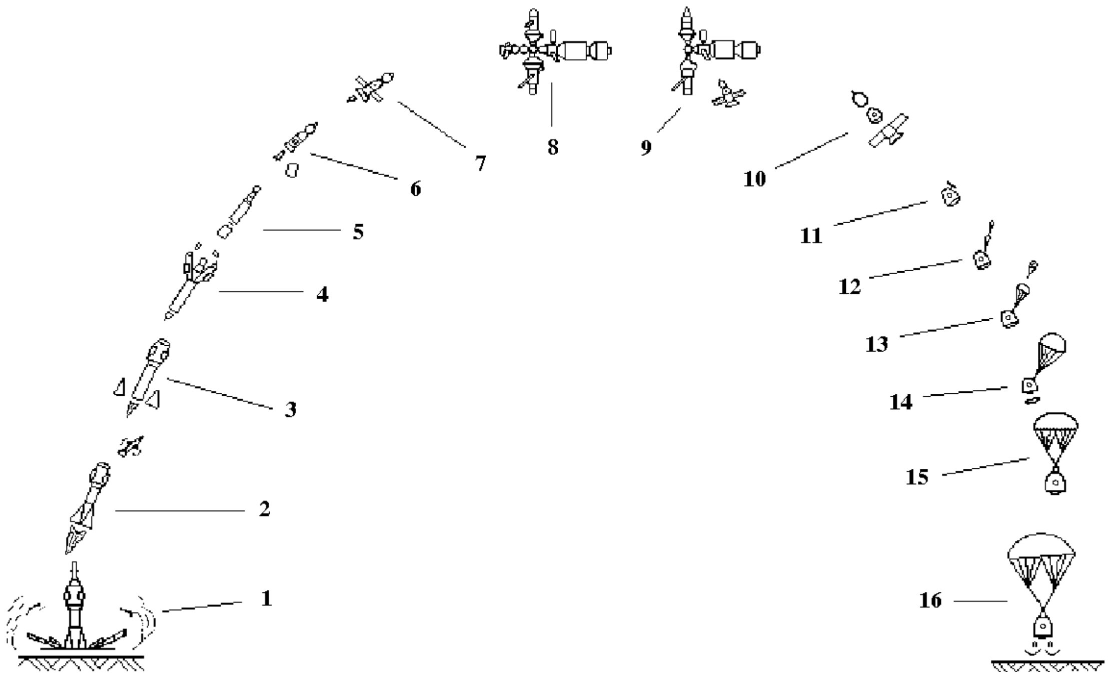
After landing onto solid ground the crew will first of all make sure the landing has taken place and only after that jettison the parachute. Then the crew checks the position of the breathing ventilation shutters - they must be open to ensure air passage into the CA Module.

After that the crew switches on the radio and light beacons to facilitate the operations of the Search/Rescue Service teams.

Besides, after the landing the crew must switch off the CA fan, the XCA CA fan and the tape recorder.

When splashing down onto water surface the crew closes the air breathing shutters and switches on the KBO Water cooling loop pump.

The crew must constantly try to establish radio contact with the ПСС Search/Rescue Service.



#	**Soyuz Spacecraft Flight Program Main Elements**
1	КП Lift Off Contact
2	ДУ САС Launch Escape System Propulsion System Jettison (H=46 km; T=115 s)
3	LV Stage I Separation (H=49 km; T=118 s)
4	ГО Aerodynamic Cap Jettison (H=84 km; T=165 s)
5	LV Stage II Separation (H=167 km; T=288 s)
6	Main Command for LV Stage III Shut Off, Weightlessness (H=202 km, T=526 s);КО Separation Contact (T=530 s)
7	Autonomous Flight (until Docking with Mir Orbital Complex) – up to 1,9 days
8	Joint Flight with Mir Orbital Complex (up to 180 days)
9	Undocking from Orbital Complex and autonomous Flight (up to 1,3 days)
10	Spacecraft Module Separation
11	ОСП Primary Parachute System Cover Jettison
12	ТП Brake Parachute Deployment
13	Brake Parachute Jettison, ОСП Main Parachute Deployment
14	Bottom Shield Jettison; Window Exterior Glass Jettison; БАРД Automatic Pressure Control Unit Opening (H=5,5 km)
15	ОСП Parachute Rope Readjustment; SW-transmission Primary Parachute System Displacement Cavity Pressurization; ЗСП Back Up Parachute System Displacement Cavity Pressure Relief in the CA
16	ДМП Soft Landing Thruster Firing; Landing; ДВ Breathing Ventilation System Valve Opening

Fig. 1. Soyuz Spacecraft General Flight Program

7. OFF-NOMINAL SITUATIONS

7.1. Off-Nominal Situation Major Terms

The off nominal (emergency) situation is a spacecraft equipment failure or an operative (non-operative) system parameter value deviation of its nominal status that could result in the nominal flight plan reconfiguration or in resorting to back up modes.
Envisaged off nominal situation is a situation which results from the equipment failure described in the FDF.
Non-envisaged off nominal situation is a situation which results from the equipment failure not described in the FDF.

7.2. Emergency and Caution/Warning Indication

For presenting emergency and caution/warning indication to the crew the ТСЭ Electroluminescent Indicator Displays located on the ПК СА Panel are used:
- The ТСЭ-4 contains yellow lights and is designed for the caution/warning indication display to the crew. Any ТСЭ-4 light illumination is accompanied by a continuous audio signal;
- The ТСЭ-3 contains red lights and is designed for the emergency indication display to the crew. When any of these red lights goes on an intermittent audio signal sounds and a special red color «ЦЕНТРАЛЬНЫЙ ОГОНЬ» (Central Light) (ЦО) blinks.

The ТСЭ lights give information to the crew on the modes currently executed and on onboard system parameter deviations beyond threshold limits, the indication signals being generated by system automatics.
When a caution/warning or emergency indication appears the audio signal is switched off by pressing the «ОТКЛ ЗВУКА» (ПК-21) key. When the audio signal is switched off the ЦО Central Light goes off. The lights go off after the cause of their illumination is eliminated, except the lights: «ВЫЗОВ НА СВЯЗЬ» (Communication Call), «АВАРИЯ БЦВК» (БЦВК Failure) (ТСЭ-4) and «АВАРИЯ ДК» (Digital Circuit Failure) (ТСЭ-3) which are put off by pressing the «СБРОС АВАР. СИГНАЛА» (Emergency Indication Reset) (ПК-9) key. When an emergency or a caution/warning signal is generated again the appropriate indication actuates again.
If when the audio signal is continuous an emergency signal appears the audio signals transfers to intermittent mode.
For checking up the ТСЭ lights one of the «КОНТР.ТСЭ» (ТСЭ Check) keys on the ПК СА (ПК-11 or ПК-23) should be pressed. For the time of this key is pressed all the ТСЭ lights are constantly illuminated The check mode is accompanied by an intermittent audio signal and the ЦО blinking.
The ТСЭ Check mode duration must not exceed 30 seconds.
When the «КОНТР. ТСЭ» (ПК -11 or ПК -23) key is released the ЦО goes off, the audio signal stops sounding and the ТСЭ lights resume their previous status.

7.3. Depressurization

In this section off nominal situations associated with the СА, БО and ПО module depressurization as well as the crew activities in these situations are treated conformably to the follow ing flight phases:
- orbit injection and the initial part of the autonomous flight;
- autonomous flight.

The «Available Time» term is used to denote the actual time at the crew's disposal for the survival operation execution in case of depressurization.

The lowest rated pressure level in habitable modules is assumed to be 400 mm Hg (i. e. the actuation pressure of the КСС System's «Argus» Sensor).
The following aids for depressurization detection and for the pressure fall rate measurement are used:
- the pressure sensors in the СА, БО and ПО Modules which send their information to the ВКУ Display;
- the МВ Vacuum Pressure Gauge for measuring pressure in the БО or in the СА+БО Volume (when the СА/БО hatch is open);
- the ДСД Pressure Caution/Warning Sensor;
- the КСС System's «Argus» pressure sensor.

In the orbit injection phase and in the initial part of the autonomous flight the crew is in the СА, the СА/БО hatch is closed, the КСС System is in the ready-to-operation mode (the space suits are donned, the helmet glasses are lowered, the gloves donned, the КСС Automatic Equipment is armed), the РПВ-1, -2 cocks are open, hoses connected to the space suits, the space suits fans are on, the ПБК toggle switch is in OFF position.

In case of the CA depressurization the crew estimates the available time judging by the pressure fall rate, switches the ПБК toggle switch into the ON position and executes descent in the second revolution.
In case of the БО depressurization the crew executes the descent ahead of time in revolution 3 or 17-19 with the БО separation.
In case of the ПО depressurization the descent ahead of time is executed in revolution 2 or 3.

In the autonomous flight the CA/БО hatch is open, the crew may be in any of the habitable modules (CA or БО), the КСС System is in the standby mode, the КСС automatic equipment is not armed, the ПБК toggle switch is in OFF position. The crew periodically checks the module pressurization using the ВКУ display and the MB Vacuum Pressure Gauge.
In case of the united module volume (CA+БО) depressurization the crew dons the space suits, transfers to the CA, closes the CA/БО hatch, connects the space suit hoses and connectors, dons the gloves, closes the helmets, switches on the space suit ventilation, arms the АКСС automatic equipment (by issuing the «АВТОМАТ КСС» (Automat Survival Aid Complex) command from the КСП-П (Ф-3), opens the РПВ-1, -2 cocks and determines which of the two modules is not integer:

- if the CA is depressurized the crew switches the ПБК toggle switch to ON and executes the descent ahead of time;
- if the БО is depressurized the crew executes the descent ahead of time;
- if the ПО is depressurized the crew executes either the descent ahead of time or the urgent descent.

In the autonomous approach, berthing and docking phase the CA/БО hatch is closed. The crew is seated in the CA with the suits donned, the КСС System is in the stand by mode (The helmet glasses are lifted, the gloves are donned).
In case of the CA or the ПО depressurization the crew terminates the approach mode, transfers the КСС System to the ready-for-operation mode, determines the available time and executes either the descent ahead of time or the urgent descent.
In case of the БО depressurization the crew terminates the approach mode and executes the descent ahead of time.

7.4. Fire

The following are the fire indications:

- burning odour;
- smoke;
- flame.

Fire on Launch Pad

If the crew detects a fire indication in the CA after the ingress into the spacecraft at the launch pad the crew immediately reports to the Launch Control and closes the space suit helmets. The launch is canceled. The ground personnel switches off the spacecraft power, the БО pressure is relieved (after the БО is oxygen-pressurized), the crew transfers to the БО, opens the БО ingress hatch jointly with the ground personnel and leaves the spacecraft.
In case of fire in the БО the spacecraft power is switched off. The launch is canceled. The crew stays in the CA and is stanby for the Launch Control instructions (The CAC Launch Escape System actuation is possible).
In case of fire indication detection in the CA in the injection active part the crew reports to the ground immediately. Using the КРЛ System the «Спасение» (Rescue) command is issued and the CAC System is actuated.
In case of fire in the БО the crew after the injection switches off the equipment operating in the БО, on the ground instruction relieves the БО pressure and executes the descent ahead of time.

Fire in Autonomous Flight

If the fire indications are detected during the autonomous flight the crew switches off the onboard equipment in order to localize the fire source and finds out the fire module and spot.
If the detected fire source is in the БО Module and the crew fails to extinguish it by switching off the equipment, then the crew transfers to the CA, switches on the CA atmosphere purification units, dons the space suits, transfers the КСС System to the Ready-for-operation mode (by issuing the «АВТОМАТ

КСС» command from the КСП-П Ф-3), closes the СА/БО hatch door, depressurizes and separates the БО Module.
In case of the СА overfilling with smoke the crew after the space suit pressurization test depending on how it feels is authorized to make a decision on the urgent descent with the СА compulsory depressurization.
If the fire source is detected in the СА and the crew fails to extinguish it by switching off the equipment, then the crew dons the space suits in the БО, transfers to the СА, checks the space suit pressurization and transfers the КСС System to the Ready-for-operation mode (by issuing the «АВТОМАТ КСС» command from the КСП-П Ф-3). To kill the fire the crew depressurizes the СА. Then depending on the time available the descent ahead of time or the urgent descent is executed.

7.5. Emergency Descent from Orbit

In the Soyuz spacecraft 4 urgent descent types are described:

1. «ДК+Пр.5+АУС» Descent

The «ДК+Пр.5+АУС» Descent is described in the «Nominal Modes» book (page 47).
This descent is executed after the spacecraft injection into orbit in case of the СА or the ПО depressurization. In this case the urgent descent cyclogram is initiated either in revolution 1 with landing in revolution 2 or in revolution 2 with landing in revolution 3.

The descent is executed in the reduced descent program - Пр. №5 and:
- the crew initiates the reduced program by issuing the РУС-2 «ПР.5» command using the РУС Handle at the Т.Пр.5 moment (Form 14);
- the ОСК orbital attitude is established using the digital circuit (БЦВК) and the ИКВ Sensor;
- the crew uses the ПК СА for the БО separation;
- the СКД Engine is configured for ignition by the Пр. №5 program marks;
- the СКД Engine is ignited automatically in 33 minutes after the Пр.№5 program initiation;
- the СКД Engine is shut off automatically when the retrofire impulse value of 89,6 m/s is reached;
- the module separation is executed by command of the Пр. №11 separation program;
- the atmosphere descent is the automatically controlled descent (АУС).

2. «ДК+Пр.5+БС(Т.СКД/Ф14/>:33)» Descent

The «ДК+Пр.5+БС(Т.СКД/Ф14/>:33)» Descent is described in the «Off Nominal Situations» book (page 75).
This descent is executed using data in Form 14 when the time available before the СКД Engine fire is more than 33 minutes.

The descent is executed in the reduced descent program - Пр. №5 and:
- the ОСК orbital attitude is established using the digital circuit (БЦВК) and the ИКВ Sensor;
- the crew uses the ПК СА for the БО separation;
- the СКД Engine is configured for ignition by the Пр. №5 program marks;
- the СКД Engine is ignited automatically in 33 minutes after the Пр.№5 program initiation;
- the СКД Engine is shut off automatically when the retrofire impulse value of 89,6 m/s (before revolution 3) or 115,2 m/s (after revolution 3 and for the rest of the flight time);
- the module separation is executed by command of the Пр. №11 separation program;
- the atmosphere descent is the ballistic descent (БС).

3. «РОАК+БС» Descent

The «РОАК+БС» Descent is described in the Off Nominal Situations» book (page 79).
This descent is executed using data in Form 14 when the time available before the СКД Engine fire is not less than 18 minutes.

This descent features the following:
- the orbital attitude establishment is executed by the crew manually using analog circuit (РО АК);
- the crew uses the ПК СА Panel for the БО separation;
- the СКД Engine is prepared for ignition and ignited manually using the ПК СА Panel;
- the СКД Engine is shut off automatically when the retrofire impulse value reaches 89,6 m/s (before revolution 3) or 115,2 m/s (after revolution 3 and for the rest of the flight time);

- the spacecraft module separation is executed on the СТД thermal sensor command;
- the atmosphere descent is the ballistic descent (БС).

4. «ДК+ВКЛ.СКД С ПК+БС»(Т.СКД/Ф14/<:33) Descent

The «ДК+ВКЛ.СКД С ПК+БС »(Т.СКД/Ф14/<:33) Descent is described in the «Off Nominal Situations» book (page 83).
This descent is executed if the necessity of the urgent descent arises after the time scheduled in this revolution for the Пр.№5 program initiation and the crew cannot wait for the Пр.№5 initiation time scheduled for the next revolution.
This descent is executed using data in Form 14 when the time available before the СКД Engine fire is less than 33 minutes.

This descent features the following:

- the crew executes the initiation of the reduced program by the РУС-2 «ПР.5» command from the РУС Handle at any moment after the urgent descent decision is made;
- the Пр.№5 program is used for recording the urgent descent setting data from the ДЗУ Memory into the БЦВК and also for selecting the thruster types and the instruments to be used for the attitude establishment. Having completed these operation the crew initiates the Пр.№3 program thus inhibiting the Пр.№5 program;
- the ОСК orbital attitude is established using the digital circuit (БЦВК) and the ИКВ Sensor;
- the crew uses the ПК СА Panel for the БО separation;
- the СКД Engine is prepared for ignition manually;
- the СКД Engine is ignited manually in the time moment prescribed by Form 14;
- the СКД Engine is shut off automatically when the retrofire impulse value reaches 89,6 m/s (before revolution 3) or 115,2 m/s (after revolution 3 and for the rest of the flight time);
- the spacecraft module separation is executed on the СТД thermal sensor command;
- the atmosphere descent is the ballistic descent (БС).

8. BALLISTICS, TRAJECTORY CONTROL AND FLIGHT CHARACTERISTICS

8.1. Orbit Injection

8.1.1. Launch Date and Daytime Selection for «Soyuz» Launch Vehicle

Launch date and daytime for the «Soyuz» Launch Vehicle with the Soyuz spacecraft are determined by the mission objectives. The illumination conditions are of major importance when selecting the spacecraft launch date. Therefore the spacecraft launch date is usually selected so as to ensure that the spacecraft orbit be in the Sunlight in revolution 34 in the communication zone with Schelkovo tracking station.
The launch daytime is selected so as to ensure coincidence of the spacecraft and station orbit planes in the rendezvous point. When the launch date is shifted the launch daytime is also shifted to earlier hours, one day shift in the launch date corresponding to 24 minute shift in the daytime.

8.1.2. Soyuz Spacecraft Injection to Orbit Scheme

The «Soyuz» Launch Vehicle, which launches the Soyuz spacecraft and injects it into orbit consists of three stages. The launch/injection active phase duration is 529.14 s. In 20 seconds after the «Launch» command the КП - Lift Off Contact actuates. Stage I burn duration is 118 s. The ДУ САС Launch Escape Propulsion System is jettisoned at the 115th second. The ГО Aerodynamic Cap sections are jettisoned at the 157th second. Stages I and II are separated at the 285th second (ГК II) and the tail flare (XO) is jettisoned at the 300th second. The injection trajectory scheme is shown in fig. 8-1.

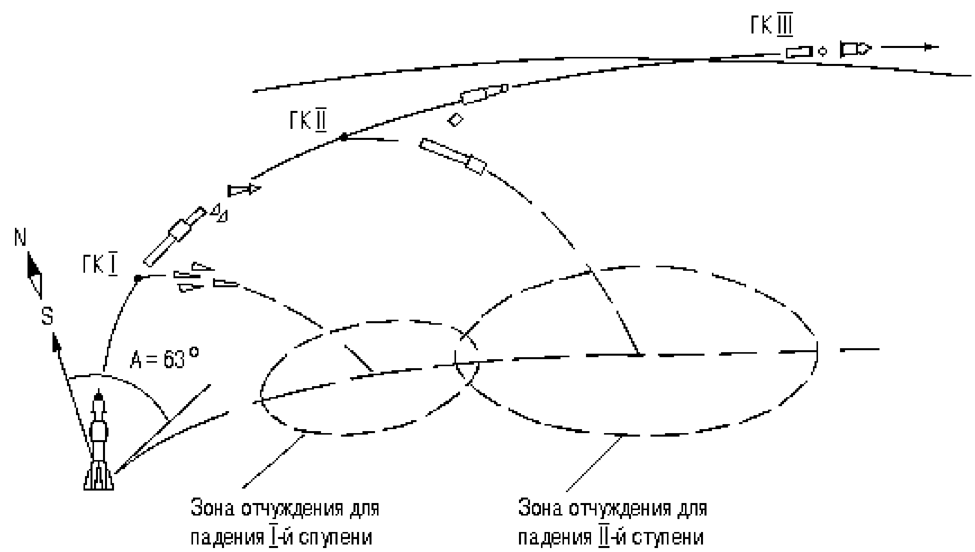


Рис.8-1: Выведение ТК "Союз ТМ" на орбиту

Fig. 8-1. Soyuz Spacecraft Injection to Orbit Trajectory Scheme.

1. Alienated area for Stage I fall down. 2. Alienated area for stage II fall down.

The burn procedure of the «Soyuz» Launch Vehicle Stages I, II and III ensures energetically optimal injection of the Soyuz spacecraft into approximately circular orbit with the mean altitude of 220 km. Besides, the Launch Vehicle motion program meets the following limitations:
1. Maximal acceleration in the spacecraft injection phase is 3.5 g which is «comfortable» enough for the crew.
2. Stage I operation program provides for the nominal dynamic ram Q.max<3700 kgf/m which limits the overloads effecting the Launch Vehicle structural body.
3. Stages I and II motion programs are selected so as to meet the requirement of the side and central rocket unit fall down within specified (alienated) areas.

Stage III pitch control program is aimed at the spacecraft injection into the nominal orbit perigee. The perigee injection target point minimizes the injection phase active part duration and consequently the gravitation losses.

The Soyuz spacecraft injection orbit parameters are shown in Table 8 -1.

Table 8-1

#	Parameter	Values
1	Period of revolution (T)	88,62 min (±22 s)
2	Inclination (i)	51,62 degr. (±3,5 min.)
3	Apogee altitude (H.max)	240 km (+43/-42 km)
4	Perigee altitude (H.min)	202 km (+7/-23 km)
5	Orbit existence time (t.сущ.)	301 revolutions

During the dynamic injection phase the Launch Vehicle is constantly in the radio «visibility» (coverage) zone of ground tracking stations (НИПs) which makes it possible to constantly receive telemetry and tracking data and estimate the injection orbit parameters.
The injection phase parameters are presented in Table 8-2.

Table 8-2

#	Parameter	Time t, s	Velocity V, m/s	Altitude H, km	Range L, km	Acceleration N.x1, g
1	Lift Off Contact	0	0	0	0	0
2	Lift	8	29	0,1	0	1,4
3	Pitch Mnvr	20	81	0,8	0	1,5
4	Ram (Q)max	65	455	11,1	16	2,2
5	St I Cut Off (ГК I)	118,03	1560	41,5	39	3,5
6	ДУ САС Jettison	121,23	1670	45,4	41	3,5
7	Cap (ГО) Jettison	156,31	1900	85	109	1,25
8	St II Cut Off (ГК II)	285,05	3680	168	418	2,46
9	Tail Flare (ХО) jettison	305,78	3809	176	500	1,0
10	St III Cut OFF (ГК III)	526,13	7492	208	1600	3,25
11	Sepacecraft/LV Separation	529,43		208	1640	0

In case of an off nominal situation onboard the spacecraft after the injection into orbit (depressurization, fire etc.) data for the descent ahead of time in revolutions 2 and 3 can be calculated using the БЦВК state vector (the radius vector R and velocity vector V projections on the axes of the selected coordinate system (inertial or Greenwich) at the given time moment t) at the moment of the spacecraft separation from the Launch Vehicle Stage III. Data for the descent ahead of time in revolution 3 can be updated on the results of the orbit radio tracking in revolution 1. The minimal required updates consist in a correction of the propulsion system retrofire ignition time and of the СУС System setting data. When there is a lack of available time for the setting data uplink by means of the КРЛ System they are communicated to the crew for manual entering using the ПК СА Panel.

8.2. Approach

8.2.1. Soyuz Spacecraft/Mir Station (ISS) Nominal Approach Scheme

The Soyuz spacecraft to Mir station (ISS) approach is executed for the crew and payload delivery onboard the station.
There are some requirements to the approach procedure:

- spacecraft to station berthing and docking must be carried out mainly in Sunlight;
- the approach conclusive operations must be conducted within the radio communication zone, maximal integral coverage of the spacecraft and station being desirable. This requirement is satisfied in the radio coverage zone of revolution 2 of the flight day;
- relative velocity (range rate) at the moment of contact must be low to provide for the «soft» spacecraft and station rendezvous.

These requirements to the approach procedure determine the rendezvous (target) point and safe rendezvous velocity (which should be practically decreased up to zero).

To ensure the spacecraft/station rendezvous in the preset point at the preset time it is necessary to choose the appropriate spacecraft waiting (phasing) orbit so as to completely eliminate the initial phase mismatch.
The phase (Φ) is defined as the angle between the spacecraft radius-vector and the station radius-vector and the initial phase (Φ.o) is the angle between the two radii-vectors at the momeny of the spacecraft separation from the Launch Vehicle (Separation Contact).
At present the Mir orbit is not corrected for a special rendezvous orbit shaping because of a large station weight which requires great characteristic velocity (energy) losses.
The initial phase Φo at the moment of the spacecraft injection may be of any value yet to minimize the spacecraft propellant consumption the initial phase is selected within 240 - 30 degrees.
This condition in turn imposes limitations to the launch date selection. And higher values of the initial phase require longer time for the spacecraft/station orbit phasing.
This requirement is satisfied by setting the rendezvous point in revolution 34 of the spacecraft flight (revolution 2 of the spacecraft and station flight day). The two-day scheme makes it possible to eliminate any initial phase mismatch.
In flight revolution 2 - 3 the spacecraft executes two orbit maneuver impulses ΔV.1 and ΔV.2 (~20 - 30 m/s) for optimal transfer to the phasing orbit (Fig. 8-2).
In revolution 17 - 18 a two impulse phasing orbit correction is scheduled, however as a rule one impulse maneuver is sufficient. This impulse corrects the phasing orbit mean altitude compensating the orbit fading due to the atmospheric drag. The ΔV.3 can be of~1 - 3 m/s value depending on state of the atmosphere. The phasing orbit parameters are selected so as to make this impulse always posigrade rather than retrograde. To optimize the approach procedure propellant consumption it is advantageous to raise the orbit altitude in correction maneuvers.
In revolutions 32 - 33 the spacecraft executes the three-impulse orbital transfer scheme (bi-elliptical transfer). The first impulse of this final maneuver is fired either in the end of revolution 32 or in the beginning of revolution 33. The second impulse is fired in 180 degrees in revolution 33 so as to ensure the rendezvous moment (arrival to the target point) with rated target vector ΔV.пр=15 m/s should taking place in a half-revolution - in the end of revolution 33 or in the beginning of revolution 34.
The target vector ΔV.пр is the difference between the station circular velocity in the target point and the spacecraft apogee velocity in the same point.
To ensure the «soft» spacecraft/station rendezvous the difference of the station and spacecraft orbital velocities ΔV.пр must be compensated for by the third spacecraft posigrade impulse. Actually the third impulse in this orbital transfer is executed by a number of small posigrade impulses which gradually diminish the spacecraft relative velocity in the station vicinity. So the actual spacecraft and station rendezvous takes place later than the preset rendezvous time T.пр. In reality the rendezvous time T.вст is 12 - 15 minutes later then the preset time T.пр. in the Schelkovo tracking station radio coverage zone.
It should be noted that as a rule all the remote guidance maneuver impulses are executed in the spacecraft orbital plane which is ensured by closed tolerances for the launch time.
Impulses correcting the orbital plane (i or Ω) are most disadvantageous. For instance to turn the plane of the spacecraft circular orbit with the Hкр=300 km just for 1 degree the maneuver impulse of ΔV=130 m/s is required which would result in absolutely intolerable propellant expenditure for the Soyuz spacecraft.

Note: For the purpose of ensuring safety the spacecraft approach with ISS is directed to the extended target point which is on the stattion OCK Coordinate System Z axis at the range of 1 km. The СУД System provides for the spacecraft motion along the target point trajectory by generating corrective lateral impulse to the spacecraft center of mass approximately 80 minutes prior to the moment of transfer to Proximity Approach portion.

8.2.2. Soyuz Autonomous Approach Flight Phase

The autonomous approach phase is actually the second interval of maneuvers , i. e. impulses ΔV.4, ΔV.5 and a series of conclusive corrections (replacing the ΔV.6 impulse in the target point) which equalize the spacecraft and the station velocities in the T.вст point (Fig. 8-3).
In the autonomous approach flight phase the «Argon-16» БЦВК (Computer) using the setting data and the uplinked spacecraft and station state vectors and on the minimal characteristic velocity consumption criterion computes the three-impulse approach scheme, i. e. the ΔV.4, ΔV.5 and ΔV.6 (ΔV.k1, ΔV.k2, ΔV.k3) impulses. At the preset time (approximately 360 degrees prior to the T.пр) the spacecraft executes the ΔV.4 posigrade maneuver. When the relative range decreases down to ρ=180 km the «Kurs» radar rendezvous system starts measuring the ρ range and the ρ’ range rate.
On the results of the relative motion parameter measurements the current spacecraft state vector is updated. A more accurate knowledge of the spacecraft motion parameters enables the БЦВК to do a new

computation of the maneuvers to be executed, this new computation as a rule resulting in a reduction of the characteristic velocity consumption and of the final spacecraft to station miss error.

When the spacecraft to station range is less than 37 km the «Kurs» System starts measuring the full scope of the relative motion parameters i. e. ρ, ρ' and Ω.лв. These measurements makes it possible to update the spacecraft motion parameters on the base of which the time, the value and the direction of the corrective impulse are determined for the two vehicle velocity equalization and elimination of the miss which might take place due to errors in the ΔV.5 maneuver execution.

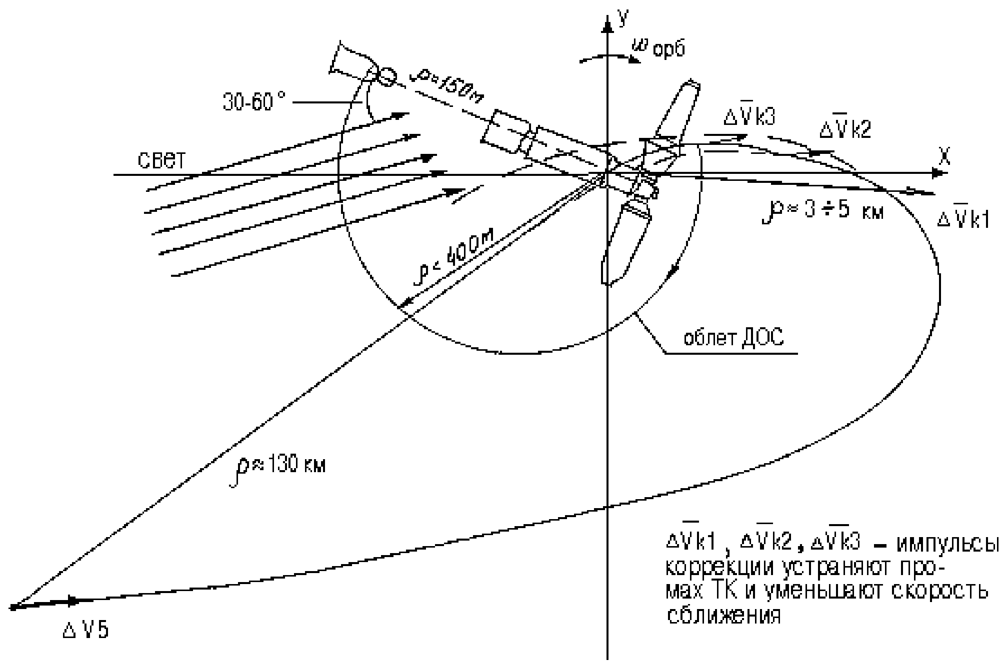


Рис.8-3: Автономный участок сближения после импульса ΔV5

Fig. 8-3. Autonomous Approach after ΔV.5 Maneuver.

1. ΔV.k1, ΔV.k2, ΔV.k3 (ΔV.6) are corrective impulses which eliminate the spacecraft miss and diminish the approach range rate. 2. Light. 3. Fly around the station.

The first corrective maneuver for the spacecraft and station velocity equalization can be executed at the ρ<13 km. Usually the relative range in this case is ρ=3-5 km. After tht correction the relative miss error is practically eliminated, however the range rate is still great enough and it should be decreased in forthcoming corrections. The first corrective impulse is usually 5-8 m/s and for diminishing the range rate 2 or 3 more such maneuvers can be executed. At the range of ρ=400 m and the range rate ρ'=2-2.5 m/s the spacecraft starts the station fly around to the docking node and simultaneously lowers the approach range rate. At the range of ρ=150 m and range rate ρ'=0 m/s the fly around is terminated (Fig. 8-4).

The approach ends with the automatic spacecraft berthing to the station at the ρ'=0.25 m/s. The target of the selected docking node must be illuminated by the Sun from below at the angle of 30 - 60 degrees. This requirement should be fulfilled in case of the automatic mode failure and transfer to the spacecraft manual control mode so as the cosmonaut be able to view the appropriate docking target in optimal light/shadow combination conditions. The light/shadow conditions do not change usually because as a rule (nominally) the Mir station (ISS) is in the inertial attitude hold mode so the sun illumination angle does not change. Prior to the range of ρ=400 m all the spacecraft maneuver impulses are calculated using the free trajectory technique and starting with the ρ=400 m the spacecraft parallel guidance algorithm is effective.

The spacecraft autonomous guidance system makes it possible to update the spacecraft state vector using the «Kurs» System measurements at ρ<180 km and while executing the ΔV.5 maneuver to partially compensate for the guidance errors (those are mainly the ΔV.4 maneuver execution errors). This resulted in a decrease of the ellipsoid of dispersion for the spacecraft/station nominal approach. After the ΔV.5 maneuver the ellipsoid of dispersion has the following dimensions:

ΔX=+1.5 km, ΔY=+0.3 km, ΔZ=+0.3 km

At the ρ<37 km the «Kurs» System takes measurements of the ρ, ρ', Ω.лв relative parameters thus determining the current spacecraft miss.
In the rendezvous target the ellipsoid of dispersion has no sense because after the first correction the spacecraft/station miss error is commensurable with the station size and is easily eliminated by subsequent control.

8.2.3. Autonomous Flight Phase Approach Techniques

8.2.3.1. Free Trajectory Technique

The free trajectory technique is the most known and simple. There are single- and multi-impulse versions of the free trajectory technique.
In the two-impulse version of the technique the first impulse provides for the trajectory passage through the target point in the preset time and the second impulse is executed at the end of approach for equalizing velocities of the spacecraft and the station. The two-impulse free trajectory technique is illustrated in Fig. 8-5. The first impulse is applied in the beginning of the maneuver at the T.o moment and must be of such value and direction as to make the two object coordinates coincide in preset interval of their subsequent free drift. The second impulse is applied in the end of the approach at the T.к moment to equalize the two object velocities for their soft contact.

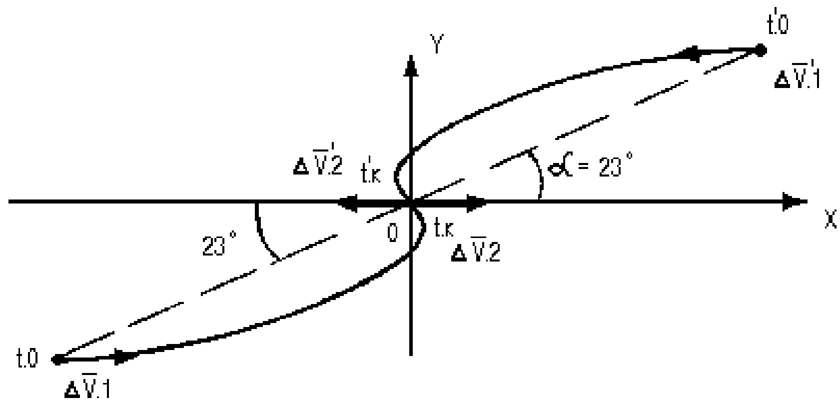


Рис.8-5: Сближение по методу свободных траекторий

Fig. 8-5. Free Trajectory Approach Technique.

When using the free trajectory technique one of the main characteristics influencing the technique efficiency is the energy consumption which can be estimated by the full characteristic velocity Vxap value. When approaching Mir station (ISS) in coplanar orbits minimal V.xap value is achieved if the approach trajectories correspond to Hohmann transfer ellipse (Fig. 8-5). The first impulse in Hohmann transfer is executed at the α angle value of α=23 degrees, the transfer orbit perigee lying in the spacecraft initial orbit and corresponding to the moment of the first impulse fire. As for the transfer orbit apogee it belongs to the Mir station orbit and corresponds to the moment of the second impulse fire. The two impulses are transversal and are directed posigrade to orbital motion.
In case the spacecraft is at a higher altitude orbit its angular velocity is lower than that of the Mir station. To ensure the rendezvous after the Hohmann transfer the spacecraft must be ahead of the station in phase and at the moment of the first impulse execution the α=23 degrees.
When the two-impulse technique is realized in practice the value and direction errors in the first impulse execution result in a miss. Therefore to ensure the required approach accuracy the multi-impulse technique is used to compensate for the miss errors by means of intermediate corrections.
In the autonomous spacecraft/station approach phase the correction times are determined on the basis of the relative motion parameters computed in the time interval preceding the correction, i. e. parameters of each successive corrective impulse are selected so as to compensate for the errors of the preceding impulse execution. The basis of the free trajectory technique control algorithms is computation of thjrust impulse parameters to change the velocity vector for the maneuver initial conditions and the preset time of

approach. The thrust impulse direction and value computation is based on solving the spacecraft and the station motion differential equations.
Before the relative range ρ=400 m all the spacecraft maneuver impulses are computed by the free trajectory technique and from ρ=400 m on the parallel guidance technique algorithm is effective.

8.2.3.2. Parallel Guidance Technique

While executing the spacecraft/station approach when the range is as small as ρ=400 m the parallel guidance technique in the ИСК inertial coordinate system begins to be used. The parallel guidance in the inertial coordinate system consists in keeping the spacecraft/station line of sight motion parallel to itself in the inertial space while the active vehicle controls the approach radial range rate (Fig. 8-6).

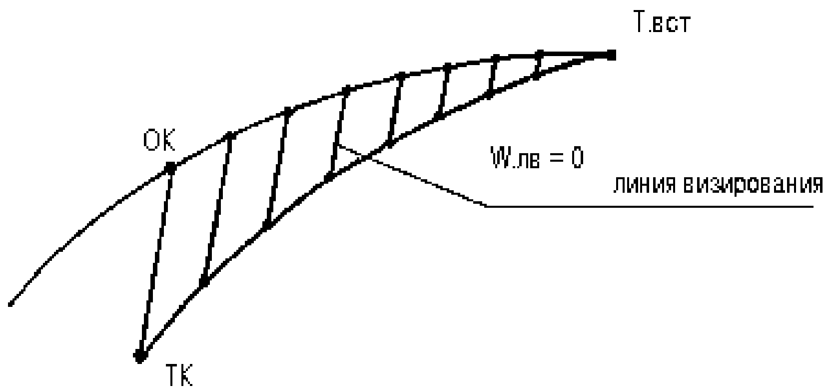


Рис.8-6: Инерциальное параллельное сближение

Fig. 8-6. Inertial Parallel Guidance.

1. Line of sight.

The inertial parallel guidance technique in practice is preferable because the modern space vehicles are equipped with gyro-stabilized platforms determining the vehicle’s inertial basis with high accuracy. In practice it is a much more complicated task to determine the orbital attitude basis (to establish the local vertical). As for the propellant consumption the inertial technique proves to be more advantageous because for the line of sight attitude hold (keeping its angular rates at zero) no propellant is consumed but for compensating for the gravitation differential accelerations. However in case of the orbital parallel guidance extra propellant consumption is required for the compensation of Coriolis acceleration which arises in rotating coordinate systems.
The parallel guidance technique is used both in the conclusive part of the automatic approach procedure (from ρ=400 m on) and in the back up manual spacecraft/station approach.

8.2.4. Soyuz Spacecraft/Mir Station (ISS) Back Up Approach Schemes

8.2.4.1. Soyuz Spacecraft Manual Control Approach

In the manual control approach procedure the parallel guidance technique is used. The manual control consists in keeping the Ω.лв=0 with the preset accuracy and keeping the radial range rate within the preset interval, that interval for the current range rate being function of the current range.
The parallel guidance technique is suitable exactly for the final part of approach as the differential gravitation accelerations is small in this part and consequently the spacecraft relative trajectory in the inertial space approximates the straight line. For the inertial parallel guidance technique realization in the final part of the approach phase minimal expenditure of the spacecraft characteristic velocity is required.
To approach to Mir station (ISS) at a low speed in order to prevent a hard impact the spacecraft control must follow a certain steering law. The steering law used in the spacecraft control is shown graphically in Fig. 8-7 by the shadowed area to denote the zone for transfer from the greater to the smaller target vector.

The lower steering law ρ'(ρ) area border defines the minimal range rate and consequently maximal time to the rendezvous moment. For the higher steering law area border the braking parabola can be used theoretically, however to meet the safety and control reliability requirements lower values for maximal range rates in manual approach are usually used.

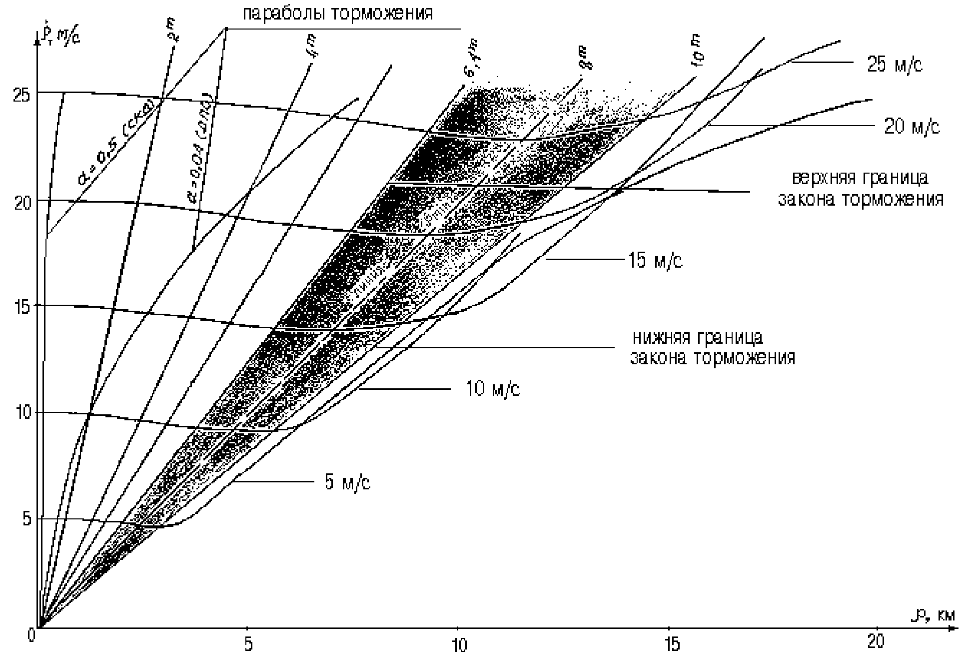


Fig. 8-7. Function ρ' of ρ for nominal hitting trajectories at:
ΔVпр=5, ΔVпр=10, ΔVпр=15, ΔVпр=20, ΔVпр=25 m/s.

1.Braking parabolas. 2. Braking law higher border. 3. Braking law lower border.

In Fig 8-8 two shadowed areas are shown for the ρ'(ρ) and Ω.лв(ρ). The approach trajectory control task is to drive the ρ and Ω.лв parameters into these areas and to keep them within the areas.

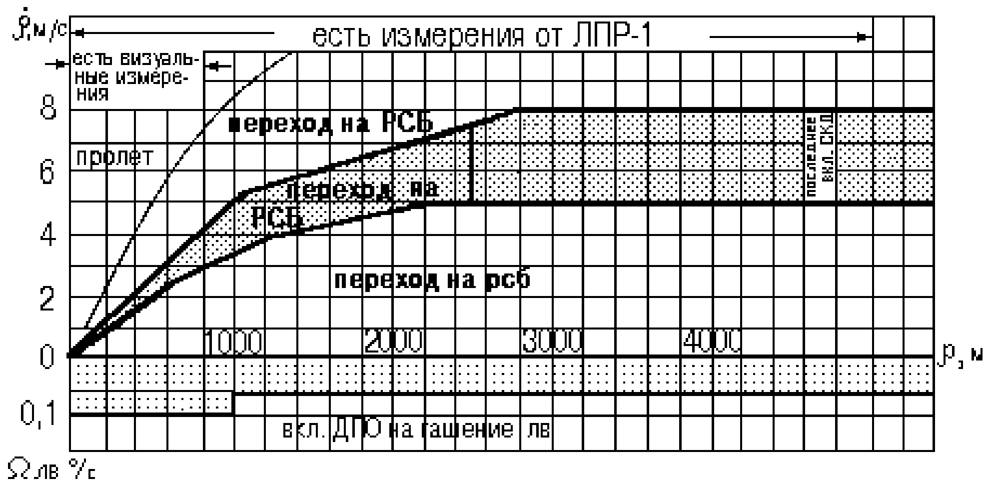


Рис.8-8: Закон управления при ручном сближении

Fig. 8-8. Steering Law in Manual Approach.

1. ДПО thruster fire for compensating the Ω.лв. 2. Transfer to manual approach. 3. Visual measurements available. 4. ЛПР-1 measurements available. 5. СКД Engine last fire. 6. Miss.

In actual flight there are conditions for transfer from the automatic approach control mode to the manual approach. At present these conditions are defined by the Soyuz spacecraft performance characteristics, its instrument equipment, orbit illumination and the relative motion parameters (ρ, ρ', Ω.лв).

The quantitative expressions of the transfer conditions are called the transfer criteria (Fig. 8-9).

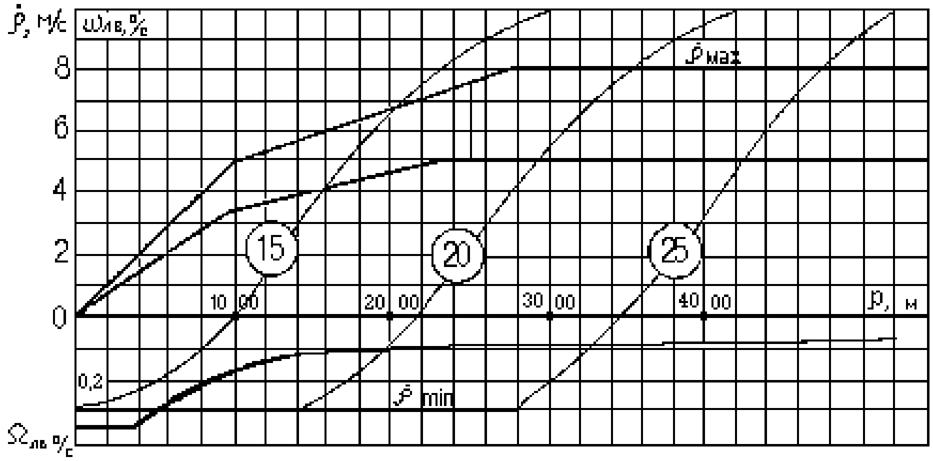


Рис.8-9: Критерии перехода в режим ручного управления и потребное время на ручное сближение до зависания

Fig. 8-9. Criteria of Transfer to Manual Control Mode and Time Required for Manual Approach until Station Keeping.

Values of criteria are determined only for the manual approach with the use of only ДПО thrusters and with the relative motion parameter measurements by means of the ЛПР-1 laser range finder at the illuminated side of the orbit at the relative range of less than 5 km.

In Fig 8-9 equal time lines are depicted (they are called «isochrones») for 15, 20 and 25 minutes. The time values correspond to the times required for manual approach from the isochrone position moment to the station keeping moment.

The value limit lines of ρ'.max, ρ'.min, Ω.лв max were determined experimentally taking in account the ДПО performance characteristics (thrust, continuous burn time, propellant stowage capability).

The criteria for transfer to the manual approach mode are prepared by the MCC in advance in the remote guidance phase and in the autonomous approach phase. In the remote guidance phase as a rule two-impulse maneuvers are executed according to the nominal scheme. In the autonomous phase the transfer criteria are developed by means of the СУД System using the uncorrectable estimation data. In this case a special «Phase Correction» program is entered into the «Argon-16» БЦВК.

Crew order of operation when executing the spacecraft/station manual approach:

While executing the manual approach procedure the Commander and the Cosmonaut Researcher are in the CA Module. The Flight Engineer is in the БО Module and using the ЛПР-1 laser range finder through the cupola/window measures the current range to the orbital station. To do so the FE should aim the ЛПР-1 to the target via the right ocular, press and hold the «ИЗМЕРЕНИЕ-1» (Measurement-1) button. In 5 seconds the green indicator light will illuminate in the left ocular which will indicate the ЛПР-1 readiness for measurements. When the green light is ON the FE releases the «ИЗМЕРЕНИЕ-1» button. If the laser ray hits the target red range indicator lights will illuminate in the left ocular (range is displayed in meters). If the laser misses the target zeros will appear in all the indicator digits.

For the second range measurement the FE must repeat the above mentioned operation steps. Using two measurement data the FE calculates the range rate by means of the БВК-1 special calculator and reports the current range and range rate data to the Cdr. The spacecraft Commander being aware of the current range and range rate values and using special technique manually controls the approach procedure starting with the 7 km range until the station keeping range of 50-150 m. After the station keeping is achieved the FE transfers to the CA Module. Then the Commander executes manual berthing and spacecraft/station docking. The steering law for the manual berthing control is shown in Fig. 8-8.

8.2.4.2. Soyuz Spacecraft Phase Correction Approach.

The phase correction approach is arranged with the target vector value ΔVпр=10 m/s. The Soyuz spacecraft crew participation in this mode execution consists in:

- detecting the Mir station against the Space or Earth background;
- pointing the spacecraft «-X» axis to the Mir station;
- setting the flag for the actual Mir station position into the «Argon» БЦВК.

In Fig. 8-10 the scheme is shown to explain the phase correction. By the moment of the estimated phase correction, i. e. the moment of fly-pass under the station the spacecraft is in the «OCK+rotation maneuver» attitude control mode. The rotation is executed in pitch for 90 degree angle so as to make the spacecraft «-X» body axis coincide with the «OY» axis of the OCK orbital coordinate system. After the station detection within the time interval preset for the phase correction the spacecraft Commander manually controlling the spacecraft rotation matches the BCK-4 cross-hair with the viewed station and the FE enters the phase correction execution flag into the БЦВК, the СУД System «reading» the spacecraft pitch rotation angle. The estimated spacecraft coordinates and the actual spacecraft direction to the station define the error of the estimated spacecraft trajectory to the station only along the OX orbital axis of the Mir station, i.e. the phase difference ΔΦ.к of the actual and calculated spacecraft positions is determined. The «lateral» (along the OZ orbital axis) and the elevation (along the OY OCK station axis) errors are not corrected.
The miss value ΔX is found from the equation:

$$\Delta X = Y_{\text{тк орб}} \bullet tg\Delta\alpha - X_{\text{тк орб}}$$

where: **Y.тк орб , X. тк орб** - spacecraft coordinates in the station's orbital coordinate system as estimated by the БЦВК,
Δα - is the spacecraft pitch angle from the orbital attitude to the actual station pointing attitude.

8.2.4.3. Soyuz Spacecraft Ballistic Precision Approach

In case the capability of executing approach using the СУД System estimations in the autonomous phase is lost the manual control transfer criteria can be realized by the Баллистическое прецизионное сближение (БПС) (Ballistic Precision Approach) scheme.
The БПС mode consists in the following. By means of the remote quidance maneuvers the spacecraft is positioned into the point 8 km ahead of the station. In this point the target velocity is reduced to zero and the spacecraft is transferred into station keeping, i. e. it moves along the same orbit as the station but with a phase mismatch. Then the spacecraft is transferred to a co-elliptic orbit by a two-impulse maneuver and after that is slowly phased into the ρ<1.5 km area (co-elliptic orbits are those having constant orbit altitude difference throughout the revolution). The БПС mode execution scheme will require more PKO orbit radio tracking sessions to enhance the orbit measurement accuracy. This scheme makes it possible to realize the criteria for the manual approach control transfer with a probability P>0.6. The nature of the relative motion parameter evolution is illustrated in Fig. 8-11

Fig. 8-11. Ballistic Precision Approach (БПС) Scheme.

1. Calculated trajectory for the preset target point.
2. Shot over trajectory.
3. Short round trajectory.
4. Up-shift trajectory.
5. Down-shift trajectory.

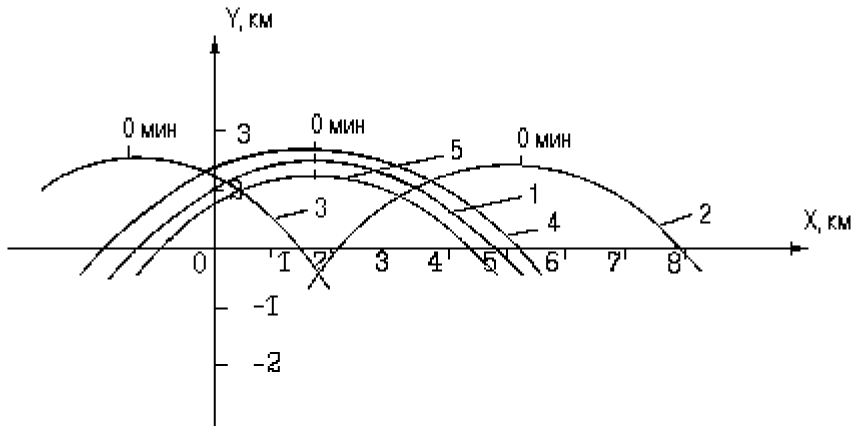


Рис.8-11: Схема баллистического прецизионного сближения (БПС)

1 - расчетная траектория для заданной прицельной точки
2 - перелетная траектория
3 - недолетная траектория
4 - траектория, смещенная вверх
5 - траектория, смещенная вниз

8.3. Descent

8.3.1. Soyuz Spacecraft Landing Time and Site Selection

In nominal descent the spacecraft lands in the preselected landing area. The nominal landing area will be reached when descending from the first three (sometimes four) revolutions of the day. The principal descent revolution is usually the first revolution of the day, i. e. the revolution of which the ascending node longitude λ.ву meats the requirement: crosses the equator closest west of longitude 20E (or 20 degrees-$\Delta\lambda$.ву<λ.ву<20 degrees, where $\Delta\lambda$.ву is the inter-revolution distance in longitude for the spacecraft orbit).
When preparing for the descent the landing point is selected for each ascending node longitude value envisaged, one of the landing point coordinates (usually the longitude) being the target parameter for the descent trajectory computation. The second landing point parameter (the latitude) is free and depends on the descent revolution ground trace and the CA Module lateral shift from the orbital plane. The totality of landing points of the preset longitude defined as a function of the descent revolution ascending node longitude is called the target line. So the target line is actually the preset longitude meridian. Nominally target lines are within the longitude range of 63-74 degrees.
The principal requirement to the landing area is the safety landing provision. This area must not include large settlements, mountains or rocks, large water reservoirs etc. The initial CA roll can shift the landing point approximately 75 km in that roll direction (Fig. 8-12). This capability of the CA landing point lateral shift makes it possible to optimize the landing area selection.

Fig. 8-12. The CA initial roll defines the landing point position relative to the initial flight trajectory.

1. Roll to the left. 2. Roll to the right. 3. Roll direction reverse.

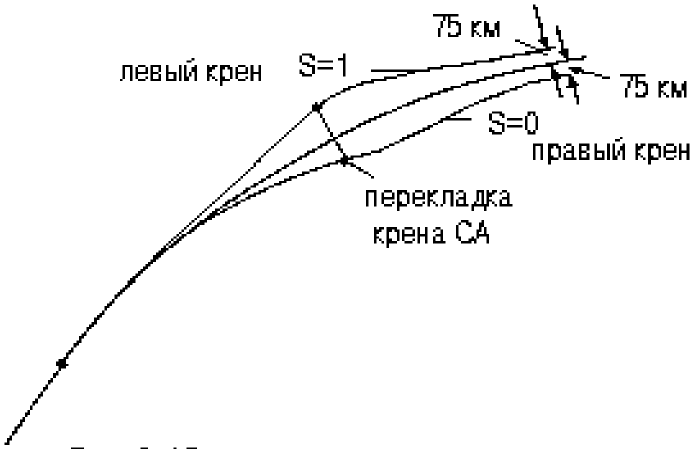


Рис.8-12: Начальный крен СА определяет положение точки посадки относительно трассы полета

8.3.2. Automatically Controlled Descent (АУС)

In order to execute the nominal descent in the АУС mode meeting the requirement of hitting the preset landing point it is necessary to determine the appropriate time moment for the СКД Engine retrofire ignition - T.скд. The retrofire impulse value is strictly determined for the known spacecraft orbit. The retrofire impulse value depends on the spacecraft orbit altitude:

for H=200-300 km - ΔV= 89,6 m/s
for H=300-330 km - ΔV= 102,4 m/s
for H>330 km - ΔV=115,2 m/s

The spacecraft/station undocking occurs 1.5 revolutions prior to the engine fire. The spacecraft undocks and the spring pushers accelerating the spacecraft up to the velocity of 0,12-0,15 m/s. When the separation range reaches the value of ρ=20-25 m the ДПО-Б thrusters are fired for 8 s accelerating the separation range rate up to 0.5 m/s. In 1.5 revolutions the spacecraft is above and behind the Mir station (ISS). The spacecraft trajectory in the station's orbital coordinate system is shown in Fig. 8-13. The spacecraft/station relative position by the T.скд moment excludes an impact of the two vehicles after the retrofire impulse is executed by the spacecraft.

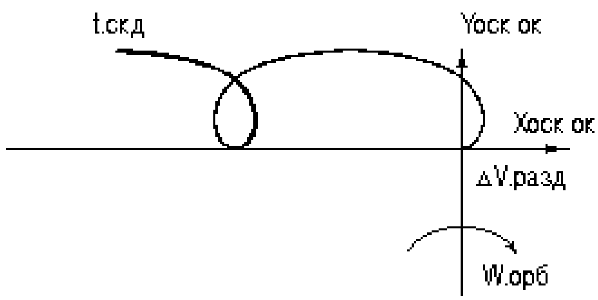


Рис.8-13:
Относительная траектория ТК после разделения с ОК "Мир" в ОСК ок

Fig. 8-13. The spacecraft relative trajectory in ОСКок (Station's orbital coordinate system) after the spacecraft separation from Mir Station (ISS).

<u>Note:</u> For ISS the full version of the nominal undocking cyclogram includes the following operations:

- *the БЦВК test immediately after the СУД System initiation;*
- *translational ДПО thruster test at the start of the БДУС gyro spinning;*
- *БДУС Unit test;*
- *СУД System operation in indicator mode up to 10 seconds after actual undocking;*
- *the preset coordinate system acquisition from the orbiter at the actual undocking;*
- *fire and 15 second burn of ДПО +X thrusters at 180 seconds after actual undocking;*
- *ДПО +X test;*
- *spacecraft rotational maneuver to the attitude defined by uplinked settings at the moment of 420 seconds after actual undocking (the target attitude presumably features spacecraft «+X» axis pointed to «nadir» and «-Y» / «+Z» bisector directed opposite to the orbital velocity vector);*
- *evasive maneuver second impulse at 550 seconds after actual undocking by means of ДПО «-Y» and «+Z» thruster burn for 30 seconds;*
- *СУД System switching off at the end of cyclogram.*

When undocking from the «tail» node of the ISS RS the second impulse is prohibited.

By the Т.скд moment the spacecraft is in the ОСК+X attitude, i. e. the engine nozzle is directed along the spacecraft heading (Fig. 8-14). At the moment of the СКД ignition the ИСКт (Current inertial attitude hold) is initiated. The impulse value (burn duration) depends on the spacecraft weight, nowadays the spacecraft retrofire impulse is executed before the БО jettison and the СКД is fired for approximately 260 s (for the impulse value of 115.2 m/s).
In a quarter of revolution (about 22.5 minutes) after the retrofire impulse execution the spacecraft is separated into the СА, ПАО and БО Modules. As the spacecraft was in the ИСКт attitude prior to separation the ПАО Module after separation moves upwards and positions itself behind the СА. The БО Module moves downwards, but having small weight (the БО Module's ballistic factor is very high) is effectively braked by the atmosphere drag and falls behind the СА. So right after the spacecraft separation the impact of the separated modules is excluded (Fig. 8-15). The separation occurs at the altitude of H=140 km.

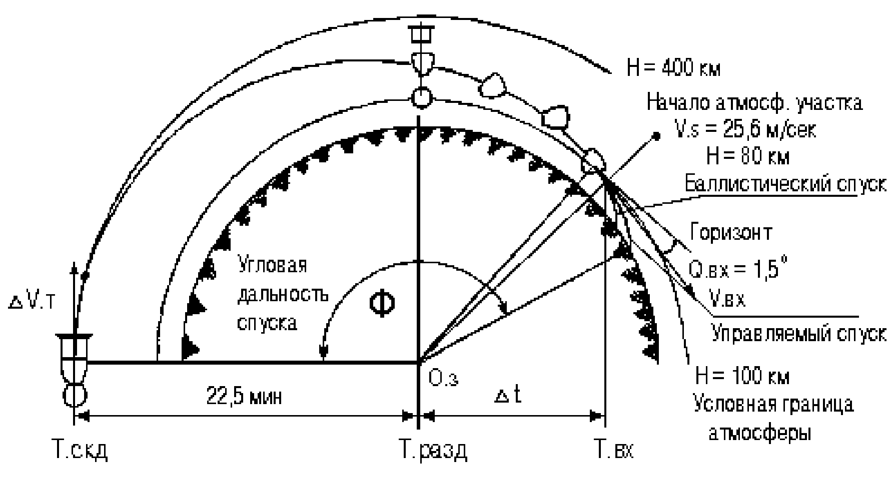


Рис.8-14: Штатная схема спуска

Fig. 8-14. Nominal Descent Diagram

1. Descent angular range. 2. Beginning of the descent atmosphere part. 3. Ballistic descent. 4. Controlled descent. 5. Conventional atmosphere border. 6. Horizont.

At the separation moment the extra-atmosphere part of the descent begins. The rated duration of this descent part does not exceed 1020 s. Actual duration time can differ from the rated value by no more than ±30 s.

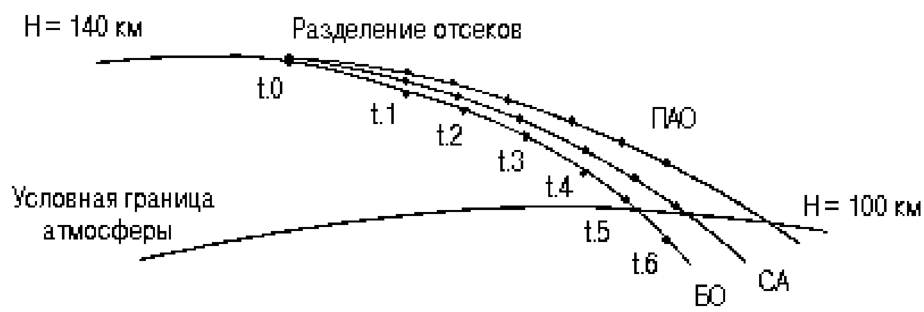


Рис.8-15: Траектории движения ПАО, СА и БО после разделения

Fig. 8-15. ПАО, СА and БО trajectories after the spacecraft separation.

1. Module separation. 2. Conventional atmosphere border.

After the spacecraft separation the CA motion control principle is as follows. The roll and yaw are hold equal to zero, the control system damping attitude rates arising in these channels. In pitch channel the CA attitude rate is limited by 2 deg./s. The CA attitude hold in roll and yaw channels is accomplished on the base of a free three-degree-of freedom gyro (СГ) which is oriented prior to separation in such a way that its kinetic moment vector (rotation axis) is directed perpendicular to the spacecraft orbital plane. In the nominal descent scheme the СГ gyro is uncaged 1 min 14 s prior to separation, and simultaneously the БДУС-2 attitude rate sensors are energized which can measure the CA pitch rate. After the spacecraft separation the crew viewing through the window can monitor the CA slow rotation in pitch. Before positioning to the balancing angle of attack the CA can make 1-2 full turns. Then 1-1.5 min, prior to the atmosphere reentry the CA rotation transfers to the CA oscillation about the balance position. The oscillation amplitude gradually decreases and the oscillation frequency increases. It is expected that at the altitude of approximately 95 km, 1 minute prior to the atmosphere reentry the CA attitude is driven by the aerodynamic forces to a stable position corresponding to the CA balancing angle of attack.
After separation the accelerometer measures apparent accelerations induced by external forces acting upon the CA along the OX body axis. In this case it is the atmosphere drag. The measured apparent acceleration is integrated to get the apparent velocity value, which is imparted to the CA by the aerodynamic force. When the apparent velocity amounts to V.s=25,6 m/s it is assumed that the CA has reentered the atmosphere. The atmosphere reentry occurs at the altitude of approximately 80 km and at that moment the atmosphere part of the descent begins. This descent parts lasts not longer than 450 - 500 s.
In the descent atmosphere part the СУС Descent Control System function are:
- roll programmed rotation control for the descent trajectory control;
- CA three axis stabilization (the CA longitudinal velocity axis is held pointed in the direction of the incoming air flow).

In case the CA has entered atmosphere in preset time T.вх.расч. which is counted from the separation moment. T.вх.расч. the CA roll angle is equal to the basic roll angle γ.o=60 degrees, the initial roll angle being set into the descent control system prior to the descent. If the apparent velocity value of 25.6 m/s is achieved in less than the preset time it means that the actual trajectory is «steeper» than the nominal trajectory and that it is necessary to increase the CA lift in the descent atmosphere part by decreasing the roll angle. If the actual reentry time, T.вх.факт. is greater than the preset time T.вх.расч. it means that the actual descent trajectory is a shot over path and that the CA roll angle should be increased with respect to the basic roll angle value. The roll angle correction value is always proportional to the reentry time error.
When executing the CA programmed attitude maneuvers for roll control the maximal attitude rate is 15 degr./s. The roll control procedure is terminated approximately 1 min, prior to the parachute system deployment at the apparent velocity value of V.s=7332 m/s. From the roll control termination up to the parachute system deployment the CA descends with the current roll angle. The main parachute is deployed at the altitude of H=9 km after which the CA is in parachuting descent for 15 minutes. The CA landing is accompanied by the ДМП soft landing thruster firing (Fig. 8-16).

One of the descent important characteristics is the landing point dispersion. In nominal descent the random dispersion errors make all of the CA possible landing points to concentrate within the dispersion ellipse around the preset landing point. The landing error is governed by the normal law of errors and is defined as the root mean square value σ.L=10 km along the trajectory path and σ.l=7 km in the direction normal to the path.
For the automatically controlled descent the descent settings are entered into the СУС System. The settings are computed by the MCC when preparing for descent:

1. **Δt.разд** - time interval from the СКД Engine fire up to the separation,

2. **Δt.вх** - time interval between the separation and the atmosphere reentry (reaching the V.s=25.6 m/s),

3. **ΔT.o, ΔK** - settings for adjusting the T.пр.(V.s) function,

4. **S= 0 or 1** - setting defining the initial sign of the basic roll angle. 0 is for the right-hand roll, 1 is for left-hand roll when viewing along the positive direction of Ov axis (the CA velocity axis or the CA heading).

8.3.3. Manually Controlled Descent (РУС)

Transfer from the АУС to the РУС mode can be executed at any moment of the autonomous CA flight either automatically or on the crew decision. Transfer to the РУС mode is irreversible. In manually controlled descent the cosmonaut using the РУС Handle buttons issues commands for the basic roll angle decrements of 15 degrees each, the maximal possible decrement being 45 degrees. In case of the attitude control equipment sensor failure the РУС mode is impossible.
For descent in the РУС mode the MCC defines the preset trajectory by the following settings:

N - number of the curve (mask) displayed on the ВКУ screen. The curve represent the selected T.пр.(V.s) function in the CA descent atmosphere part,

K - current time conversion factor which defines the marker horizontal velocity on the ВКУ screen,

t.c - the preset time moment for the crew to issue the «включение t.c.» command from the РУС Handle to initiate the marker motion on the ВКУ screen along the time coordinate.

The t.c. setting value is close to the nominal atmosphere reentry time and differs by the value corresponding to the preset range difference of the АУС and РУС trajectories.
In the РУС mode the ВКУ marker in the vertical coordinate displays the V.s current value, and in the horizontal coordinate - atmosphere part programmed time starting at the t.c. moment. The marker deflected position from the programmed T.пр.(V.s) curve shows the difference between the actual and the programmed times for the current V.s value (Fig. 8-17). The cosmonaut by adjusting the roll angle value changes the apparent velocity accumulation rate. Thus there is a capability using roll control to «track» the mask displayed on the ВКУ so as to minimize the final landing point error (the integrated marker deflection from the programmed curve and the final time error with respect to the mask must compensate each other). The РУС mode control must also minimize maximal acceleration load acting upon the crew.

It should be noted that the landing accuracy in the РУС mode is worse than in the АУС mode, the range error being ΔL=3σ.L=60 km (σ.L=20 km). Still the РУС mode provides for an enhancement of the descent control capability.

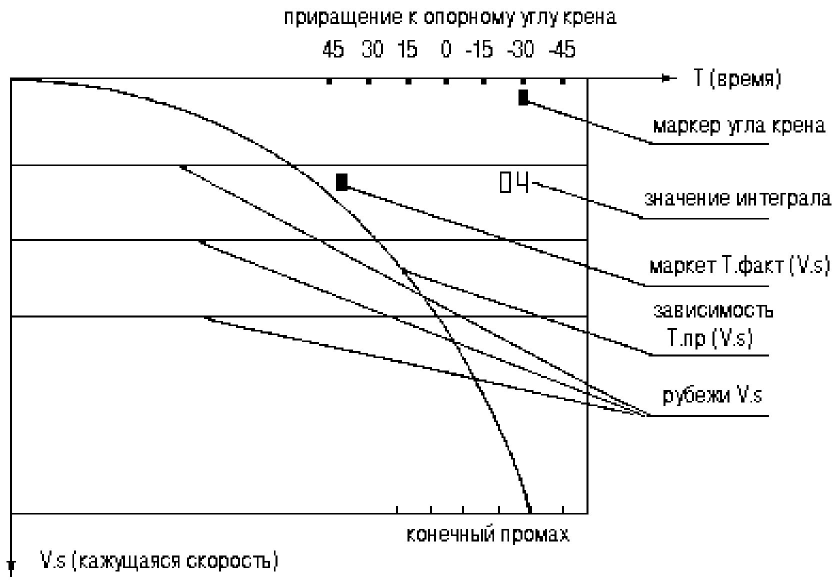


Рис. 8-17 : Формат РУС

Fig. 8-17. РУС Format.

1.Basic roll angle decrements. 2. Time. 3. Roll angle marker. 4. Integral value. 5. Marker displaying Т.факт (V.s) function. 6. Т.пр.(V.s) curve. 7. V.s accumulation stages. 8. Final error. 9. Apparent velocity.

8.3.4. Ballistic Descent (БС)

The БС ballistic descent is the descent with the average-integral zero lift. The БС is a back up descent mode used in case of the РУС mode failure or "nominally" is most emergency descent modes. However this mode, just like the АУС mode, can be selected in advance or can be transferred to from the controlled descent procedure in case off nominal deviation occurs in the СА or its system operation. The latter case is called the «fall into БС». The ballistic descent can be executed in case of the descent control system failures resulting in loss of the spacecraft or the СА attitude control, failures in the descent reaction control system (the СА attitude control thrusters) etc. In all such cases the СА is driven into rotation about its velocity axis Oxv with the rate of ω.x=12.5 degr./s. The БС trajectory mainly features the atmosphere part rang decrease by approximately 400 km with respect to the controlled descent and also the axial acceleration increase up to n.x=8.5 g (Fig. 8-16).

In case of a failure in the primary equipment set used in the ballistic descent transfer to the back up ballistic mode (БСР) is executed.

Unconditional compulsory selection of the ballistic descent is provided for the urgent descent from orbit in case of off-nominal situations jeopardizing the crew safety (depressurization, fire etc.). The ballistic (trajectory) support for such situations is envisaged: once a day (if no dynamic operations are accomplished) form №23-14 is uplinked to the crew onboard the Mir station (ISS), that form containing data on the engine ignition and the retrofire impulse value for each revolution.

Example:

Form № 23

Date:	02.04.96
Nв/Nвс:	01014/08 (total # of revolution/revolution of the day)
Equator passing time:	00.23.17
Equator longitude:	-144.3397
Orbit shadow enter/exit:	00.43-01-19
Radio communication session:	00.25-00.32

Form № 14

Date:	02.04.96
Propulsion System burn time:	ТДУ=217
Impulse value:	ИМП=115.2
	1013/07 = 00.13.36 = 144

where: - **1013/07** - current (flight elapsed) revolution/revolution of the day for engine fire,
- **00.13.35** - engine ignition time,
- **144** - descent angular range.

The ignition time is selected so as to ensure landing in areas which are called back up landing areas and which are selected in advance taking into account the arbitrary position of the orbital path with respect to the Earth surface (Table 8-3). The БС landing point error root mean square value is σ.L=25 km along the trajectory path and σ.L=10 km in the direction normal to the path.

Soyuz Spacecraft Landing Areas

Table 8-3

Revolution #	Target Point Longitude φ (degrees)	Range of Ascending Node Longitudes λ.ву (degrees)		Geographical Region
1	69	17	3,5	Nominal landing area
1	63	3,5	-3,0	Nominal landing area
2,3	67,33	-3	-28	Nominal landing area
3	64	-28	-34	Nominal lansing area
3	67,33	-34	-40	Nominal landing area
3,4	63	-40	-55	Nominal landing area
4,5	44	-55	-77	Lower Volga
5.6	50+0,233•λ.ву	-77	-98	Varna, Odessa
6	18	-98	-101	Hungary
6	3	-101	-105	France
6	19+0,167•λ.ву	-105	-110,8	France
6.7	0,5	-110,8	-123	France
7	-89	-123	-128	USA
7	-134,2-0,28•λ.ву	-128	-133	USA
7.8	-74,4+0,17•λ.ву	-133	-160	USA
8,9,10	-103	-160	150	USA
10,11	-65,8-0,24•λ.ву	150	130	USA
11,12	123+0,2•λ.ву	130	115	USA
12	-214+•λ.ву	115	109	USA
12	-171,8+0,55•λ.ву	109	104	USA
12,13	100,4+0,357•λ.ву	104	90	Sea of Japan
13,14,15,16	138	90	30	Khabarovsk Territory
16.1	64	30	17	Kazakhstan, Uzbekistan

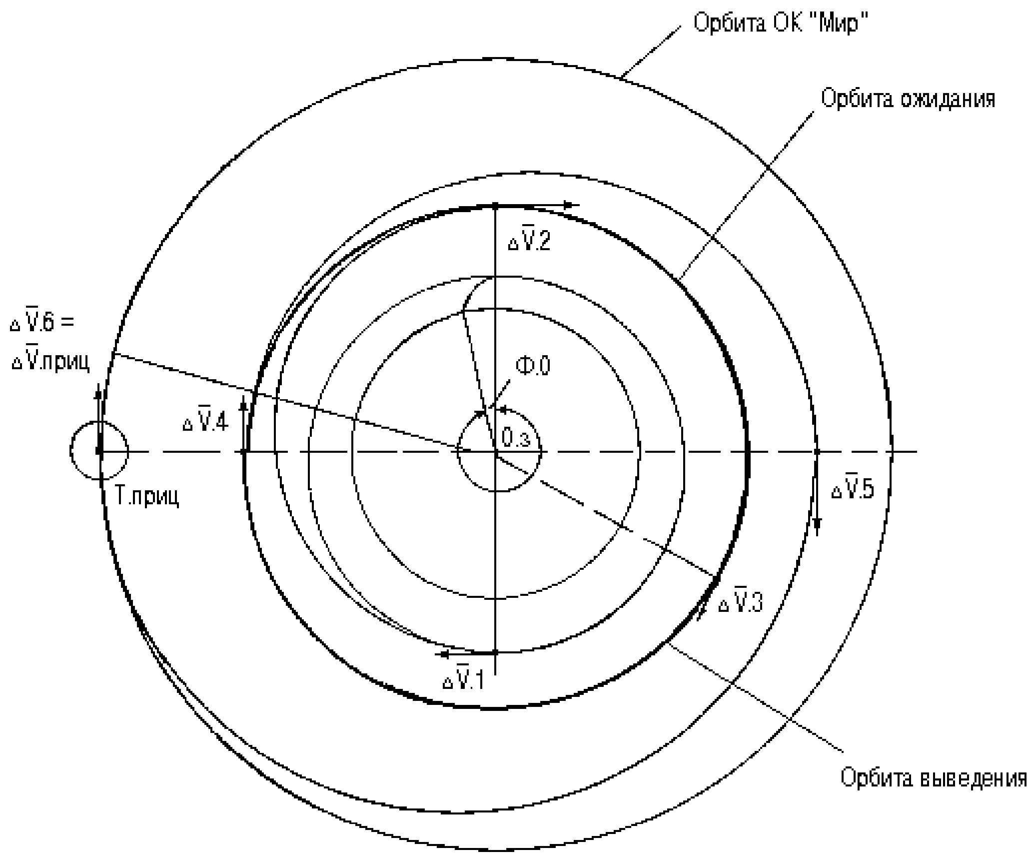


Рис.8-2 : Двухсуточная схема сближения ТК "Союз ТМ" и ОК "Мир"

Fig. 8-2: Soyuz Spacecraft/Mir Station (ISS) two-day Approach Scheme

1. Mir Station (ISS) Orbit. 2. Spacecraft Waiting Orbit. 3.Injection Orbit. 4. Target Point.

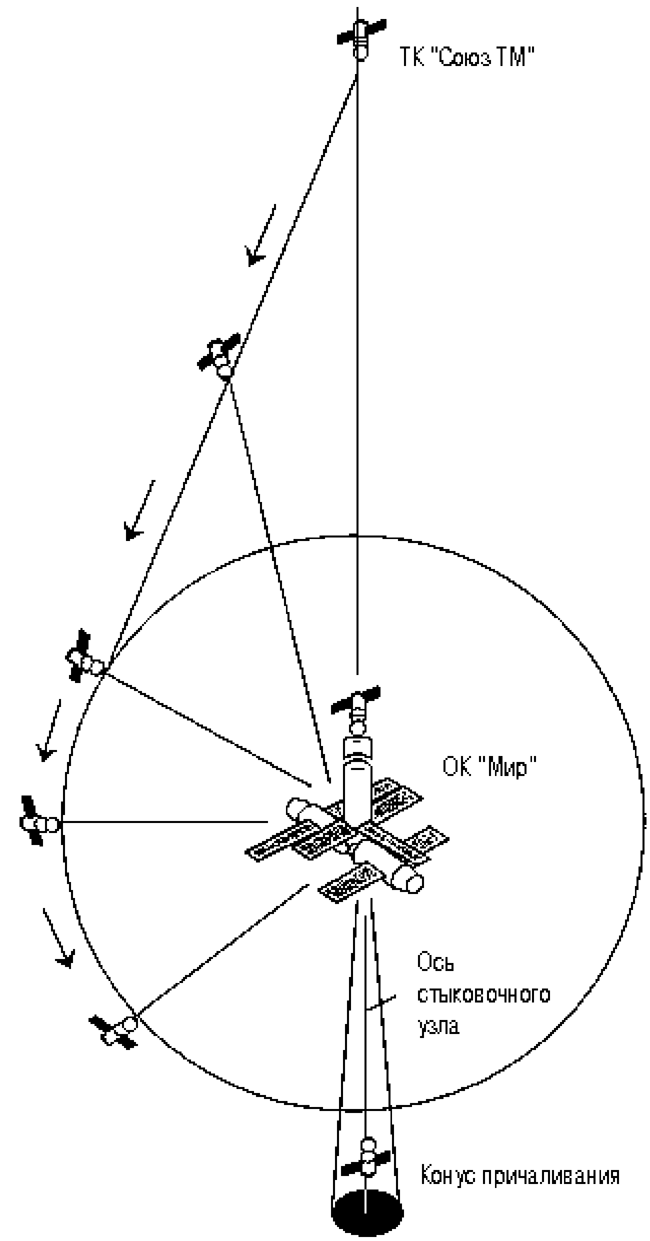


Рис.8-4: Облет ТК "Союз ТМ" орбитального комплекса "Мир"

Fig. 8-4: Mir Station (ISS) Fly Around by Soyuz Spacecraft

1.Berthing Cone. 2 Docking Node Axis.

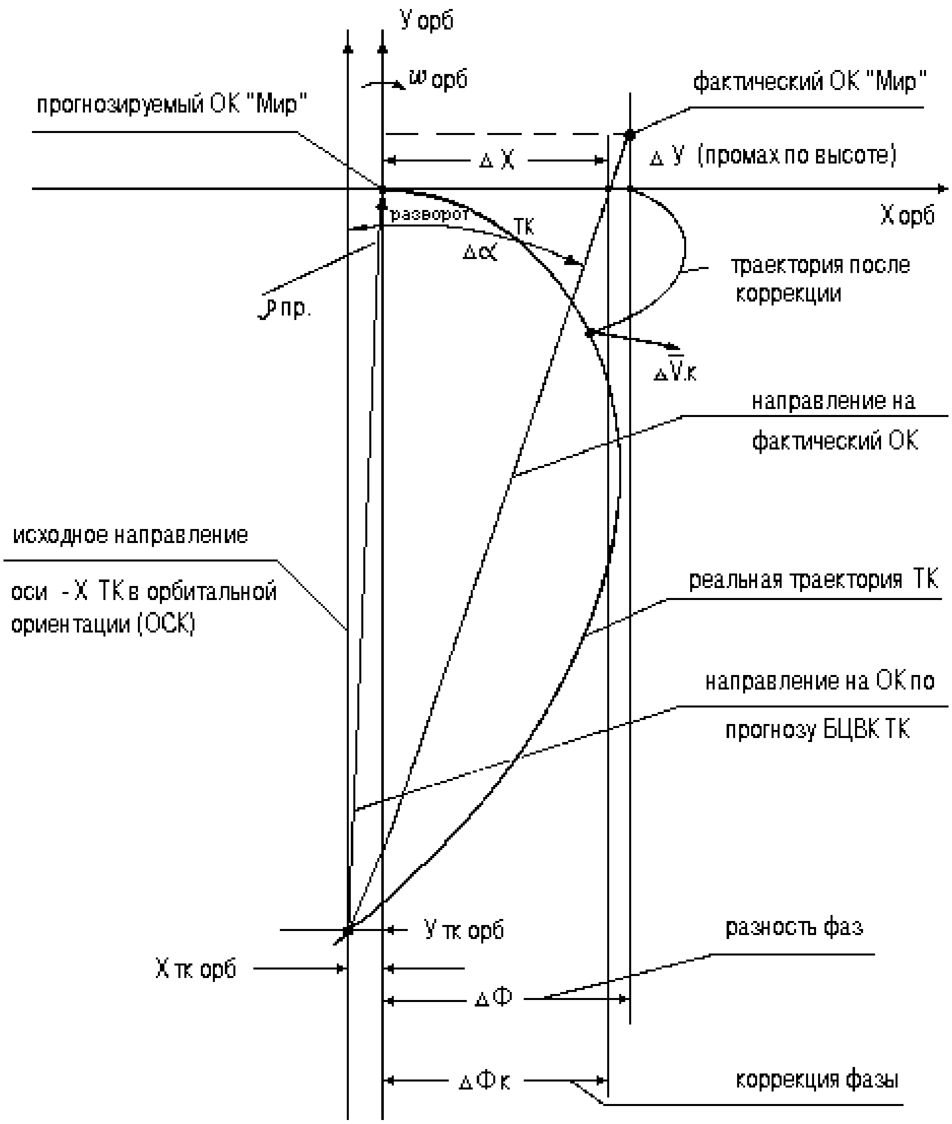


Рис.8-10: Коррекция фазы

Fig. 8-10: Phase Correction

1. Phase correction. 2. Phase difference. 3. Direction to the orbiter as estimated by the БЦВК. 4. Actual spacecraft trajectory. 5. Direction to actual obiter. 6. Trajectory after correction. 7. Miss in elevation. 8. Actual Mir station (ISS). 9. Estimated Mir station (ISS). 10. Spacecraft -X axis initial direction in the OCK orbital coordinate system. 11. Rotation maneuver.

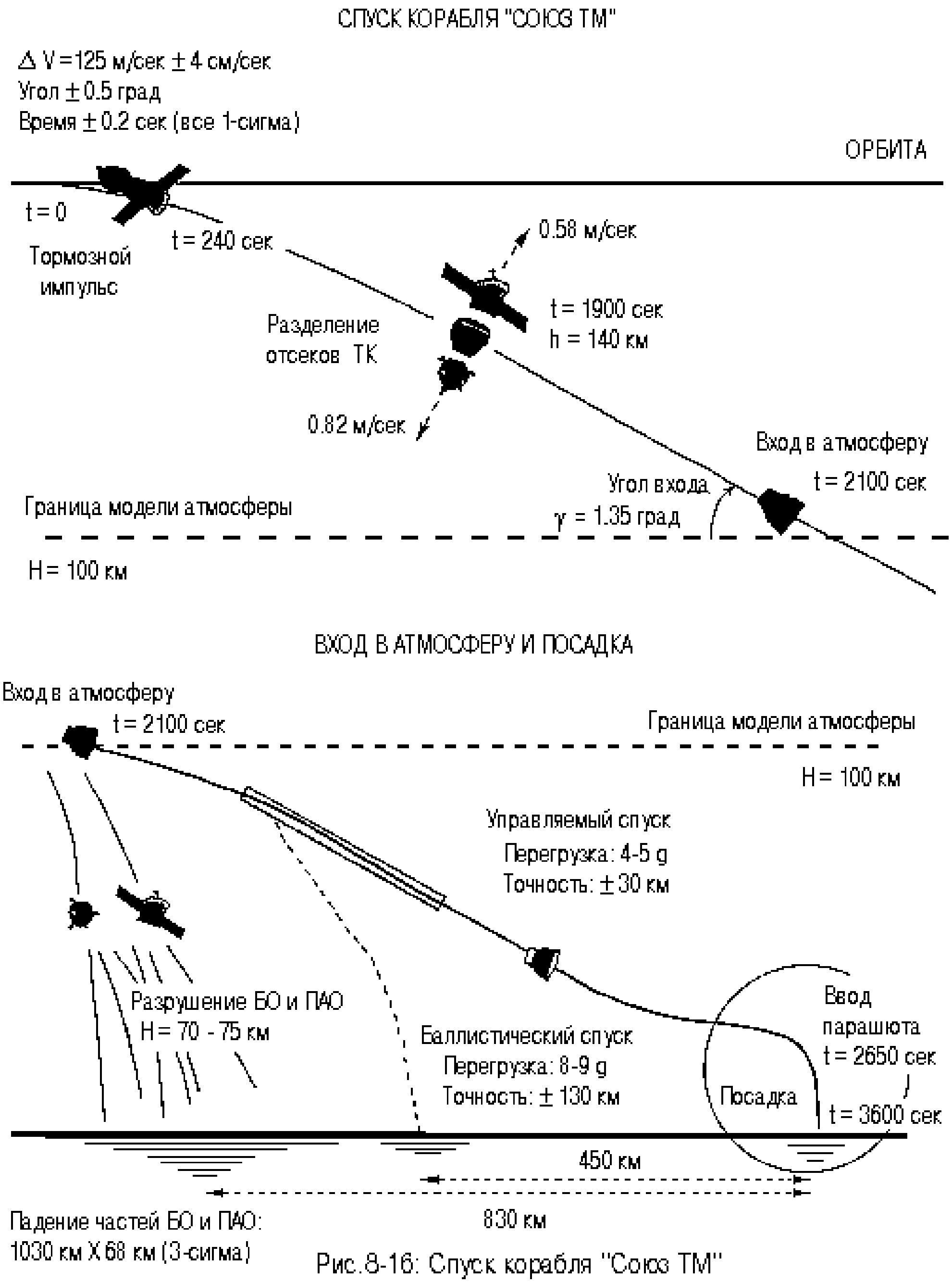


Рис.8-16: Спуск корабля "Союз ТМ"

Fig. 8-16: Soyuz Spacecraft Descent

1.Soyuz spacecraft descent (extra atmosphere part). 2. Velocity increment (V=125 m/s), angle and time (all 1σ). 3. Orbit. 4. Retrofire impulse. 5. Module separation. 6. Atmosphere reentry (t=2100 s). 7. Reentry angle. 8. Model atmosphere border (H=100 km). 9. Atmosphere reentry and landing. 10. Atmosphere reentry (t=2100 s). 11. Controlled descent: acceleration - 4-5 g, accuracy - ±30 km. 12. ПАО and БО destruction (H=70-75 km). 13. Ballistic descent: acceleration - 8-9 g, accuracy - ±130 km. 14. Parachute deployment (t=2650 s). 15. Landing. 16. ПАО and БО fragment fall down (3 σ).

9. COMPLEX OPERATIONS

9.1. In Flight Crew Member Duties and Cooperation

The Soyuz spacecraft is a transport vehicle used for:
- two-man or three-man crew and payload delivery onboard the orbital station;
- crew and payload return to the Earth;
- execution of fly around, redocking.

Apart from its main purpose the spacecraft can be used as unmanned or piloted solely by the Commander rescue vehicle or as unmanned payload returning vehicle for delivering to the Earth 250 kg load.

Generally when developing training programs it is assumed that the Soyuz spacecraft can be used in two basic versions: for the crew rotation (replacement) and for the crew rescue.
When the Soyuz spacecraft is used for the crew rotation the crew is delivered onboard the station by Soyuz spacecraft and the crew return can be accomplished either by the Space Shuttle or by the Soyuz spacecraft.
When the Soyuz spacecraft is used for the crew rescue the crew is delivered onboard the station by the Space Shuttle and the crew return can be accomplished either by the Space Shuttle or by the Soyuz spacecraft. The Soyuz spacecraft can also be used for the descent ahead of time or for the urgent descent.

The Soyuz spacecraft crew consists of two or three crew members:
- командир корабля (КК) (spacecraft commander), occupying the central seat;
- бортинженер (БИ) (flight engineer), left seat;
- космонавт-исследователь 1 (КИ1) (cosmonaut researcher 1), left seat (in three man version);
- космонавт-исследователь 2 (КИ2) (cosmonaut-researcher 2), right seat (in three man version);
- пассажир (ПС) (passenger), right seat (in three man version).

Only a cosmonaut, representative of the Russian Space Agency can be appointed the Soyuz spacecraft commander. Representatives of both the Russian Space Agency and other space agencies (NASA, ESA etc.) can be appointed the flight engineer, the cosmonaut-researcher and the passenger. In case there are two non-Russian crew members in the crew the left-seated crew member can fulfill functions of either the БИ and the КИ1 and the right-seated crew member can perform functions of either the КИ2 or the ПС.

Spacecraft Commander (КК)'s Functions

- supervision of the crew procedures in all flight phases as the onboard principal executive person responsible for the overall flight plan accomplishment and the crew safety;
- making decisions in off-nominal situations including the urgent descent decision in case of communication loss with the MCC and shortage of available time;
- monitoring the system automatic operation mode execution and the spacecraft system and structure status;
- execution of manual or semiautomatic system operation modes;
- spacecraft motion control in manual control modes while approaching, berthing, docking and redocking, in descent and in attitude establishment;
- maintaining communication with the MCC;
- ensuring personal life support;
- spacecraft egress after landing onto solid ground or splashing down onto water surface.

Flight Engineer (БИ)'s Functions:

- ensuring the spacecraft system appropriate usage by the crew as the person responsible for the onboard system performance;
- monitoring the system automatic operation mode execution and the spacecraft system and structure status;
- preparing data for the decision making on the onboard system usage in off-nominal situations;
- execution of manual or semiautomatic system operation modes;
- maintaining communication with the MCC;
- ensuring personal life support;
- spacecraft egress after landing onto solid ground or splashing down onto water surface.

Cosmonaut-Researcher (КИ)'s Functions:

- ensuring personal life support;
- maintaining communication with the MCC;
- issuing necessary control commands on the КК (БИ) or MCC instruction;
- spacecraft egress after landing onto solid ground or splashing down onto water surface.

Those were the functions of the КИ2 occupying the right seat.
The cosmonaut-researcher КИ1, occupying the left seat is additionally charged with the following functions:
- execution in proper way and proper time of the spacecraft system control operations (data exchange with the БЦВК, automatic approach procedure monitoring, manually controlled descent in the atmosphere part etc.) on the КК instruction and under his supervision;
- measuring and computing the relative motion parameters in the manual approach procedure without the «Kurs» radar rendezvous system.

Passenger (ПС)'s Functions:

- ensuring personal life support;
- issuing necessary control commands on the КК (БИ) or MCC instruction;
- spacecraft egress after landing onto solid ground or splashing down onto water surface.

Each crew member is responsible during the flight for:
- performing his functions as indicated above;
- fulfilling the FDF requirements and instructions of the spacecraft commander and the MCC;

Besides:

The КК is responsible for:
- responsible for the overall flight plan accomplishment and the crew safety;
- crew procedure supervision;
- making decisions in off-nominal situations including the urgent descent decision in case of communication loss with the MCC and shortage of available time.

The БИ is responsible for:
- the appropriate usage of the spacecraft systems including in off-nominal situations.

The КИ is responsible for:
- independent operations with the onboard radio and TV systems in nominal and off-nominal situations;
- correctness of issuing necessary control commands on the КК(БИ) and the MCC instruction.

The ПС is responsible for:
- independent operations for insuring personal life support;
- correctness of issuing necessary control commands on the КК(БИ) and the MCC instruction.

When executing the nominal flight plan the crew must:
- perform operations in accordance with the FDF and the MCC instructions taking into account the functional duty distribution and onboard actual situation;
- monitor and report the onboard system status;
- register command issue or passage actual times as well as operation execution time;
- inform the MCC on the operations fulfilled and on the results of onboard system monitoring and the spacecraft usage.

In case of an off nominal situation occurrence in flight the crew must:
- take necessary measures according to the FDF;
- register (on the tape-recorder and in the FDF) the off-nominal situation occurrence and the measures taken;
- Immediately report to the MCC on the off-nominal situation and the measures taken.

The crew can make a decision independently in the following cases:
- on elimination of an off nominal situation not envisaged in the FDF to proceed the flight plan execution if the cause of it and its elimination method are determined undoubtedly;

– on the urgent descent (taking into account the spacecraft system status and light/shadow circumstances) when an off nominal situation not envisaged in the FDF occurs which is considered hazardous for the crew lives.

9.2. Crew/MCC(ЦУП) Joint Activities in Various Flight Phases

9.2.1. Main Operative Control Group (ГОГУ) Structure and Tasks

When conducting the space flight tests the Главная оперативная группа управления (ГОГУ) (Main Operative Control Group) of the Центр управления полетом (ЦУП-М) (Mission Control Center) (MCC-M) is responsible for the Soyuz spacecraft flight plan execution and for the crew safety. The ГОГУ group performs the following tasks:

- real time centralized control of the Soyuz spacecraft flight from the moment of the KO separation contact;
- organization and coordination of operations of the Ground Control Complex elements, MCC branches, other Services involved and cooperation with them;
- development and issue of the Flight Data File and other document used in the flight procedures;
- development and issue of the reports on the flight plan execution;
- training of the flight control personnel for the specific spacecraft mission.

The following principles are laid in the basis of the ГОГУ structure:

- centralized one-man management in all the control levels;
- using the automated flight control system for the control of the ground segment and space segment facilities;
- provision of the crew participation in the spacecraft control ad monitoring.

The integrated task of the Soyuz spacecraft flight control is subdivided into separate functional tasks entrusted to various ГОГУ groups.

The ГОГУ group types are:

- general functional groups which ensure the flight plan task execution by the ГОГУ personnel and the control circuit performance;
- specialized functional groups which ensure the flight control of specific space vehicles such as Mir orbital complex, Soyuz spacecraft, Progress-M cargo vehicle etc.

The ГОГУ consists of:

- ГОГУ Management;
- Soyuz spacecraft operative control group;
- general functional groups with attached services and facilities.

ГОГУ shift consists of:

- Soyuz spacecraft control shifts;
- general functional group shifts which ensure the ГОГУ operation and the control circuit performance.

The ГОГУ shift operation is supervised by the Soyuz spacecraft Сменный руководитель полета (СРП) (Shift Flight Director).
The СРП is assisted by the Shift Flight Director deputies (ЗСРП):

- Deputy Shift Flight Director for the ground control complex (ЗРСП по НКУ);
- Deputy Shift Flight Director for the ЦУП (ЗСРП по ЦУП);
- Deputy Shift Flight Director for the crew training (ЗСРП по ПЭ) , being also the chief crew communication operator (ГО).

The ГОГУ flight control personnel is grouped in shifts and works on a shift basis. Shifts of the functional groups are headed by group shift managers.
The specialized Soyuz spacecraft functional group shift managers are subordinates to the СРП.

The ground control personnel is functionally subdivided into two categories:

- Soyuz spacecraft flight control personnel;
- flight control facility service personnel.

The Soyuz spacecraft flight control personnel which executes the spacecraft control operations throughout its flight in accordance with the flight plan and ensures the control circuit performance constitutes the ГОГУ Group.
Personnel of all the groups included into the ГОГУ is the flight control personnel and is subordinate to the ГОГУ Management irrespective of the organization it may belong to.
The flight control facility service personnel does not participate in the operative flight control circuit and remains administratively within the structure of the organizations to which the flight control facilities belong.

9.2.2. ГОГУ Operation Modes in Various Soyuz Spacecraft Flight Phases

In various Soyuz spacecraft flight phases when performing flight operations in accordance with the flight plan the ГОГУ Groups works in various modes characterized by specific tasks, personnel operation conditions, control facilities used, composition of the groups and the order of their cooperation.
The ГОГУ structure and specialists participating in its operation modes depend on the task set and the mode execution peculiarities (subordination in the shift, necessity of urgent decisions, cooperation with other organizations, need of enlisting supplementary facilities and personnel, their location in the MCC rooms etc.).
The Chief crew communication operators in all the Soyuz spacecraft flight phases are the Soyuz spacecraft crew training instructors - representatives of the Центр по дготовки космонавтов (ЦПК) (Cosmonaut Training Center).

The ГОГУ Group main operational modes are:
- launch/injection;
- approach/docking;
- orbit correction;
- descent.

Launch/Injection

The injection mode is the real time spacecraft flight control in revolutions 1 to 6 of the first flight day.
When injecting the manned spacecraft version the ПСК Search and Rescue team is included into the Group. The team personnel should include the highest class specialists.

In this ГОГУ mode apart from the nominal shift personnel the following specialists participate:
- Deputy Flight Director (ЗРП) for the control functional tasks;
- Leading Designer;
- Leading specialists;
- System designers as required by the ЗРП for the control functional tasks and by group managers;
- Crew training instructor.

The ГОГУ analysis group shift personnel obtains telemetry data on the spacecraft system initial status at the launch pad at the T-40 minutes countdown time. The

telemetry data is processed using the ЦУП computer complex aids and analyzed by the analysis group personnel for detection of deviations and off nominal situations. The Сменный руководитель группы анализа (СРГА) (Analysis Group Shift Manager) immediately reports about deviations in the telemetry data to the СРП and the latter includes the deviation data into the circular report for the Launch Control Manager. The list of parameters to be included into the ;paging report is determined by the СРГА.

Approach/Docking

The approach mode is the real time spacecraft flight control starting from the last remote approach maneuver and up to docking procedure completion, pressurization test and the transfer hatch opening.
The «Approach» subgroup and the «ССВП» (Docking and Internal Transfer System) subgroup are subordinates directly to the СРП of the group executing the active approach procedure.
In the subgroups specialists on the «Kurs» system active and passive equipment and on the СУД (Motion Control System) and the ССВП systems are included.
The list of the telemetry parameters is determined by the analysis group shift manager and by the «Approach» and the «ССВП» subgroup managers.
The specialists participating in the approach mode should be of highest qualification.

In this ГОГУ mode apart from the nominal shift personnel the following specialists participate:
- Deputy Flight Director (ЗРП) for the control functional tasks;

- Leading Designer;
- Leading specialists;
- System designers as required by the ЗРП for the control functional tasks and by group managers;
- Crew training instructor.

When executing docking of the Progress-M cargo transport vehicle with the Mir orbital complex the chief crew communication operator - the ЦПК representative is included into the control group and is located in the cargo transport vehicle flight control room.

Orbit Correction (Test and Dynamic Operation)

The orbit correction mode (test and dynamic operation) is the real time spacecraft flight control in the correction maneuver day (test and dynamic operation) from the beginning of the preparatory operations (configuring the onboard systems into the initial state, entering setting data etc.) up to the conclusive operations.
The ГОГУ shift structure and personnel and their operation order are nominal.
When conducting tests in the analysis groups test mode subgroups are formed with the participation of the system designers.

Descent

The descent mode is the real time Soyuz spacecraft flight control starting from the spacecraft depreservation and crew transfer into it up to the moment of the СКД retrofire burn cut off.
The shift personnel should be of the highest qualification.

In this ГОГУ mode apart from the nominal shift personnel the following specialists participate:
- Deputy Flight Director (ЗРП) for the control functional tasks;
- Customer representative;
- Leading Designer;
- Leading specialists;
- System designers as required by the ЗРП for the control functional tasks and by group managers;
- Crew training instructor.

To enhance the flight control reliability in the descent phase the СУД system operation control is executed by two subgroups:
- СУД system complex analysis subgroup (subordinate to the СРГА);
- СУД system designer subgroup (subordinate to the СРП).

All the СУД system analysis specialists are provided with all necessary telemetry data and communication links.

9.2.3. ГОГУ Decision Making Procedure in Off-Nominal Situations

The ГОГУ makes decisions and takes measures for the off-nominal situation elimination in the real time of the crew communication session only if the situation:
- jeopardizes crew safety;
- results in the spacecraft operability failure;
- results in intolerable propellant or electric energy consumption;
- results in failure to achieve mission objectives;
- results in failure to accomplish the main flight plan task of the current day, provided that the off-nominal situation is envisaged by the FDF and is undoubtedly identified.

In all other cases the decision is made after a detailed off-nominal situation analysis and recommendation development with the participation of the designers.

If the recommendations for the off-nominal situation elimination are not described in the FDF or the situation is not undoubtedly identified the ГОГУ shift in the communication session should be aimed at preventing the situation inadvertent development.
In case the decision is not to be realized in the current communication session the ГОГУ appropriate operation is performed taking into account time available for the decision making in accordance with the expert recommendations and the FDF requirements.

The available time is determined by the СРП taking in account the requirements of the crew safety and the spacecraft operability.

In case of an off nominal situation occurrence hazard which requires real time intervention into the spacecraft control via the КРЛ uplink it is admissible to issue separate unplanned commands on the СРП's instruction if sufficient time is available for the spacecraft flying to a НИП ground control/tracking site and for the command uplinking.

All the data exchange between various ГОГУ groups in case of an off-nominal situation detection is accomplished in circular communication mode.

9.2.4. Crew/ЦУП Cooperation in Various Flight Phases

Rev.#	Spacecraft Operations	Crew Activities	Downlink Reports	Uplink Data
CT20. INJECTION. TESTS. FIRST MANEUVER.				
1	-Injection -Antenna/Solar Battery deployment -ВИПШ (Rod extension to initial position)	-System monitoring -СА/БО pressuri zation check -Ф.03 Form -ТД (Thermal Sensors) inhibit -ВИПШ exec.	-Injection reporting -Report on: КО, pressurization, АО-ВКА antenna deploy-ment, СА/БО integrity, КДУ/СИОС parameters. -Health status report	-Radio/message on (R/M): orbit injection & appendage depl. -R/M: ТД inhibit -Data verifica-tion on СУД test #1 -preliminary orbit parameters
2	-СУД test #1 («Kurs» test, ОСК (ИКВ1+ ИКВ2) with ДПО-М1, Acce-lerometer test, РУО АК test) -Solar barbecue in POAK	-System monitor in tests, -РУО АК test, -Transfer to БО, -БОА sw. On in БО, -Space suit doff., and drying, -Purif. Cartr. Sw. On in БО	-Report on СА, БО, ПО integrity, -Report on ВИПШ compl., -Reporting on test passage, -R/M:Ф.03 Form	-БЧК time sync, R/M: Mnvr 1, -GO for transf. to БО & suit doffing, -R/M: solar barbecue in POAK
3	-Mnvr 1 (two impulse, without pre-orientation)	-Attitude & system monitor in Mnvr 1	-Report: СУД test 1 over, -БОА-БО is On - Р.ТК(МВ),Р.N2 -Mnvr 1 start	-R/M: Setting uplink by КРЛ -Mnvr № 1 data, -Mnvr № 1 Cycl., -R/M: Ф.14, -БЧК time sync
4	-Cont. Of Mnvr 1 -Solar barbecue in POAK -TV test	-Solar barbecue in POAK exec. -Communication, -TV nest exec. -Meal taking	-Report on Mnvr & barbeque exec. & system status, -R/M: Ф.03	-R/M: Ф.23-14 -R/M: Ф.02
5		-Communication, -«Globe» correction, -suit foxing, -condens. pump.	-Health status report, -Report on TV test results	-Operation schedule for the next day
6-11		Sleep period		
CT21. SECOND MANEUVER.				
12		-reveille, -morning toilet		
13		-Condens. pump. -Communication -System monitor., -Meal taking	-Health status report	-R/M: Ф.23-14
14		-Communication, -БО work station configure	-R/M: Ф.03	-Prompting on БО work station configure, on РУД2 test
15	- РУД2 test	-Communication, -РУД2 test, -purif. Cartridge replace in БО,СА	-Report on БО work station, -Report on РУД2 test results	-R/M: purif. Cartridge replacement in БО,СА
16		-Condens. pump -Communication, -Prepare for Mnvr 2	-Report on purif. Cartridge replacement	-R/M: pre-orient setting enter by КРЛ, -data for Mnvr 2 (Т.пуск,Т.РРП) -БЧК time sync

Rev.#	Spacecraft Operations	Crew Activities	Downlink Reports	Uplink Data
17(1)	-РУО 2 test, -Mnvr2, (1-imp., with pre-orient), -barbecue in POAK	-РУО 2 test, -Orient and syst. monitor in Mn 2, -exec b.b.q in POAK	-Report on РУО2 test results, -Report on Mnvr2 initiation	-Data for Mnvr2 (Т.ввода) -R/M: settings enter by КРЛ -Mnvr.2 Cycl.
18(2)		-System monitor, -Communication, -Ф.03 Form, -personal/resting time	-Report on Mnvr passage /system performance -Report on b.b.q in POAK exec	-R/M:Ф.23-14 -R/M:Ф.02
19(3)-20(4)		-Communication, -personal time		
21(8)		-Condens. pump -Purif cartr repl. In CA & БО		-R/M: purific. Cartridge replacement
22(6)-27(11)		Sleep period		
		CT22. THREE IMPULSE AUTONOMOUS APPROACH.		
28(12)		-reveille, -morning toilet -condens. pump		
29(13)		-Communication, -system monitor, -Ф.03 monitor	-Health status report -R/M:Ф.03	-R/M: Ф.23-14
30(14)		-Communication, -«Globe» correct. -personal time		-R/M: settings via КРЛ, -Approach vers., R/M: Ф.02
31(15)		-Communication, -Belt/suit don, -Trans to CA, -CA/БО hatch cl, -БОА CA sw On		-БЧК time sync, -R/M: РБ sw.On by КРЛ, -Promp: ПКО, ВКУ oper mode
32(16)	-Approach	-Attitude monitor -System monitor in autonomous approach	-Reporting on approach initiation and execution	-Data for approach, -Approach Cyclogram
33(1)	-Approach («Kurs» sw. On and test)	-Communication, -System monitor in autonomous approach exec.	-Report on approach exec and on system performance	-R/M: Ф.23-14, -Prompt on communication via CP
34(2)	-Fly around, -Station keep, -Berthing, -Docking	-Approach, berth, docking monitor, -Module/interf. Integrity check, -Transfer to БО, -Suit doff/dry	-Report on approach, berth., docking exec.	-R/M: GO for berthing, -R/M: Ф.23-14
35(3)	-Hook closing, -Transfer hatch opening	-TK, ОБ press equaliz reduced procedure, -transf hatch opening, -БОА in БО off, -Transf. to ОБ, -System monitor (Ф.03), -Condens pump, -Meal taking	-Report on module, interface integr test results, -R/M:Ф.03, -Report on transfer hatch opening exec	-R/M: transfer to combined power supply, -R/M: settings via КРЛ, -GO for transfer hatch opening
36(4)	-TK preservation	-TK preserv. -suit packing,		-R/M: Purificat. Cartridge repl

Rev.#	Spacecraft Operations	Crew Activities	Downlink Reports	Uplink Data
		-purification cartridge replace in CA, БО		in CA, БО
37(5)		-Communication, -Operation accor to ОБ FDF	-Report on TK preservation, -on cartr repl	
CT23. REDOCKING.				
(14)	-TK depreserv	-Operation accor to ОБ FDF, -TK depreserv -Auton pwr On		-R/M: Transf. to auton power, -redock data, -R/M: TK depr, -R/M: Ф.03 Form
(15)	-Transfer hatch closing	-sw БО БОА On -Transf hatch closing, -pressure relief from СУ assy -transfer hatch integrity test, -prep undock, -condens pump	-Report on TK depres exec, -Report on auton pwr trans exec, -Reporting on transf hatch closing, -R/M:Ф.03	-GO for transf hatch closing, -R/M: Ф.02
(16)		-suit donning, -CA/БО hatch closing, -sw CA БОА On	-Report on transfer hatch integrity	-R/M: settings via КРЛ
(1)	-Redocking	-Redocking exec, -Transf hatch integrity check, -БОА CA Off, -Trans to БО, -Suit don, dry	-Report on redocking exec procedure	-R/M: transfer to combined pwr, -R/M: TK battery charge
(2)		-Transfer to combined power, -TK charge On, -Syst monitor, -Interf pressuriz test	-Report on dock execution, -Report on module integrity test results	
(3)	-Transfer hatch opening	-TK, ОБ press equaliz reduced procedure, -Trans hatch opening, -БО БОА Off	-Report on Interface pressur test results, -Report on trans hatch open exec -R/M: Ф.03	-GO for trans hatch opening
		-Trans to ОБ, -Meal taking		
(4)	-TK preserv	-TK preserv, -Cond pump, -Oper accor to ОБ FDF	-Report on TK preservation execution	
(5)		Oper accor to ОБ FDF		
CT24. СУД #2 IN SPACECRAFT/ORBITER DOCKED CLUSTER.				
(14)		Oper accor to ОБ FDF		
(15)	-TK depreserv	-Transfer to TK -TK syst monitor -Prep for СУД test 2	-R/M: Ф.03	-Data for СУД test 2, -GO for СУД test 2
(1)	-СУД test 2	-СУД test 2 execution, -TK syst monitor -Trans to ОБ	-Reporting on СУД test 2 and system performance	-R/M: Ф.03 Form
(2)		-Communication, - Oper accor to ОБ FDF	-R/M:Ф.03	

Rev.#	Spacecraft Operations	Crew Activities	Downlink Reports	Uplink Data
CT25. UNDOCKING. DESCENT FROM REVOLUTION 1 IN ГЦ БЦВК.				
(11)		-Oper accor to ОБ FDF		
(12)	-TK depreservation	-TK depreserv, -Concl payload packing, -Auton pwr On -«Globe» corr., -Cond pump, -Ф.03 Form		-R/M: Transfer to autonom pwr, -Data for descent -R/M: Ф2 -Prompt: bring to TK Ф.23-14, food rations, -R/M: Ф.03 Form
(13)	-Transfer hatch closing	-БО БОА On' -Transfer hatch closing exec, -Press relief from СУ node, -Transfer hatch integrity check	-Report on TK depreser exec, -Report on trans to autonom pwr execution, -Reporting on hatch closing, -R/M:Ф.03	-GO for trans hatch closing, -R/M: settings via КРЛ, -Prompt: on belt, suit donning and water/salt additive taking
(14)	-Suit pressuriz test, -CA.БО hatch integrity test	-Belt, suit donning, -БО БОА Off, -Trans to CA, -CA БОА On, -CA/БО hatch closing, -suit integr test, -150 mm relief from БО, -CA/БО hatch integr test	-Report on trans hatch integrity test results	-Data for undocking, -БЧК time sync, -Descent cyclogram, -Prompt: on reporting until landing
(15)	-Undocking	-Undock exec, -Syst monitor, -БЦВК setting monitoring, -Meal taking, -Cond pumping	-Report on suit, CA/БО hatch integrity test results -Reporting on undocking	-GO for undock, -Prompt:БЦВК setting monitor, -БЧК time sync.
(16)	-Descent in ГЦ БЦВК (ОСК (ИКВ1)+ДПО-М1), -СКД burn (impulse Vскд=115,2 m/s)	-Attitude control monitoring, -System monitor, -Prep for descent.	-Report on readiness for descent, -Syst status report, -Report on Attitude control procedure, -Report on БЦВК, АУС, РУС setting monitoring	-R/M: settings via КРЛ, -data for descent, -R/M: landing area weather conditions, reference altitude
(1)	-Module separation, -Controlled descent, -Parachuting, -Landing	-System monitoring in descent	-Reporting on descent procedure, on system performance	

Soyuz Crew Operations Manual (SoyCOM) (ROP-19)
(June, 1999)

APPENDIX A

ПРИЛОЖЕНИЕ А

EXTERNAL VIEW OF CONTROL PANELS

Внешний вид панелей управления

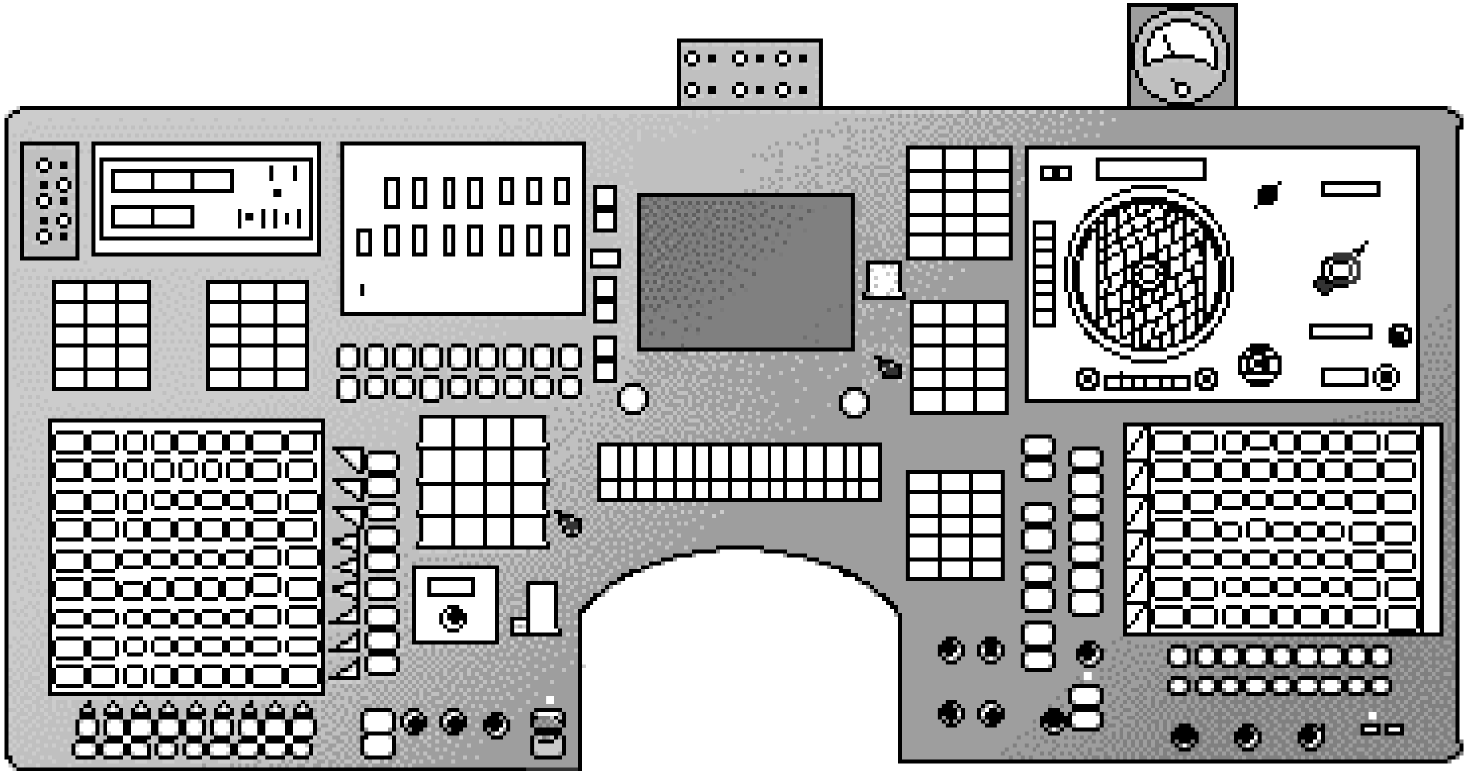


Fig.1. ПК СА Front panel

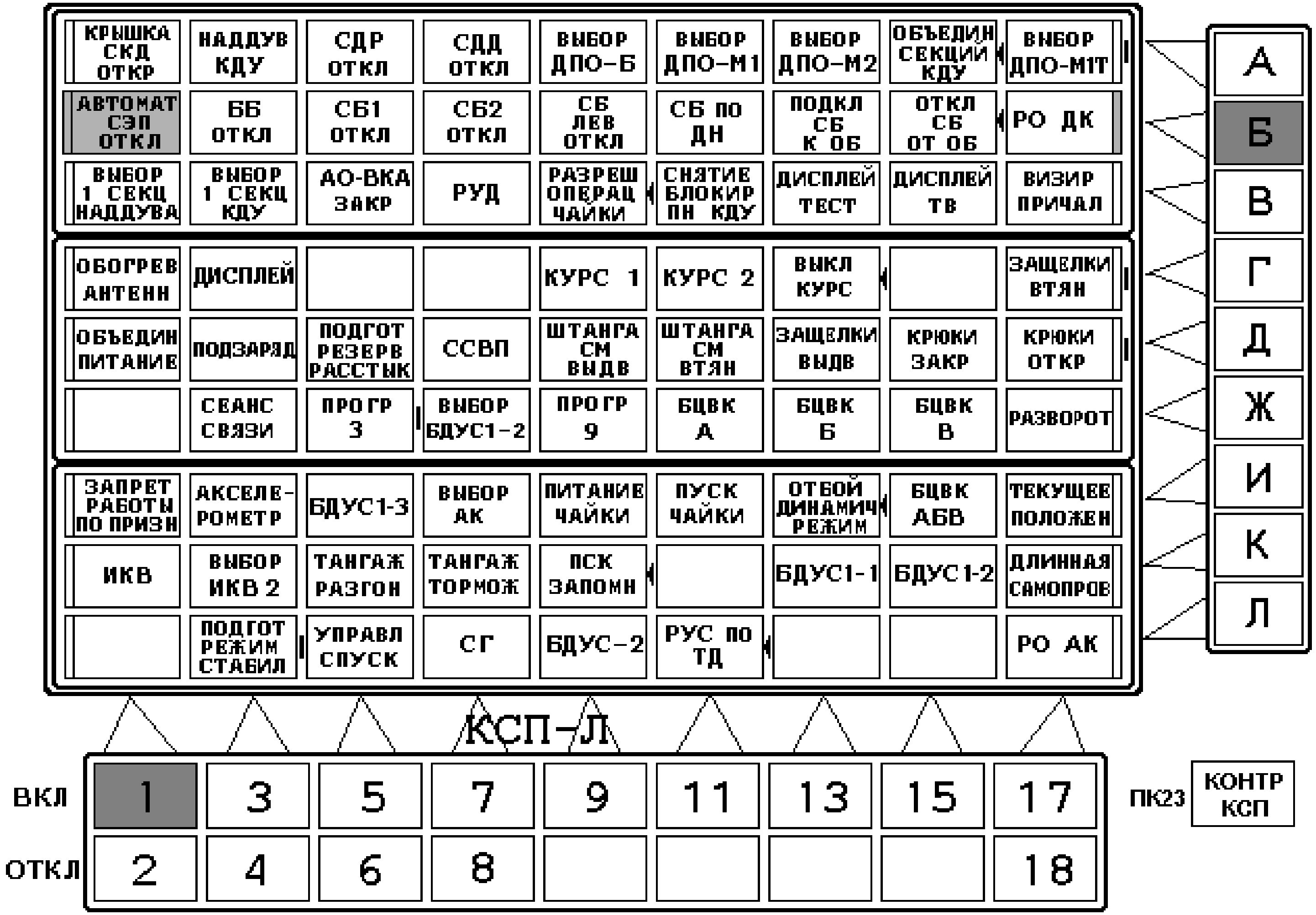


Fig.2. Command/Signal Panel - Left (КСП-Л)

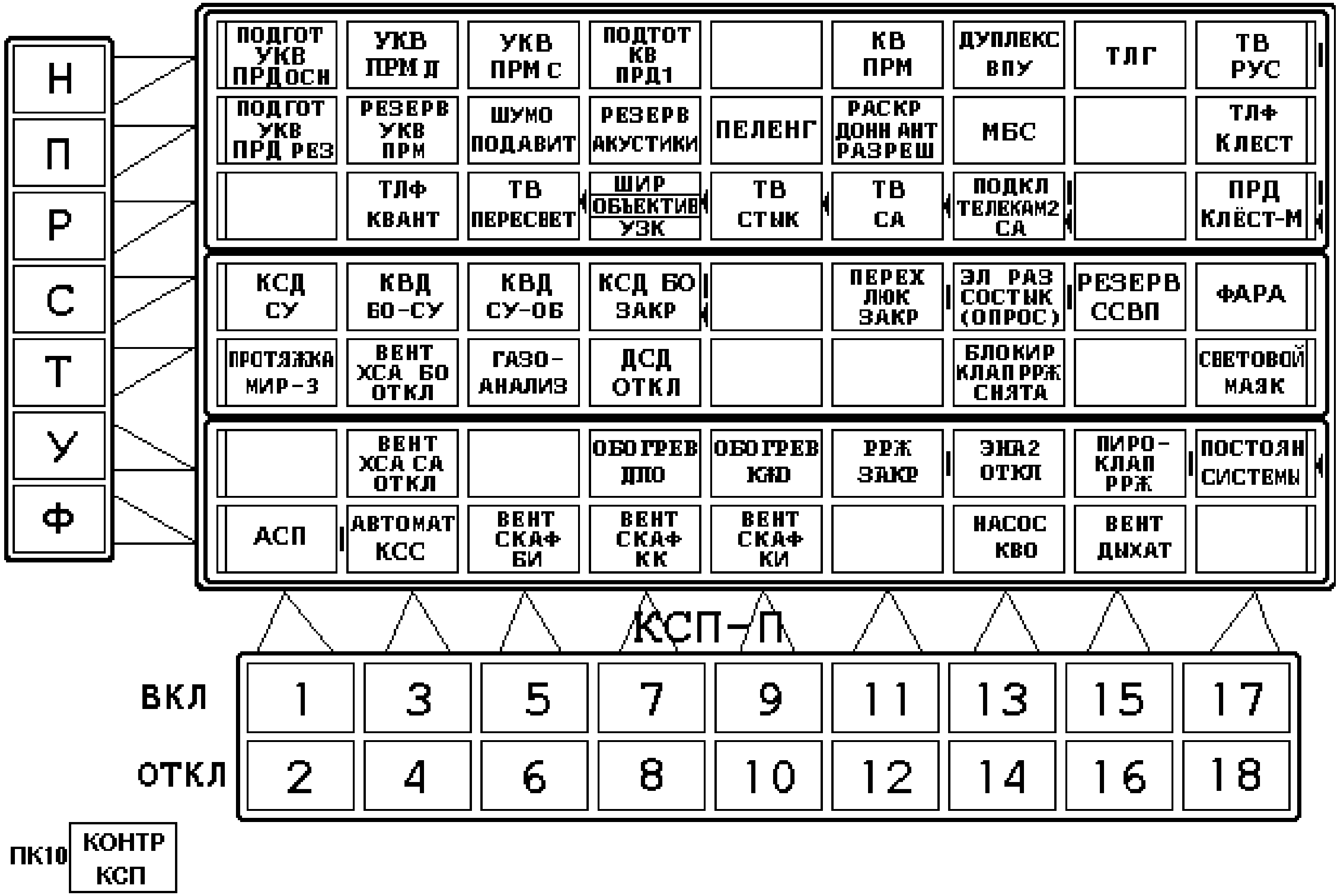


Fig.3. Command/Signal Panel - Right (КСП-П)

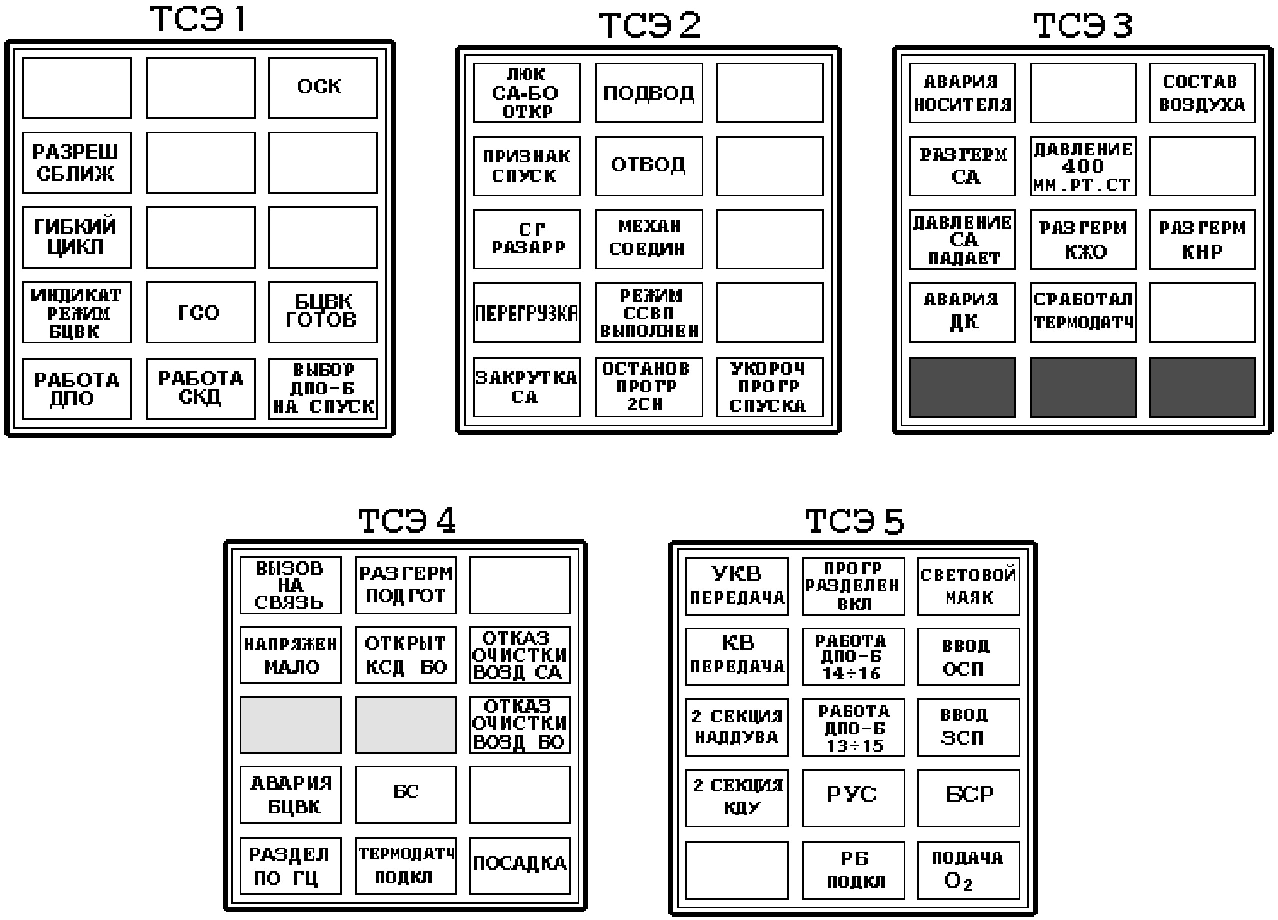


Fig.4. Electroluminescent Indicator Displays (ТСЭ)

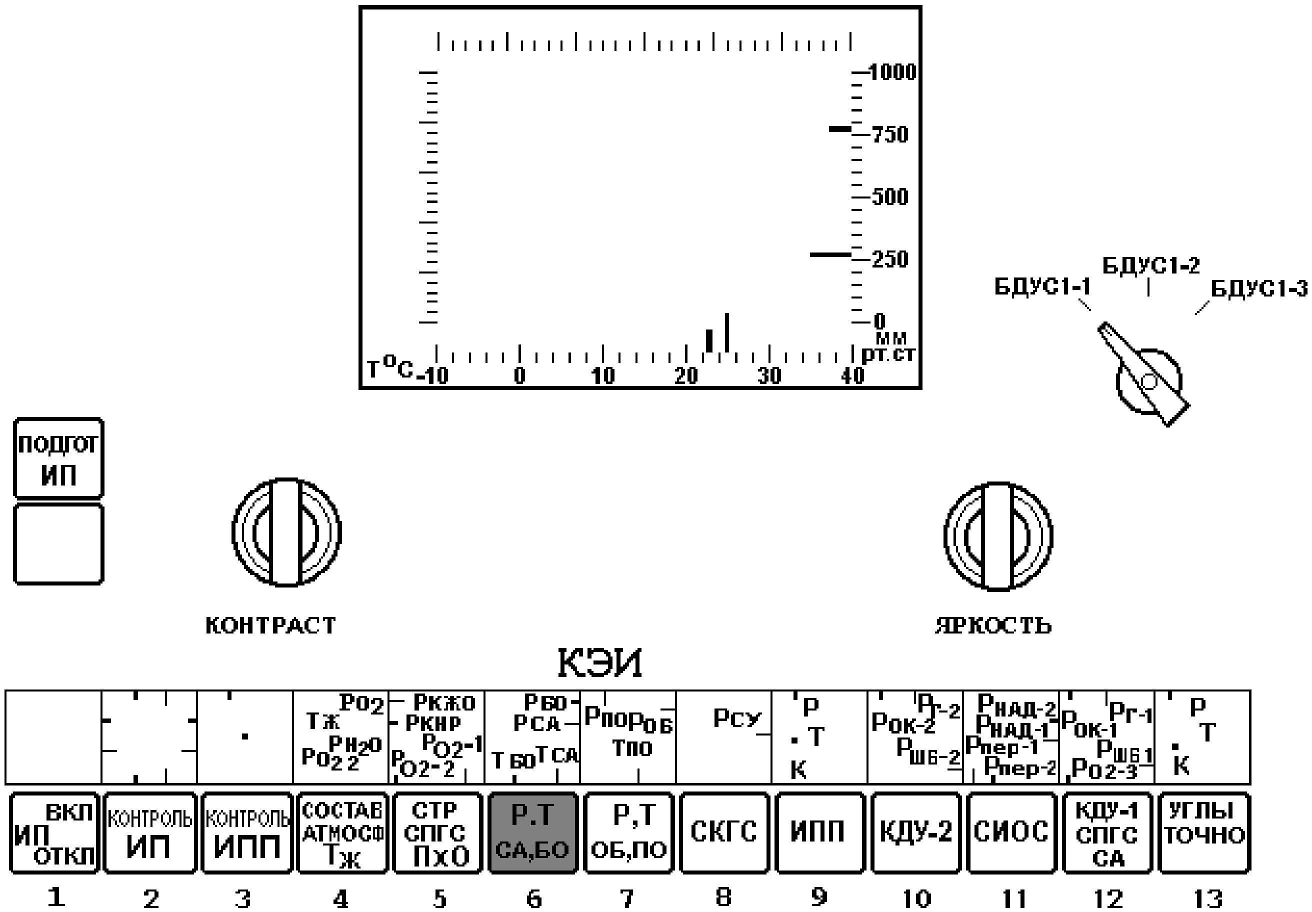


Fig.5. Combined Electronic Indicator (КЭИ)

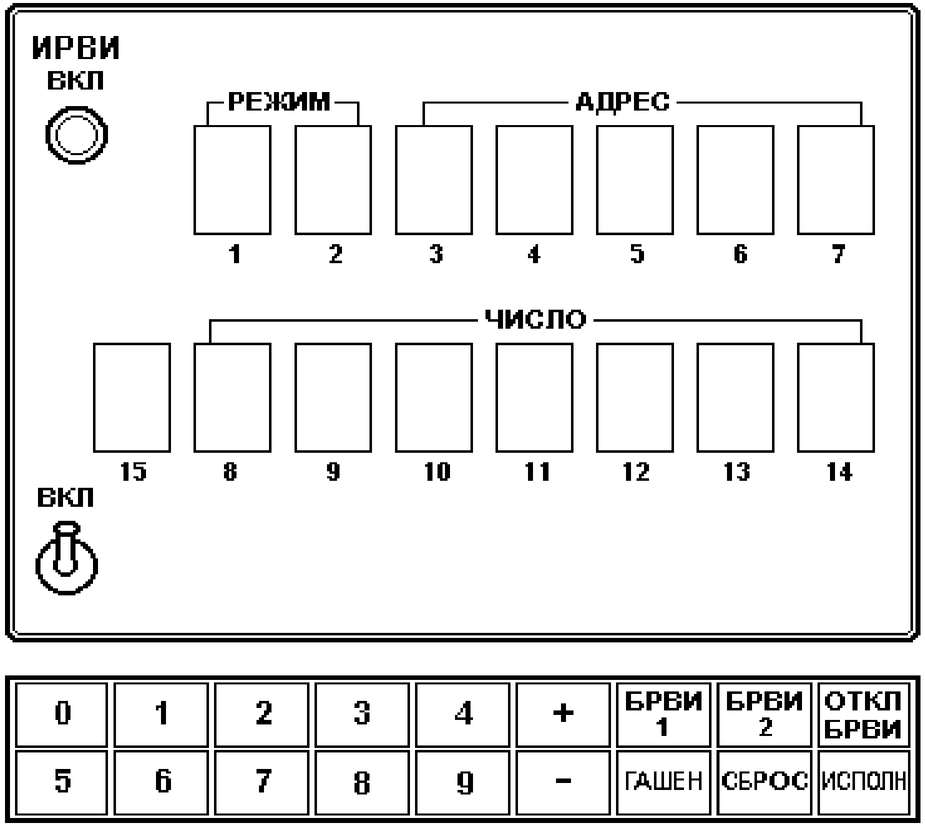


Fig.6. Manual Data Load Panel (ПРВИ)

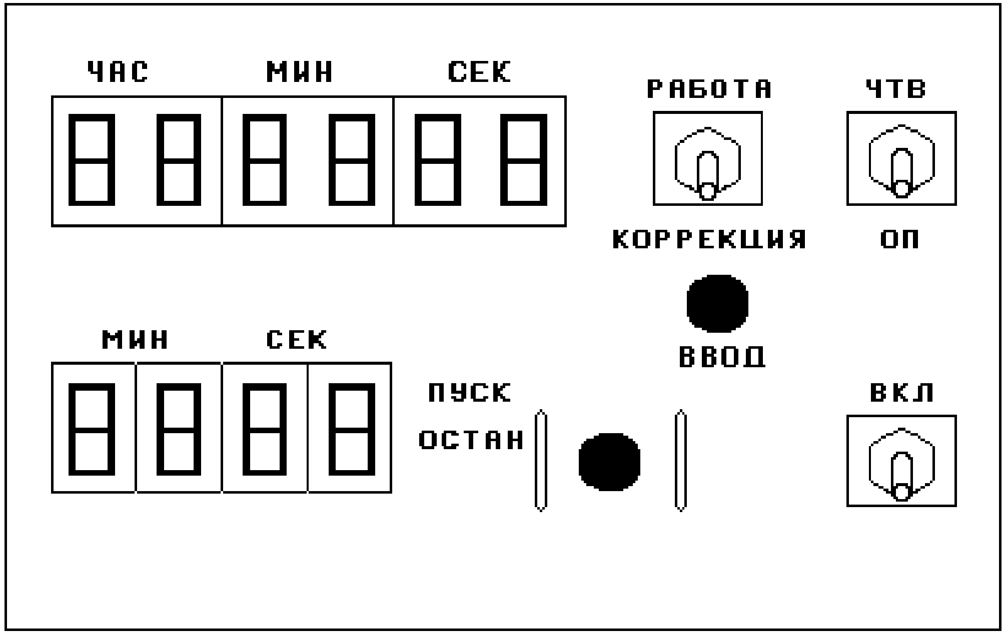


Fig.7. Onboard Clock (БЧК)

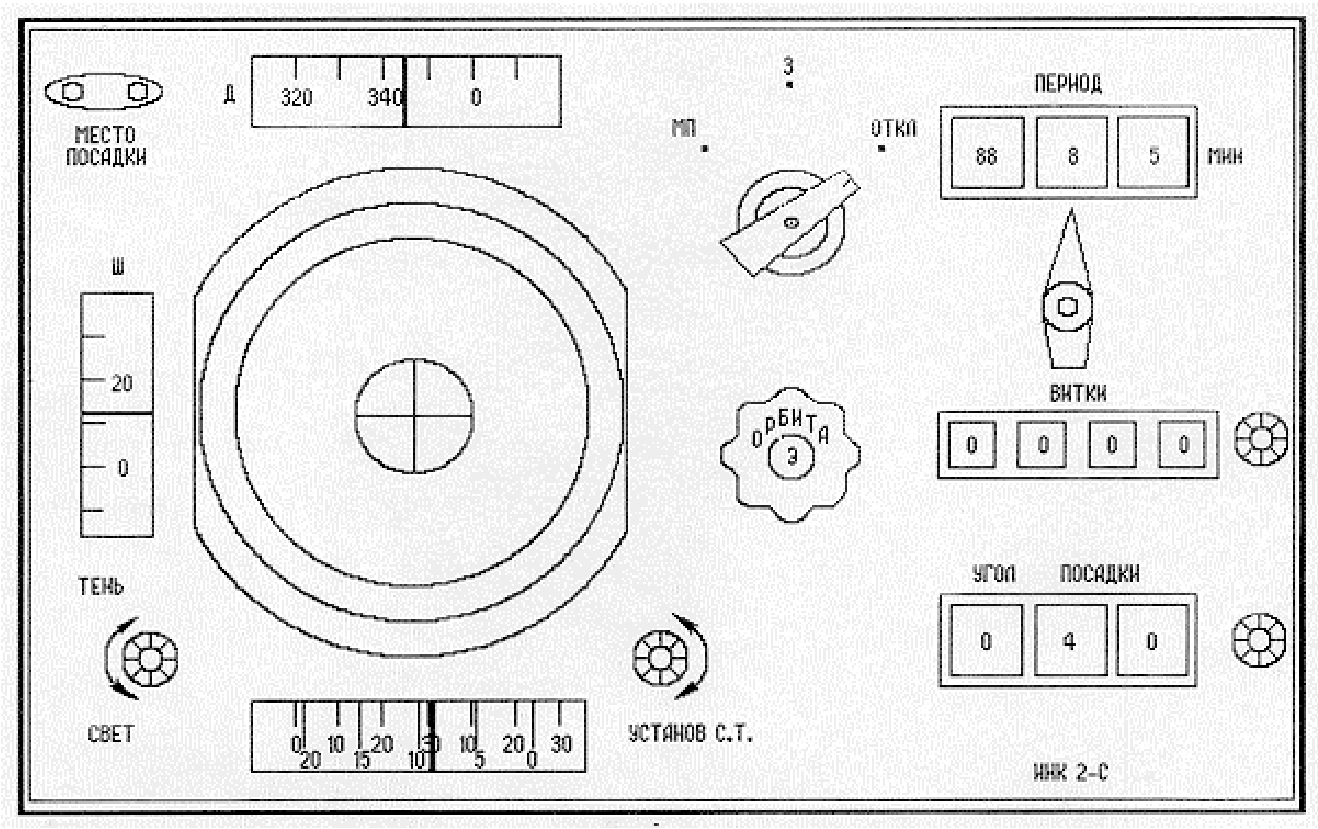


Fig.8. Space Navigation Indicator (ИНК)

Fig.9. Propellant Quantity Meter (СИ)

Fig.10. Critical Command Keys (ОВК)

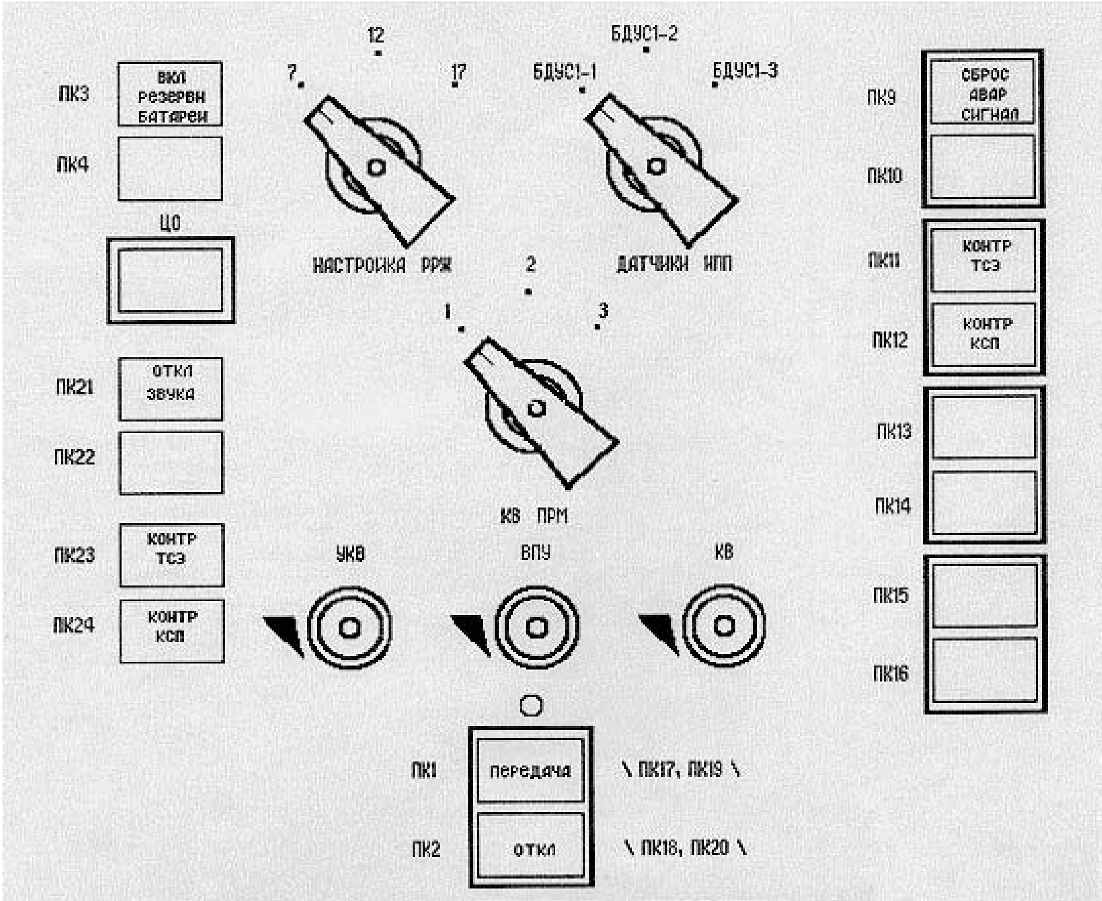


Fig.11. Separate Controls on ПК СА Panel

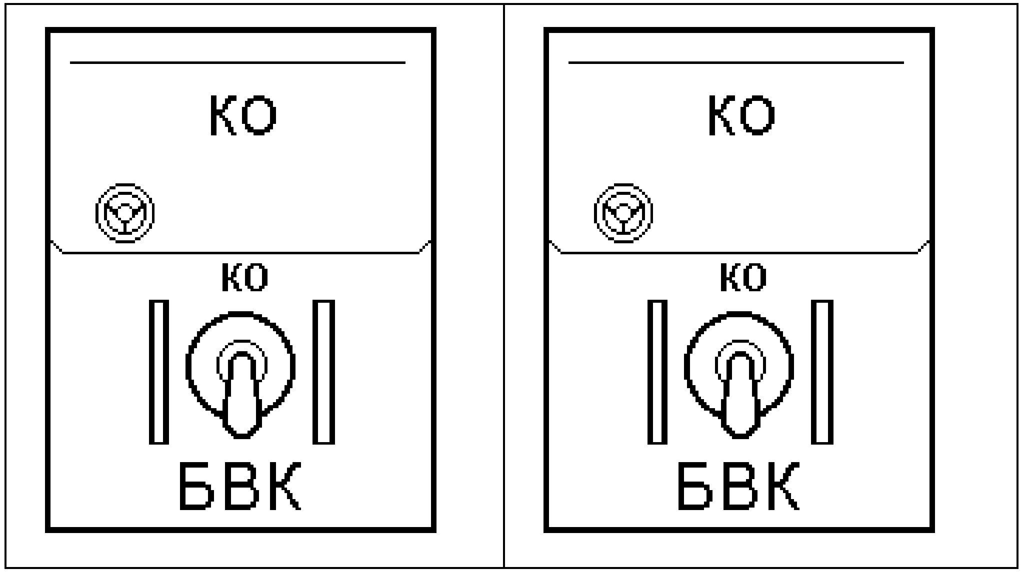


Fig.12. “Separation Contact” Command Issue Unit (БВК)

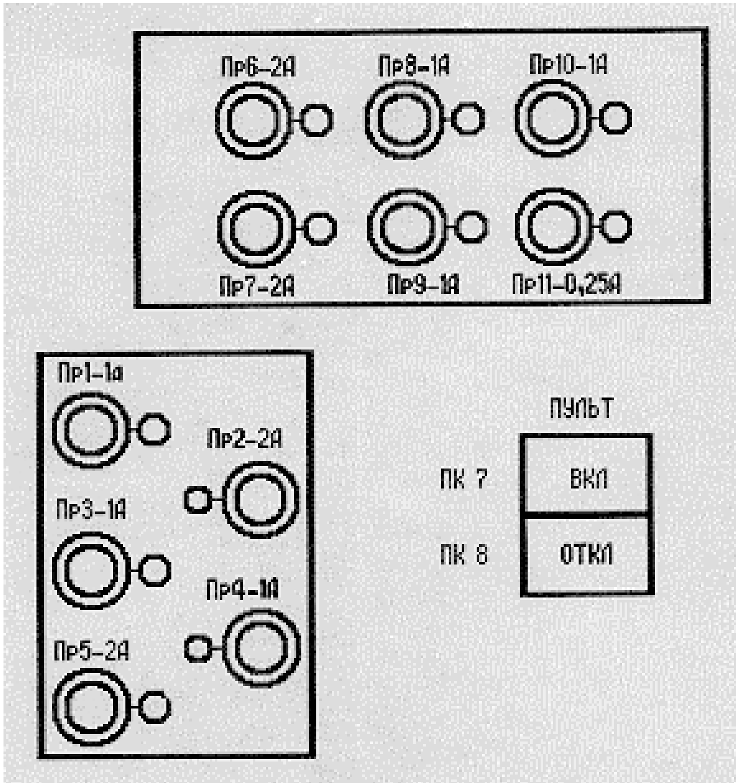


Fig.13. Circuit Breaker Sets and ПК СА Power Distribution

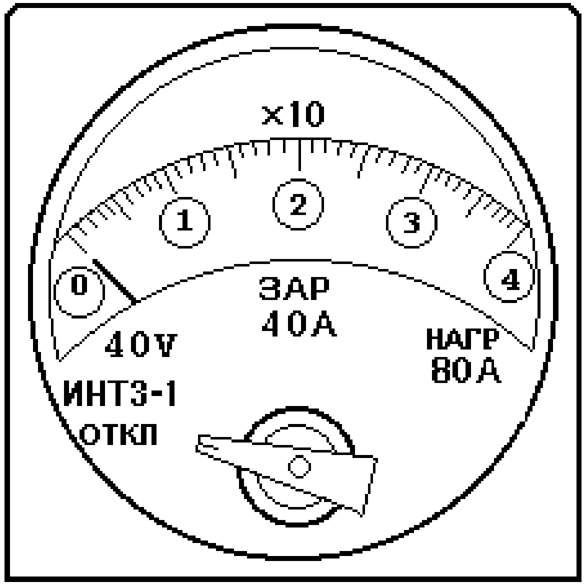


Fig.14. Voltage & Current Indicator (ИНТ)

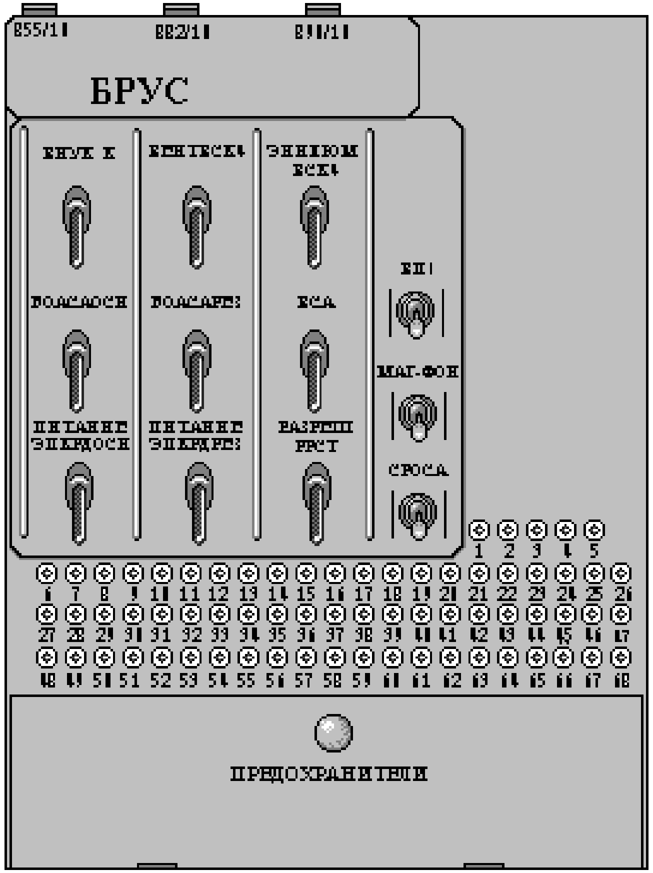


Fig.15. CA Manual Control Unit (БРУС)

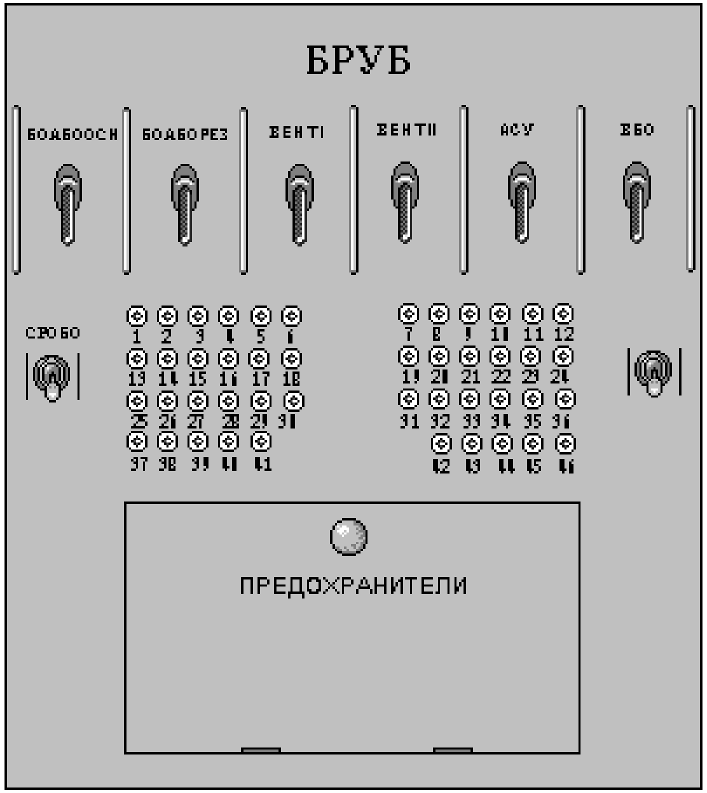


Fig.16. БО Manual Control Unit (БРУБ)

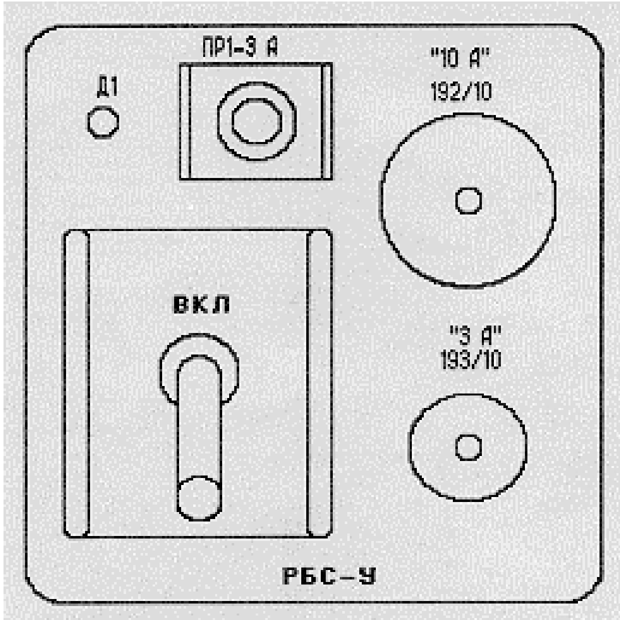


Fig.17. Universal Onboard Network Outlet (РБС-У)

Fig.18. Space Suit Power Supply Panel (ППС)

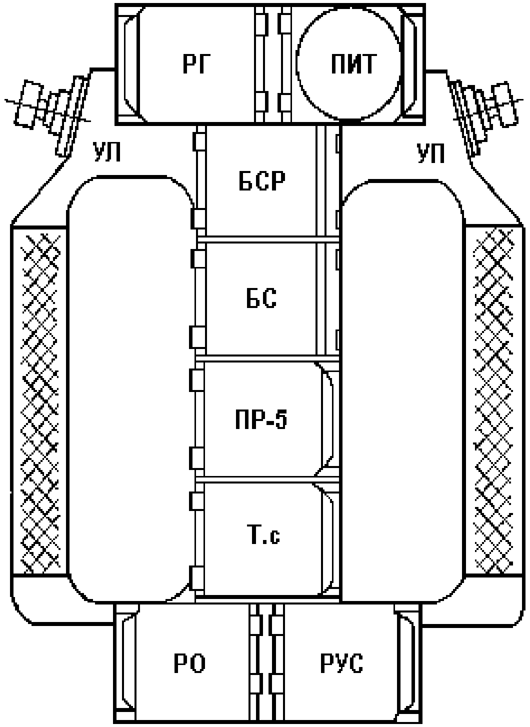


Fig.19. Descent Control Handle (РУС)

APPENDIX B

ПРИЛОЖЕНИЕ Б

EXTERNAL VIEW OF DISPLAYS

Внешний вид дисплеев

Form 41
MODE SETTING

Form 41 is used for the БЦВК setting data monitoring.

ТП=00.17.31С - БЦВК start time is 17 min 31 sec
Т0=14.05.08С - integration start time

УПР СЛОВА - БЦВК control words
B1, B6, B10, A20, A21, A30, R1, R6

ВРЕМЯ СБЛИЖЕН - times defining approach mode cyclogram
113T1=00.00.00С - "Kurs" Equipment energizing time
114T2=00.14.00С - "Kurs" Equipment "Захват" (Lock-on) monitoring time
115T3=00.14.00С - approach mode automatic termination time

УСТАВКИ - settings for corrective maneuver impulses by СКД Engine or ДПО-Бт Thurster burns

41V1=115,20 M/C	first corrective impulse value
42t1=2221C	first flexible time value
43L0=0.77777	attitude maneuver quaternion component 0 - $\lambda 0$
44L1=0.00000	attitude maneuver quaternion component 1 - $\lambda 1$
45L2=0.00000	attitude maneuver quaternion component 2 - $\lambda 2$
46L3=0.00000	attitude maneuver quaternion component 3 - $\lambda 3$
101V2=016,96 M/C	second corrective impulse value
102t1=0681C	second flexible time value
103L0=0.05447	attitude maneuver quaternion component 0 - $\lambda 0$
104L1=0.00000	attitude maneuver quaternion component 1 - $\lambda 1$
105L2=1.00174	attitude maneuver quaternion component 2 - $\lambda 2$
106L3=0.00000	attitude maneuver quaternion component 3 - $\lambda 3$

А НЕТ 00	No failure
ИН НЕТ	No checklist

Form 42
ATTITUDE CONTROL

Form 42 is used for monitoring the spacecraft attitude establishment and attitude hold.

ТП=00.18.09С - БЦВК start time is 18 min 09 sec

РЕЖИМ: ОСК - current attitude control mode is ОСК mode

ОПЕРАЦИИ: - operations currently being performed (if any)

ГСО 1 - Attitude Control System 1 Configured

ДАТЧИКИ: БДУС1, 2 ИКВ1 - sensors included into the control circuit

γ=3,00 Г - ИКВ signal error in roll γ between the strap-down and basic ОСК coordinate systems is 3 degrees
θ=3,00 Г - ИКВ signal error in pitch θ between the strap-down and basic ОСК coordinate systems is 3 degrees

УГЛ СКОРОСТЬ - attitude rates as measured by the БДУС sensor unit (actually absolute attitude rate vector projections onto the strap-down axes)
ωX=-0.751Г/С roll rate
ωY= 0.000Г/С yaw rate
ωZ=-0.751Г/С pitch rate

ΩКОРРЕК - instrument basis correction attitude rate (in БЦВК)
ΩX=-0.751Г/С correction roll rate
ΩY= 0.000ГС correction yaw rate
ΩZ=-0.751Г/С correction pitch rate

GO006.5 КГ current propellant consumption for spacecraft attitude control
GП067.9 КГ current propellant consumption for spacecraft translation
BR • • КГ propellant quantity allowed for spacecraft attitude control and translation

ИНДИКАТОР local vertical bias indicator relative to the spacecraft strap-down coordinate system:
upper horizontal axis - bias in yaw
lower horizontal axis - bias in roll
vertical axis - bias in pitch

А НЕТ 00 No failure
ИН НЕТ No checklist

Form 43
APPROACH

Form 43 is used for approach mode monitoring

ТП = 00.18.27С - БЦВК start time is 18 min 27 sec

ЗАПР СБ - Approach mode inhibited

АВТ - automatic mode

P •• propellant amount available for approach mode (in m/s)
C0.00000 "Kurs" Equipment reliable measurement data display

ОСК - current attitude control mode is ОСК mode

ГСО 1 - Attitude Control System 1 Configured

ГРАФИК range rate/relative range relationship chart:
horizontal axis - relative range in logarithm scale
vertical axis - radial range rate

ρ 00,000 relative range (БЦВК) in km
ρ' 000.00 radial range rate (БЦВК) in m/s

ΩY 0,000 line of sight yaw rate (БЦВК) in degrees/s
ΩZ 0,000 line of sight pitch rate (БЦВК) in degrees/s

УСТ ЛСК projections of the corrective impulse applied to the spacecraft center of mass onto the ЛСК coordinate system axes
ΔVX, ΔVY, ΔVZ

γ 00,00 roll angle ("Kurs" System data) in degrees
η 00,00 yaw angle ("Kurs") in degrees
θ 00,00 pitch angle ("Kurs") in degrees
ωX -0,743 roll rate as measured by БДУС sensor unit in degrees
ωY -0,003 yaw rate as measured by БДУС sensor unit in degrees
ωZ –0,761 pitch rate as measured by БДУС sensor unit in degrees

ИНДИКАТОР line of sight attitude relative to the spacecraft strap-down coordinate system:
upper horizontal axis - mutual roll angle
lower horizontal axis - line of sight bias in yaw
vertical axis - line of sight bias in pitch

"Ф" - БЦВК parameter display ("К" - "Kurs" System parameter display)

А НЕТ 00 No failure
ИН НЕТ No checklist

Form 44
BERTHING

Form 44 is used for data display in the berthing mode and for the filter algorithm operation monitoring

ТП = 00.18.45С - БЦВК start time is 18 min 45 sec

ЗАПР СБ - Approach mode inhibited

АВТ - automatic mode

Р •• propellant amount available for approach mode (in m/s)
С0.00000 "Kurs" Equipment reliable measurement data display

ОСК - current attitude control mode is ОСК mode

ГСО 1 - Attitude Control System 1 Configured

ГРАФИК range rate/relative range relationship chart:
horizontal axis - relative range in logarithm scale
vertical axis - radial range rate

ρ 00,000 relative range (БЦВК) in km
ρ' 000.00 radial range rate (БЦВК) in m/s

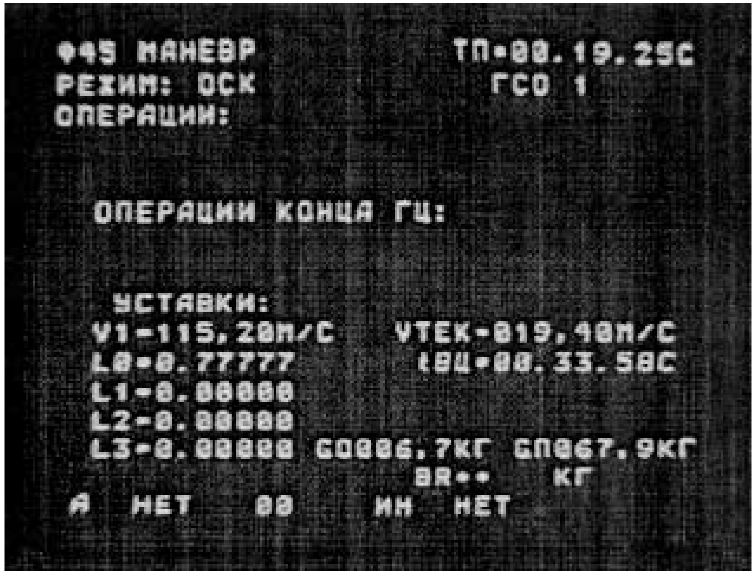
ΩY 0,000 line of sight yaw rate (БЦВК) in degrees/s
ΩZ 0,000 line of sight pitch rate (БЦВК) in degrees/s

ωX -0,734 roll rate as measured by БДУС sensor unit in degrees
ωY -0,009 yaw rate as measured by БДУС sensor unit in degrees
ωZ –0,761 pitch rate as measured by БДУС sensor unit in degrees

КУРС - "Kurs" Equipment measurement data

γ 00,00 roll angle ("Kurs") in degrees
ηп 00,00 direction angle in yaw channel ("Kurs") in degrees
θп 00,00 direction angle in pitch channel("Kurs") in degrees
ρ 00,000 relative range ("Kurs") in km
ρ' 000.00 radial range rate ("Kurs") in m/s
ΩZ 0,000 line of sight pitch rate ("Kurs") in degrees/s
ΩY 0,000 line of sight correction yaw rate ("Kurs") in degrees/s

А НЕТ 00 No failure
ИН НЕТ No checklist



Form 45
Maneuver

Form 45 is used for maneuver execution monitoring.

ТП=00.19.25С - БЦВК start time is 19 min 25 sec

РЕЖИМ: ОСК - current attitude control mode is ОСК mode

ОПЕРАЦИИ: - operations currently being performed (if any)

ГСО 1 - Attitude Control System 1 Configured

ОПЕРАЦИИ КОНЦА ГЦ - БЦВК flexible cycle end operations (if any)

УСТАВКИ - settings for corrective maneuver impulses by СКД Engine or ДПО-Бт Thurster burns

V1=115,20 М/С	impulse value
L0=0.77777	attitude maneuver quaternion component 0 - $\lambda 0$
L1=0.00000	attitude maneuver quaternion component 1 - $\lambda 1$
L2=0.00000	attitude maneuver quaternion component 2 - $\lambda 2$
L3=0.00000	attitude maneuver quaternion component 3 - $\lambda 3$
VTEK=019,40 М/С	accumulated impulse current value
tВЦ=00.33.58С	flexible cycle time (decreasing value)
GO006.7 КГ	current propellant consumption for spacecraft attitude control
GП067.9 КГ	current propellant consumption for spacecraft translation
BR • • КГ	propellant quantity allowed for spacecraft attitude control and translation
А НЕТ 00	No failure
ИН НЕТ	No checklist

Form 46
STATUS MONITOR

Form 46 is used for Motion Control System status monitoring

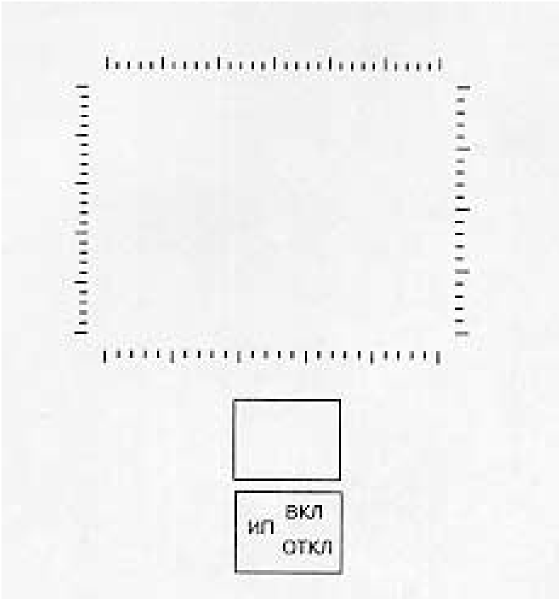
ТП=00.19.25С - БЦВК start time is 19 min 25 sec

АВАРИЯ: НЕТ - no failure

ИНСТРУКЦИЯ: НЕТ - no checklist

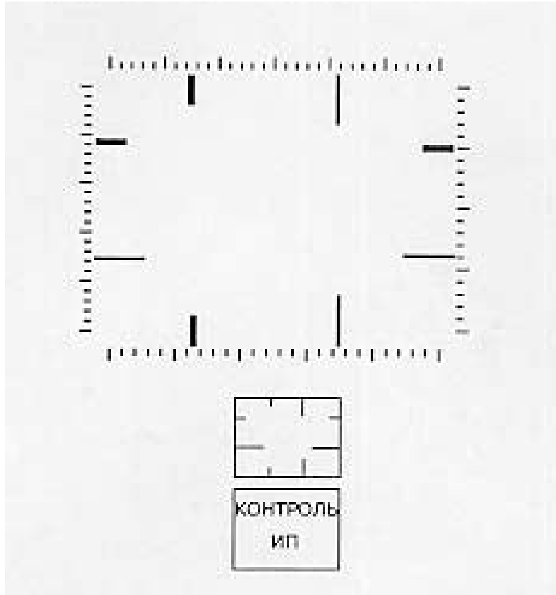
GO006.7 КГ current propellant consumption for spacecraft attitude control
GП067.9 КГ current propellant consumption for spacecraft translation
BR • • КГ propellant quantity allowed for spacecraft attitude control and translation

TBC09.29.30 C time moment of the spacecraft reaching the orbiter proximity area (dispersion ellipsoid)



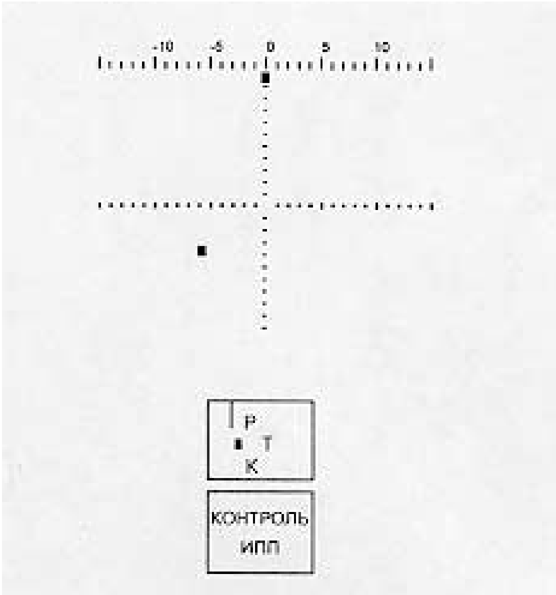
КЭИ-1
ИП ВКЛ ОТКЛ

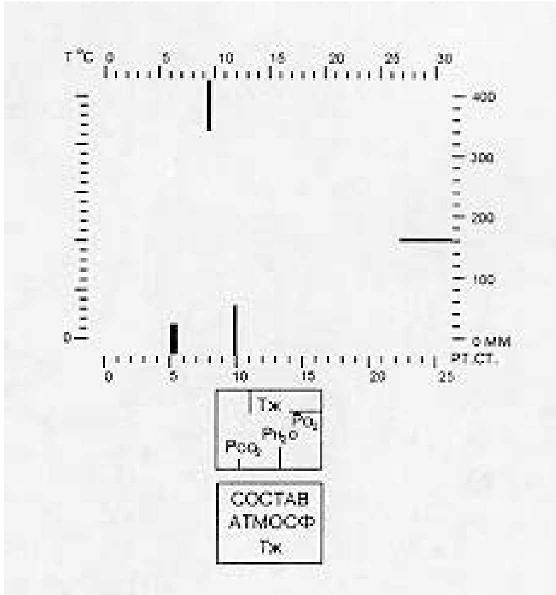
(Indicator Power ON/OFF)



КЭИ-2
КОНТРОЛЬ ИП

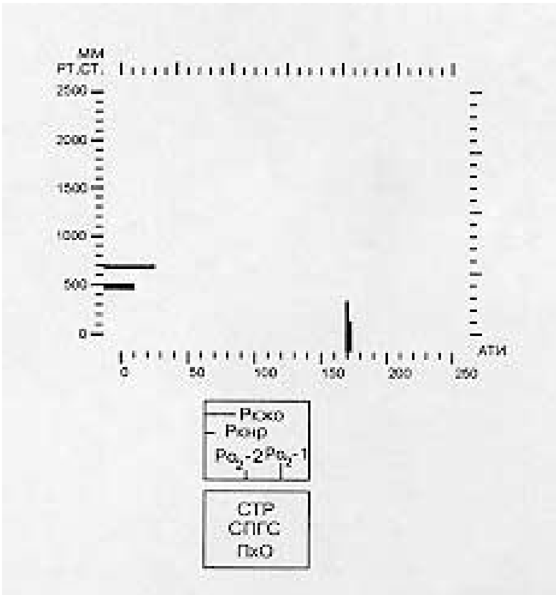
(Parameter Indicator Monitor)


-10
-5
0
5
10
P
T
K
КОНТРОЛЬ
ИПП


T °C
0
5
10
15
20
25
30
400
300
200
100
0 ММ
РТ.СТ.
0
5
10
15
20
25
Тж
P_{O_2}
P_{H_2O}
P_{CO_2}
СОСТАВ
АТМОСФ
Тж

КЭИ-3
КОНТРОЛЬ ИПП

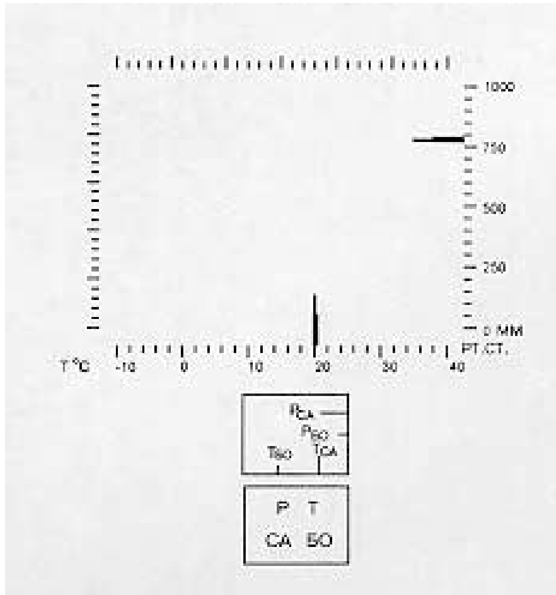
(Current en Route Position Indicator Monitor)



КЭИ-4
СОСТАВ АТМОСФЕРЫ $Т_ж$

(Atmosphere Composition, Тж)

PO_2 – Oxigen Partial Pressure (0-300 мм Hg)
PCO_2 – Carbon Dioxide Partial Pressure (0-25 мм Hg)
PH_2O – Water Vapor Partial Pressure (5-15 мм Hg)
$Т_ж$ – СОТР System Agent Temperature (0-20°C)



КЭИ-5
СТР СПГС ПхО

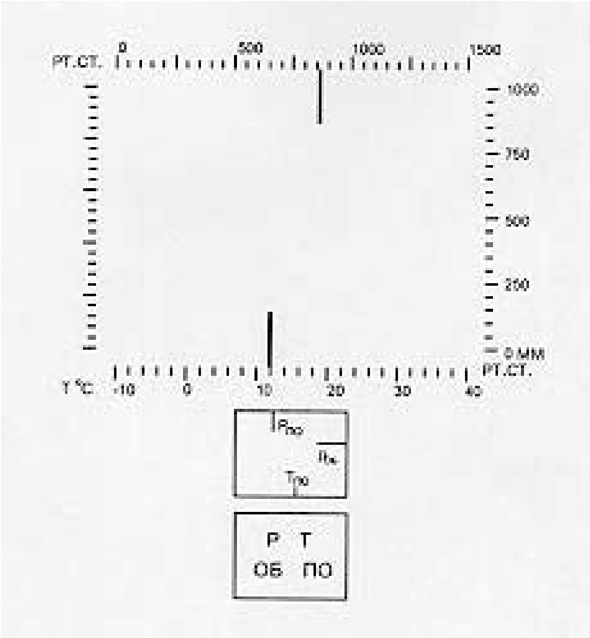
(СТР System and ПхО Module СПГС System Parameter Monitor)

$P_{кжо}$ – Habitable Module Loop Pressure (100-2300 мм Hg)
$P_{кнр}$ – Attached Radiator Loop Pressure (100-2300 мм Hg)
PO_2-1 – ПхО Module Section 1 Oxygen Bottle Pressure (0-250 kgf/cm2)
PO_2-2 – ПхО Module Section 2 Oxygen Bottle Pressure (0-250 kgf/cm2)

КЭИ-6
Р, Т СА БО

(СА/БО Module Pressure and Temperature Monitor)

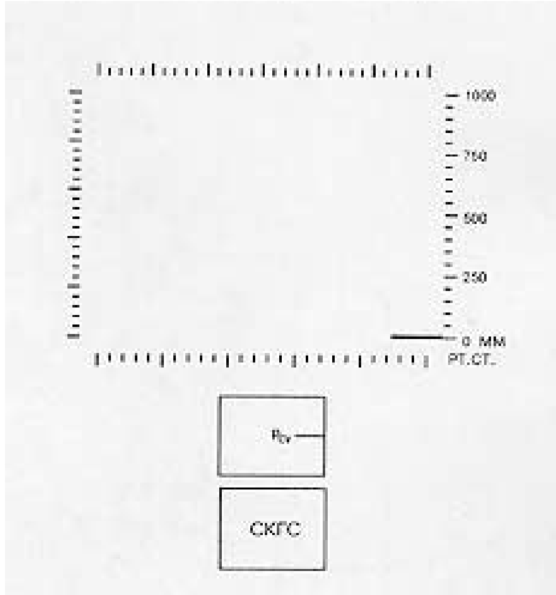
P_{CA} – СА Module Pressure (1-1000 мм Hg)
$P_{БО}$ – БО Module Pressure (1-1000 мм Hg)
T_{CA} – СА Module Temperature (0-40^{0}C)
$T_{БО}$ – БО Module Temperature (0-40^{0}C)



КЭИ-7
Р, Т ОБ ПО

(ОБ/ПО Module Pressure and Temperature Monitor)

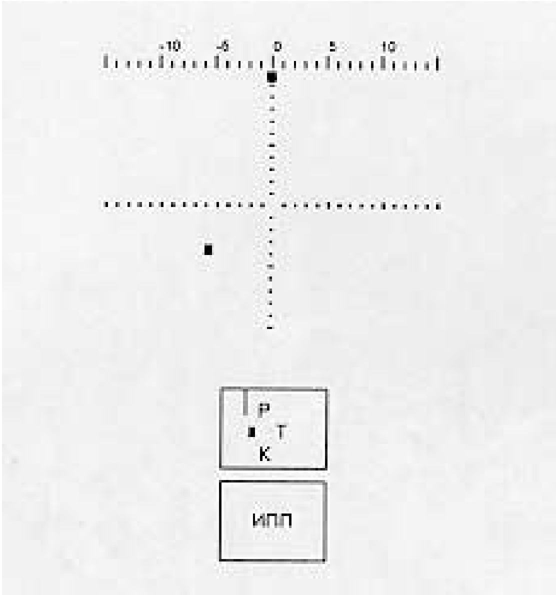
$P_{ОБ}$– ОБ Module Pressure (1-1000 мм Hg)
$P_{ПО}$ – ПО Module Pressure (1-1500 мм Hg)
$T_{ПО}$ – ПО Module Temperature (0-40^{0}C)



КЭИ-8
СКГС

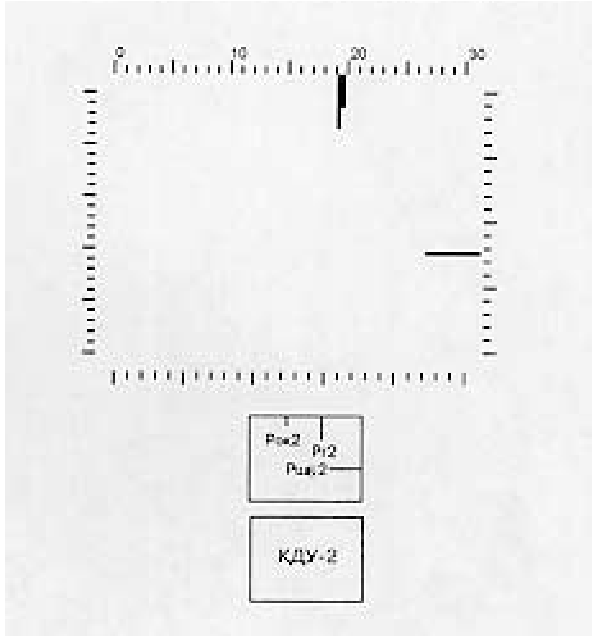
(СКГС System Monitor)

P_{cy} – СУ Assembly Pressure (1-1000 мм Hg)



КЭИ-9
ИПП

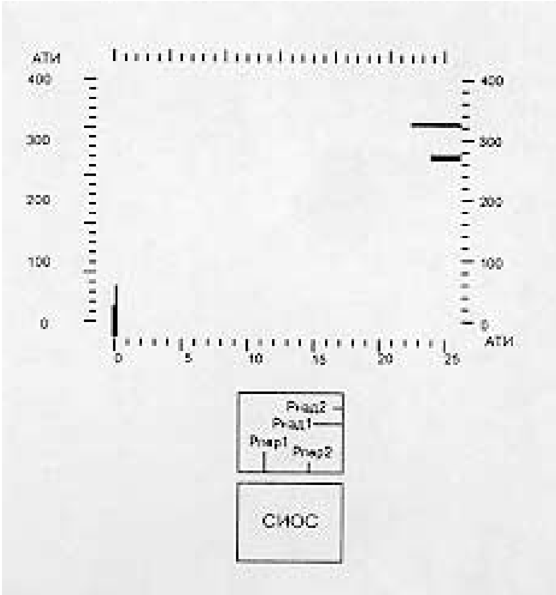
(Current en Route Position Indicator)



КЭИ-10
КДУ-2

(КДУ System Section 2 Parameter Monitor)

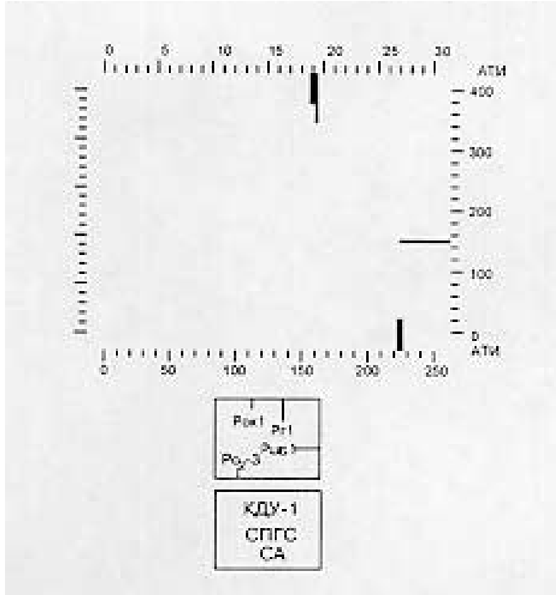
$P_{г2}$ – Section 2 Fuel Tank Pressure (0-30 kgf/cm2)
$P_{ок2}$ – Section 2 Oxidizer Tank Pressure (0-30 kgf/cm2)
$P_{шб2}$ – Section 2 Spherical Bottle Pressure (0-400 kgf/cm2)



КЭИ-11
СИОС

(СИОС System Monitor)

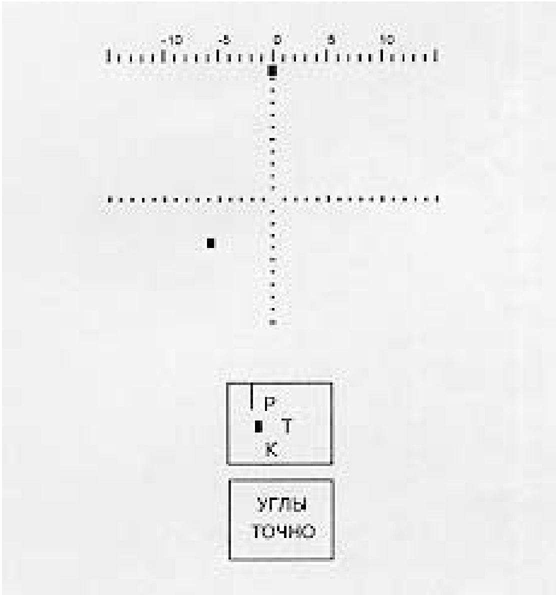
$P_{над1}$ – СИОС Section 1 Pressurization Pressure (0-350 kgf/cm2)
$P_{над2}$ – СИОС Section 2 Pressurization Pressure (0-350 kgf/cm2)
$P_{пер1}$ – Peroxide Tank 1 Pressure (0-25 kgf/cm2)
$P_{пер2}$ – Peroxide Tank 2 Pressure (0-25 kgf/cm2)



КЭИ-12
КДУ-1 СПГС СА

(КДУ System Section 1 and CA Module СПГС System Parameter Monitor)

$P_{ок1}$ – Section 1 Oxidizer Tank Pressure (0-30 kgf/cm2)
$P_{г1}$ – Section 1 Fuel Tank Pressure (0-30 kgf/cm2)
$P_{шб1}$ – Section 1 Spherical Bottle Pressure (0-400 kgf/cm2)
PO_2-3 – CA Module Oxygen Bottle Pressure(0-250 kgf/cm2)



КЭИ-13
УГЛЫ ТОЧНО

(Precise Angles)

(БДУС 1-3 Sensor Unit data)

APPENDIX C

ПРИЛОЖЕНИЕ В

GLOSSARY
OF SOYUZ ABBREVIATIONS AND ACRONYMS

Словарь сокращений и акронимов
по кораблю “Союз ТМ”

А

А	Апогей	Apogee
АВД	Аварийное Выключение Двигателя	Emergency Engine Cut-off
Авт.	Автоматический	Automatic
АДРЕС 8	Адрес Восьмеричный	Octal Address
АДРЕС 2	Адрес Двоичный	Binary Address
АЗ	Азимут Запуска	Launch Azimuth
АЗС	Автомат Защиты Сети	Circuit Breaker
АИМ	Амплитудно-Импульсная Модуляция	Pulse Amplitude Modulation
АК	Аналоговый Контур	Analog Circuit
АК	Аэродинамическое Качество	Lift/Drag Ratio
АКСС	Автоматика Комплекса Средств Спасения	Survival Aid Complex Automatic Equipment
АЛГ	Алгоритм	Algorithm
АМ	Амплитудная Модуляция	Amplitude Modulation
Амп	Амперы	Amperes
АО	Агрегатный Отсек	Instrument Module
АО	Антенна Кругового Обзора	All-Around Antenna
АПАС	Андрогинный Периферийный Агрегат Стыковки	Androgynous Peripheral Docking Assembly
АПСС	Андрогинная Периферийная Система Стыковки	Androgynous Peripheral Docking System
АС	Американский Сегмент	American Segment
АС	Антенна Автосопровождения	Autofollow(ing) Antenna
АСП	Автоматика Системы Приземления	Landing System Automatic Equipment
АСУ	Ассенизационно-Санитарная Установка	Waste Management System
ата	Атмосфера	Atmosphere
АУС	Автоматический Управляемый Спуск	Automatically Controlled Descent
АФУ	Антенно-Фидерное Устройство	Antenna Feeder System

Б

б	Бит	Bit
БА	Блок Акселерометров	Accelerometer Assembly
Балл.	Баллистический	Ballistic
БАП	Блок Автоматических Переключателей	Automatic Switching Unit
БАРД	Блок Автоматического Регулирования Давления	Automatic Pressure Control Unit
ББ	Базовый Блок (17КС)	Mir Core Module (17KS)
ББ	Буферная Батарея	Buffer Battery
ББР	Блок Бароpеле	Barometric Relay Unit
БВ	Блок Вентиляторов	Fan Unit
БВС	Блок Вентиляции Скафандров	Spacesuit Ventilation Unit
БВ СА	Блок Вентиляторов СА	Descent Module Fan Unit
БВВ	Блок Включения Вентилятора	Fan Control Unit
БВК	Блок Выдачи Команд	Command Issue Unit
БД	Блок Датчиков	Sensors Unit
БД	Боковая Дальность	Cross Range
Б/Д	Бортовая Документация	Flight Data File, Onboard Documentation
БДУС	Блок Датчиков Угловых Скоростей	Attitude Rate Sensor Unit
Безоп.	Безопасность	Safety
Б/Ж	Бортовой Журнал	Flight Log Book

БИ	Бортинженер	Flight Engineer
Б/И	Бортовая Инструкция	Onboard Checklist
БКС	Блок Кабельной Сети	Cable Network Unit
БКП	Блок Коммутации Питания	Power Switching Unit
БК	Бортовой Контейнер	Onboard Container
БКС	Блок Коммутации Сигналов	Signals Switching Unit
БКС	Бортовая Кабельная Сеть	Onboard Cable Network
БК ГА	Блок Контроля Газоанализатора	Gas Analyser Monitoring Unit
Бл.	Блокировка	Interlock
БЛП	Блок Логики Пульта	Console Logic Unit
БНО	Баллистическое Навигационное Обеспечение	Ballistic Navigation Support
БО	Бытовой Отсек	Habitable Module, Resting Module
БОА	Блок Очистки Атмосферы	Atmosphere Purification Unit
БП	Блок Питания	Power Unit
БП	Большая Полость	Greater Volume
Б/П	Беспилотный	Unmanned, Pilotless
БПП	Блок Плавких Предохранителей	Fuse (Protection) Unit
БР-1	Блок Распределительный-1	Distribution Unit-1
БРВИ	Блок Ручного Ввода-Вывода Информации	Manual Data Load Unit
БРС	Быстроразъемное Соединение	Quick Disconnect
БРТК	Бортовой Радиотехнический Комплекс	Onboard Communication Complex
БРУБ	Блок Ручного Управления БО	OM Manual Control Unit
БРУС	Блок Ручного Управления СА	DM Manual Control Unit
БС	Боковая Скорость	Side Velosity
БС	Баллистический Спуск	Ballistic Descent
БСА	Батарея СА	DM Battery
БСА	Блок Силовой Автоматики	Actuation Automatic Unit
БСР	Баллистический Спуск Резервный	Backup Ballistic Descent
БУ	Блок Управления	Control Unit
БФИ	Блок Формирования Информации	Data Generation Unit
БЦВК	Бортовой Цифровой Вычислительный Комплекс	Onboard Digital Computing Complex
БЦИ	Блок Цифровой Индикации	Digital Display Unit
БЧК	Бортовые Часы Космические	Onboard Clock

В

В	Виток	Revolution (Orbit)
В	Вольт	Volt
ВА	Всенаправленная Антенна	Omnidirectional Antenna
ВБО	Вентилятор БО	Orbital Module Fan
ВВ	Вентилятор Воздуховода	Air Duct Fan
ВВ	Воздуховод	Air Pipe, Air Tube
ВВД	Время Включения Двигателя	Ignition Time
ВВФ	Внешние Возмущающие Факторы	Externally Acting Factors
ВДВ	Восточное Дневное Время	Eastern Daylight Time
ВЕНТ	Вентилятор	Ventilation Fan
Верт.	Вертолет	Helicopter
ВЖВ	Выживание	Survival
ВИПШ	Выдвижение Штанги в Исходное Положение	Rod Extension to Initial Position
ВК	Видеокамера	Camcorder
ВК	Выключатель Концевой	Switch
ВКД	Внекорабельная Деятельность	Extravehicular Activity
ВКЛ	Включить	Turn ON
ВКУ	Видео-Контрольное Устройство	Video Monitoring Device
ВМ	Вычислительная Машина	Computer or Calculator

ВНУК	Визир Ночного Управления по Курсу	Night Vision Instrument
ВО	Внутреннее Освещение	Internal Lighting
ВОС	Внешние Огни Сближения	External Rendezvous Lights
ВП	Вектор Положения	State Vector
ВП	Высотомер Парашютный	Parachute Altimeter
ВП	Вытяжной Парашют	Auxiliary Parachute
ВП-1	Визир Пилота	Pilot's Sight
ВПУ	Внутреннее Переговорное Устройство	Internal Communication System
ВРД	Время Работы Двигателя	Engine Burn Time
Вр.	Вращение	Rotation, Spin
ВС	Вектор Скорости	Velocity Vector
ВСА	Вентилятор СА	Descent Module Fan
ВСВ	Восточное Стандартное Время	Eastern Standart Time
ВСК	Визир Специальный Космический	Orientation Sight
Вт	Ватт	Watt
ВхТ	Вход в Тень	Sunset, Entrance into Shadow
ВЧ	Высокая Частота	High Frequency
ВЫКЛ	Выключить	Turn OFF
ВыхТ	Выход из Тени	Sunrise, Exit from Shadow
ВЭН	Воздушный Электронагреватель	Electric Air Heater
H	Водород	Hydrogen

Г

Г	Горючее	Fuel
ГА	Газоанализатор	Gas Analyser
ГЕРМЕТ	Герметичность	Pressure Integrity
ГЖА	Газожидкостный Агрегат	Gas-Liquid Unit
ГЗВ	Гринвичское Звездное Время	Greenwich Siderial Time
ГИР	Гироскоп	Gyroscope
ГК	Грузовой Корабль	Cargo Vehicle
ГК	Главная Команда на Выключение СКД	Main Command for OME Shutdown
ГК III	Главная Команда на Выключение III ступени	Main Command for3-rd Stage Shutdown
ГЛ	Гидролаборатория	Neutral Buoyancy LAB
ГЛВ	Гамма-Лучевой Высотомер	Gamma Ray Altimeter
ГМ	Гринвичский Меридиан	Greenwich Meridian
ГО	Главный Оператор (Связи)	Capcom
ГО	Герметичный Отсек	Pressurized Compartment
ГО	Головной Обтекатель	Cap
ГОГУ	Главная Оперативная Группа Управления	Main Operative Control Group
ГП	Гибкая Программа	Flexible Program
ГР	Герморазъем	Pressure Vessel Connector
Град.	Градус	Degree
ГСВ	Гринвичское Среднее Время	Greenwich Mean Time
ГСН	Головка Самонаведения	Homing Head
ГСО	Готовность Системы Ориентации	Orientation System Readiness
Гц	Герц	Hertz
ГЦ	Гибкий Цикл	Flexible Timeline
ГШ	Гермошлем	Pressure Helmet
He	Гелий	Helium

Д

Д	Дальность	Range
Д	Датчик	Sensor or Tracker
Д	Диаметр	Diameter
Д	Долгота	Longitude

Давл.	Давление	Pressure
ДАД	Датчик Абсолютного Давления	Absolute Pressure Sensor
ДАЛЬН	Дальномер	Range Finder
ДВ	Дыхательная Вентиляция	Respiratory Fan
Двиг.	Двигатель	Engine, Jet
ДД	Датчик Давления	Pressure Cover Sensor
ДЖТ	Датчик Температуры Жидкости	Liquid Temperature Sensor
ДЗК	Датчик Закрытия Крышки	Closure Sensor
ДЗС	Датчик Закрытия Стыка	Interface Closure Sensor
ДЗГ	Датчик Захвата Головки	Rod Head Capture Sensor
ДК	Дискретный Контур	Discrete Circuit
ДК1(2)	Датчик Касания 1(2)	Contact Sensor 1(2)
ДКР	Датчик Контроля Расстыковки	Undocking Sensor
ДКС	Давление в Камере Сгорания	Chamber Pressure
ДКУ	Датчик Контакта Уплотнения	Seal Contact Sensor
ДМВ	Декретное Московское Время	Moscow Standard Time
ДМП	Двигатель Мягкой Посадки	Soft Landing Thruster
ДМШ	Датчик Малогабаритный Шлемофонный (Микрофон)	Microphone
ДО	Двигатель Ориентации	Attitude Control Thruster
ДОГ	Датчик Обеспечения Герметичности	Pressurization Sensor
ДОПК	Датчик Отстрела Пассивных Крюков	Passive Hooks Jettison Sensor
ДОУ	Датчик Обжатия Уплотнения	Seal Preload Sensor
ДП	Дистанционный Переключатель	Remote Switch
ДПО	Двигатели Причаливания и Ориентации	Berthing and Attitude Control Thrusters
ДПО-Б	Двигатели Причаливания и Ориентации – Большие	Primary Berthing and Attitude Control Thrusters
ДПО-М	Двигатели Причаливания и Ориентации – Малые	Secondary Berthing and Attitude Control Thrusters
ДпоУЗ	Действовать по Указанию Земли	Operate on Ground Cue
ДР	Датчик Рассогласования	Misalignment Sensor
ДСД	Датчик-Сигнализатор Давления	Pressure Caution&Warning Sensor
ДСК	Датчик Совмещения Колец	Guide Rings Sensor
ДТ	Датчик Температуры	Temperature Sensor
ДТВ	Датчик Температуры Воздуха	Air Temperature Sensor
ДТП	Долгота Точки Прицеливания	Landing Site Longitude
ДУ	Двигательная Установка	Engine Unit
ДУПЛ	Дуплекс, Дуплексный	Duplex
ДШБ	Датчик Давления Газа в ШБ	Spherical Bottle Gas Pressure Sensor

Е

ЕДВ	Емкость Для Воды	Water (Storage) Tank
ЕКА	Европейское Космическое Агентство	European Space Agency
Емк.	Емкость	Volume, Capacity

Ж

ЖЖТ	Жидкостно-жидкостный Теплообменник	Liquid/Liquid Heat Exchanger
ЖО	Жизнеобеспечение	Life Support
ЖУ	Жесткий Упор	Stiff Stop
ЖЦ	Жесткий Цикл	Hard Timeline (Circle)
ЖЭН	Жидкостной Электронагреватель	Liquid Electric Heater

З

З	Земля, Земной	Ground, Earth, Land
ЗАЗЕМ	Заземление	Ground (Electrical)
ЗАКР	Закрыть	Close
Зач.	Зачет	Test
ЗнаС	Закрутка на Солнце	Sun Orientation and Spin (Sun Turn, Barbecue Rotation)
ЗПЛ	Закрытие Переходного Люка	Transfer Hatch Closing
ЗРП	Заместитель Руководителя Полетом	Deputy Flight Controller (Director)
ЗРП	Запрет Работы по Признакам	Onboard Computer Command Inhibit
ЗСШ	Замок Стыковочного Шпангоута	Docking Ring Latch
ЗСП	Запасная Система Парашютов	Backup Parachute System
ЗУ	Запоминающее Устройство	Data Storage Unit

И

ИД	Индивидуальный Дозиметр	Crew Radiation Dosimeter
ИД	Индикатор Давления	Pressure Gauge
ИДТ	Индикатор Давления и Температуры	Pressure and Temperature Indicator
Изол.	Изоляция	Insulation, Isolation
ИЗС	Индивидуальное Защитное Снаряжение	Personal Protective Equipment
ИЗС	Индикатор Звуковой Сигнализации	Audio Caution & Warning Indicator
ИКА	Итальянское Космическое Агентство	Italian Space Agency
ИКВ	Инфракрасная Вертикаль	Infrared Vertical Sensor
ИЛЛ	Иллюминатор	Window, Viewport
ИМ	Исследовательский Модуль	Research Module
ИМП	Импульс	Impulse
ИНТ	Индикатор Напряжения и Тока	Voltage & Current Indicator
ИП	Измерение Параметров	Parametres Measurement
ИП	Источник Питания	Power Supply
ИПК	Изолирующий Противогаз	Oxygen Breatring Gas Mask
ИПП	Индикатор Пространственного Положения	Attitude Direction Indicator
ИР	Индикаторный Режим	Indicator Mode, Free Drift
ИРВИ	Индикатор Ручного Ввода Информации	Indicator of Manual Input-Output of Data
ИСА	Интегрирующий Счетчик Амперчасов	Integrating Amper-Hours Counter
ИСК	Инерциальная Система Координат	Inertial Coordinate System
ИСКТ	Инерциальная Система Координат Текущая	Current (Epoch) Inertial Coordinates
ИСХ	Исходный	Initial
ИТВ	Индикатор Текущего Времени	Current Time Indicator
ИЭ	Инструкция по Эксплуатации	Operational Instruction

К

К	Канал	Channel, Duct
К	Командир	Commander
к	Кило	Kilo
КА	Космический Аппарат	Space Vehicle
КАЧ	Качество (АУС)	Efficiency
КВ	Короткие Волны	Short Waves
КВД	Клапан Выравнивания Давления	Pressure Equalization Valve
КВО	Контур Водяного Охлаждения	Water Coolant Loop
КВУ	Команды Взаимного Управления	Interactive Multisystem Control Commands
КВЭ	Корабль Возвращения Экипажа	Assured Crew Return Vehicle
квт	Киловатт	Kilowatt
квт.ч	Киловатт в час	Kilowatt Hour
КГ	Коррекция Глобуса	Tracking Globe Correction
кг	Килограмм	Kilogram

кГц	Килогерц	Kilohertz
КДУ	Комбинированная Двигательная Установка	Combined Engine Propulsion
КЖО	Контур Жилых Отсеков	Habitation Module Thermal Regulation Loop
КЗ	Короткое Замыкание	Short Circuit
КИ	Космонавт-Исследователь	Cosmonaut-Researcher
КИК	Конструкция и Компоновка	Construct & Configuration
КК	Космический Корабль	Spacecraft
ККА	Канадское Космическое Агентство	Canadian Space Agency
ККС	Клапан Контроля Стыка (Малой Полости)	Interface Check Valve (Small Volume)
ККТ	Клапан Контроля Тоннеля (Большой Полости)	Tunnel Pressurization Check Valve (Large Volume)
КЛАСС	Класс (учебный)	Classroom
км	Километр	Kilometer
КМК	Колодка Медконтроля (клеммная)	Medical Monitoring Terminal Block
КНР	Контур Навесных Радиаторов	Hinged Radiators Loop
КО	Контакт Отделения	Separation Contact
КО	Обратный клапан	Check Valve
КОБ	Контур Обогрева	Heating Loop
КОК	Контур Откачки Конденсата	Condensate Evacuation Loop
Консерв.	Консервация	Conservation, Pickling
Конс.	Консультация	Cosultation
КОНТ	Контролировать	Periodic Monitoring
КОРР	Коррекция (Маневр)	Maneuver
КОТ	Контейнер для Отходов	Waste Container
КОХ	Контур Охлаждения	Coolant Loop
КП	Кнопка Передачи	Push-To-Talk Button
КП	Комплексная Подготовка	Complex Training
КП	Контакт Подъема	Lifting Contact
КПА	Пироклапан Пуска Азота	Nitrogen Purge Squib Valve
КПД	Предохранительный Клапан Дренажный	Drainage/Pressure Releif Valve
КПП	Пусковой Пироклапан	Squib-Operated Start Valve
Кр.	Крен	Roll
КРЛ	Командная Радиолиния	Command Radio-Line
КРУД	Коммутатор РУД	THC Commutator
КРУО	Коммутатор РУО	RHC Commutator
КС	Комплексный Стенд	Systems Stand
КС	Конец Связи	Loss of Signal
К-С	Корабль-Спасатель	Rescue Vehicle
КСД	Клапан Стравливания Давления	Pressure Relief Valve
КСП	Комплекс Средств Приземления	Landing Aids Complex
КСП	Пироклапан Слива Перекиси	Peroxide Drain Squib Valve
КСП-Л	Командно-Сигнальное Поле Левое	Command-Signal Panel-Left
КСП-П	Командно-Сигнальное Поле Правое	Command-Signal Panel-Right
КСС	Комплекс Средств Спасения	Rescue Aids Complex
КСУ	Командно-Сигнальное Устройство	Command-Signal Device
КТ	Комплексный Тренажер	Complex Simulator
КТО	Контейнер Твердых Отходов	Solid Waste Container
КТС	Космическая Транспортная Система	Space Transportation System
КУ	Курсовой Угол	Azimuth Angle
Ку.	Курс	Yaw, Course, Azimuth
КЦ	Космический Центр	Space Centre
КЦГ	Космический Центр им. Годдарда	Goddard Space Flight Centre
КЦД	Космический Центр им. Джонсона	Johnson Space Centre
КЦК	Космический Центр им. Кеннеди	Kennedy Space Centre
КЦМ	Космический Центр им. Маршалла	Marshall Space Flight Centre
КЭ	Командир Экипажа	Crew Commander
КЭИ	Комбинированный Электро-люминисцентный Индикатор	Combined Electro-luminescent Indicator

Л

Лаб.	Лаборатория	Laboratory
ЛВ	Линия Визирования	Line of Sight
Лев.	Левый, Левосторонний	Left Hand
ЛЗП	Ламель Закрытого Положения	Closed Position Wafer Switch
ЛИ	Летные Испытания	Flight Test
ЛЛ	Летающая Лаборатория	Airborne Laboratory
Л-Л	Люк-лаз	Hatch Manhole
ЛП	Литиевый Поглотитель CO2	Lithium CO2 Absorber
ЛПР	Лазерный Дальномер	Laser Range Finder
ЛСК	Лучевая Система Координат	Radial Coordinate System

М

м	Метр	Meter
м/сек	Метров в Секунду	Meters per Second
МАГ	Магнитофон	Tape Recorder
МБС	Межбортовая Связь	Space-to-Space Communications
МВ	Мановакуумметр	Vacuum Pressure Gauge
МВ	Московское Время	Moscow Time
МВ	Местная Вертикаль	Local Vertical
МГ	Местная Горизонталь	Local Horizontal
МГК	Механизм Герметизации Крышки	Door Sealing Mechanism
МГС	Механизм Герметизации Стыка	Interface Pressurization Mechanism
МГц	МегаГерц	Megahertz
мин	Минута	Minute
МК	Медицинский Контроль	Medical Monitoring
МКС	Международная Космическая Станция	International Space Station
МКФ	Микрофон	Microphone
МК34	Максимальное Напряжение(датчик)	Maximum Voltage (Sensor)34
ММ	Математическая Модель	Math Model
мм	Миллиметр	Millimeter
мм.рт.ст.	Миллиметр Ртутного Столба	Millimeters of Mercury
МНМ	Манометр	Pressure Gauge, Manometer
МН26	Минимальное Напряжение (датчик)26	Minimum Voltage (Sensor)26
МО	Математическое Обеспечение	Software
МП	Малая Полость	Minor Volume
МП	Мягкое Причаливание	Soft Berthing
МС	Мягкая Стыковка	Soft Docking
МСК	Московское Время (Декретное)	Moscow (Standart) Time
МСП	Многосегментная Подготовка	Multi-Segment Training
МСПЭ	Многосегментная Подготовка Экипажа	Crew Multi-Segment Training
МУ	Мягкий Упор	Soft Stop

Н

НА	Научная Аппаратура	Scientific Hardware
НАЗ	Носимый Аварийный Запас	Post-Landing Survival Kit
Накл.	Наклонение	Inclination
НАСА	Национальное Управление по аэронавтике и исследованию космического пространства	National Aeronautics and Space Administration
НАСДА	Национальное Агентство по аэронавтике и исследованию космического пространства Японии	National Aeronautics/Space Development Agency of Japan
НВ	Начало Витка	Ascending Node, Beginning of the Orbit

НД	Наружный Диаметр	Outside Diameter
НДМГ	Несимметричный Диметилгидразин	Unsymmetrical Dimethylhudrazine
Негерм.	Негерметичность	Leakage
НК	Начало Координат	Origin of Coordinates
НКО	Наземная Комплексная Отладка	Ground Complex Adjustment
НМ	Наружная Магистраль	External Manifold
НО	Наземный Ориентир	Landmark
НОК	Насос Откачки Конденсата	Condensate Evacuation Pump
НПО	Научно-Производственное Объединение	Scientific Production Association
НР	Насос Ручной	Manual Pump
НРОК	Насос Ручной Откачки Конденсата	Manual Condensate Evacuation Pump
НС	Начало Связи	Acquisition of Signal
НС	Нерасчетная Ситуация	Off-Design Situation
Н/С	Нештатные Ситуации (б/д)	Off-Normal Situations Checklist
НХР	Навесной Холодильный Радиатор	Attached Cooling Radiator
НХР	Наружный Холодильный Радиатор	External Cooling Radiator
НЦУ	Наземный Центр Управление	Ground Control Center
НШС	Нештатная Ситуация	Off-Normal Situation, Off-Nominal Situation
НЭП	Научно-Энергетическая Платформа	Scientific Power Platform

О

О	Окислитель	Oxidizer
ОБ	Орбитальный Блок (Модуль)	Orbital Unit (Module)
Об.	Оборот	Revolution (Orbit)
ОБЛ	Область	Region
ОВ	Оптический Визир	Optical Sight
ОВ	Ось Вращения	Axis of Rotation
ОВК	Особо Важные Команды	Critical Commands
ОВП	Оптико-Визуальные Приборы	Optical-Visual Devices
ОГБ	Отделяемый Головной Блок	Main Separable Unit
ОДР	Отбой Динамических Режимов	Dinamic Modes Termination
ОЗУ	Оперативное Запоминающее Устройство	Operative RAM (Random Access Memory)
ОК	Отсечной Клапан	Shutoff Valve
ОК	Обобщенная Команда	Generalized Command
ОК	Орбитальный Комплекс "Мир"	Mir Station
ОК	Орбитальный Корабль	Orbiter
ОКП	Общекосмическая Подготовка	General Space Training, Basic Training
ОМСП	Объединенная Многосегментная Подготовка	Joint Multi-segment Training
ОО	Оптическая Ось	Optic Axis
ОП	Оповещатель	Informer
ОПЛ	Открытие Переходного Люка	Transfer Hatch Opening
ОРИЕНТ	Ориентация	Orientation, Attitude
ОС	Обратная Связь	Feedback
ОС	Ось Симметрии	Centre Line, Axis of Summetry
ОС ЦУП	Оператор Связи ЦУП	Mission Control Communicator
ОСК	Орбитальная Система Координат	Orbital Coordinate System
ОСП	Основная Система Парашютов	Primary Parachute System
Отд.	Отделение	Separation
ОТКЛ	Отключить	Disconnect
ОТКР	Открыть, Открыто	Open
Отр.	Отрицательный	Negative
ОТСТЫК	Отстыковать	Undock

П

П	Период	Period
П	Подготовка	Training, Preparation
П СО2	Поглотитель СО2	Carbon Dioxide Absorber
ПАО	Приборно-Агрегатный Отсек	Instrument Module
ПАУ	Полуавтоматическое Управление	Semi-Automated Control
ПБ	Подготовка на Борту	On-Board Training
ПБВ	Пироклапан Безопасности при Приводнении	Splashdown Safety Pyrovalve
ПБК	Пульт Блокировки Клапана	Valve Inhibit Switch
ПВ	Полетное Время	Mission Elapsed Time
ПВЖВ	Подготовка по Выживанию	Survival Training
ПВК	Пульт Выдачи Команд	Command Panel
ПВМ	Программно-Временной Механизм	Program Timing Mechanism
ПВУ	Программно-Временное Устройство	Program Timing Device
ПГ	Подготовка в Составе Группы	Group Training Phase, Advanced Training
ПГ	Полезный Груз	Payload
ПГ	Привод Упоров Гнезда	Drogue Stops Drive
ПГА	Пневмогидроагрегат	Pneumatic/Hydraulic Unit
ПГЗ	Противогаз	Breatring Gas Mask
ПГС	Привод Герметизации Стыка	Interface Sealing Drive
ПД	Приборная Доска	Instrument Panel
ПДУ	Посадочная Двигательная Установка	Soft Landing Rocket Motors System
Перекл.	Переключатель	Switch, Selector
Пер.Т	Переменный Ток	Alternating Current
ПЗ	Привод Защелок	Latch Drive
ПЗ	Полетное Задание	Mission Task
ПЗ	Практические Занятия	Practical Studies
ПЗВС	Пульт Защиты Вентиляторов Скафандров	Spacesuit Fan Circuit Braker Panel
ПЗУ	Постоянное Запоминающее Устройство	Non-Volitale ROM (Read-Only Memory)
ПК	Пироклапан	Pyrovalve
ПК	Предварительный Клапан	Prevalve
ПК	Предохранительный Клапан	Safety Valve, Pyrovalve
ПК	Пульт Команд	Command Panel
ПК	Пульт Космонавта	Crew Display, Control Panel
ПКГ	Пироклапан Герметизации	Pressurization Pyrovalve
ПКН	Преобразователь Код-Напряжение	Code-Voltage Transducer
ПКП	Промежуточный Контур Подогрева	Intermediate Heating Loop
ПМ	Пружинный Механизм	Spring Mechanism
ПМО	Пульт Медицинских Обследований	Medical Examinations Panel
ПН	Пиропатрон	Pyro Cartridge
ПНК	Преобразователь Напряжение-Код	Voltage-Code Transducer
ПО	Патрон Очистки	Purification Cartridge
ПО	Подлежит Определению	To Be Determined
ПО	Полетные Операции	Flight Operations
ПО	Приборный Отсек	Instrument Module
ПО	Продольная Ось	Centreline
ПОДГОТ	Подготовить	Prepare
ПОДКЛ	Подключить	Connect, Hook Up, Plug In
ПОДСТЫК	Подстыковать	Connect
Пол.	Положительный	Positive
Пост.Т	Постоянный Ток	Direct Current
ПоЧС	По Часовой Стрелке	Clockwise
ПП	Практическая Подготовка	Practical Training
ПП	Пространственное Положение	Attitude
П/П	Программа Полета (б/д)	Flight Program Checklist
ППК	Послеполетный Профилактический	Postflight Adaptation Suit

	Костюм	
ППК	Противоперегрузочный Костюм	Anti-Gravity Suit
ППН	Подготовка по Поддержанию Навыков	Proficiency Training
ППС	Пульт Питания Систем	Systems Power Supply Panel
ППШ	Потенциометр Положения Штанг	Rods Position Potentiometer
ППЭ	Программа Полета Экспедиции	Flight Mission Plan
ПР	Подлежит Решению	To Be Resolved
Прав.	Правый, Правосторонний	Right Hand
Пр.	Программа (ПВУ)	Program Timing Device
ПрЧС	Против Часовой Стрелки	Counter Clockwise
ПРД	Передатчик	Transmitter
ПРМ	Приемник	Receiver
ПРОВ	Проверить	Verify, Check
ПРШ	Потенциометр Рассогласования Штанг	Rods Misalignment Potentiometer
ПС	Пассажир	Passenger
ПС	Подготовка по Системам	Systems Training
ПС	Пульт Связи	Communication Panel
ПСК	Поисково-Спасательный Комплекс	Search-Rescue Complex
ПСК	Приборная Система Координат	Instrument Coordinate System
ПСМ	Привод Стыковочного Механизма	Docking Mechanism Actuator
ПСП	Подготовка ЦУП-Экипаж по Сегменту Партнера	MCC-Crew Partner Segment Training
ПСС	Поисково-Спасательная Служба	Search-Rescue Service
ПТР	Подготовка к Работе на Тренажере	Presimulator Training
ПУ	Панель Управления	Control Panel
ПУ	Приемное Устройство	Drinking Dispenser
ПУ	Программное Устройство	Sequencer
ПУ	Пульт Управления	Control Panel
ПУ	Пусковая Установка	Launcher
ПхО	Переходной Отсек	Transfer Module
ПЭ	Подготовка в Составе Экипажа	Crew Training, Increment Specific Training

Р

Разарр.	Разарретирование	Uncage, Free
РАЗГЕРМ	Разгерметизация	Depressurization
РАЗГЕРМ	Разгерметизировать	Depressurize
Разг.	Разгон	Acceleration
РАП	Ручной Антенный Переключатель	Manual Antenna Switch
РАССТ	Расстыковка, Расстыковать	Undocking, Undock
РАСФИКСИР	Расфиксировать	Unfasten, Unlock
РБ	Резервная Батарея	Backup Battery
РБС	Розетка Бортовой Сети	Onboard NetWork Outlet
РБС-У	Розетка Бортовой Сети Унифицированная	Universal Onboard NetWork Outlet
РВ	Реле Времени	Time Relay, Timer
РГ	Режим Готовности	Stand By Mode
Р/Г	Радиограмма	Radiogram, Radio Message
РД	Регулятор Давления	Pressure Regulator
РД	Редуктор Низкого Давления	Pressure Reducing Valve
РДСП	Регулятор Давления с Подсосом	Inleakage Pressure Regulator
РЕГ	Регулировка	Adjustment
Рег.	Регулятор	Regulator
РЕГУЛИР	Регулировать	Adjust, Regulate
РЕЖ	Режим	Mode
РЗ	Режим Захвата	Capture Mode, Lock-On Mode
РК	Ручной Клапан	Manual Valve
РКА	Российское Космическое Агентство	Russian Space Agency
РКК	Ракетно-Космическая Корпорация	Rocket Space Corporation

РКК-Э	Ракетно-Космическая Корпорация"Энергия"	Rocket Space Corporation Energia
РКО	Радиоконтроль Орбиты	Orbit Radio Tracking
РМ	Рабочее Место	Work Station (Place)
РН	Ракета-Носитель	Launch Vehicle
РНОК	Ручной Насос Откачки Конденсата	Manual Condensate Evacuation Pump
РО	Рабочий Отсек	Work Module
РО	Ручная Ориентация	Manual Orientation
РП	Район Приземления	Landing Site
РП	Рацион Питания	Food Ration
РП	Руководитель Полета	Flight Director
РП	Ручное Причаливание	Manual Berthing
РПВ	Регулятор Потока Воздуха	Air Flow Regulator
РПВ	Ручная Подача Воздуха	Manual Air Supply
РР	Режим Ретрансляции	Retransmission Mode, Relay Mode
Р/Р	Резервные Режимы (б/д)	Backup Modes Checklist
РРВ	Регулятор Расхода Воздуха	Air Flow Regulator
РРЖ	Регулятор Расхода Жидкости	Liquid Flow Regulator
РРП	Разрешение Работы По Признакам	Onboard Computer Command Clearance
РРСТ	Разрешение Расстыковки	Undocking Permission
РС	Радиосистема	Radio System
РС	Российский Сегмент	Russian Segment
РСБ	Ручное Сближение	Manual Approach
РСТ	Ручная Стыковка	Manual Docking
РТМС	Радиотелеметрическая Система	Radio Telemetry System
РТС	Радиотехническая Система	Radio Engineering System
РТСС	Радиотехническая Система Стыковки	Radio Engineering System Approach
РУАС	Расчет Уставок Автоматического Спуска	Automatic Descent Dataset Calculation
РУ	Регенерационная Установка	Regeneration Unit
РУ	Ручное Управление	Manual Control
РУД	Ручка Управления Движением	Translation Hand Controller
РУО	Ручка Управления Ориентацией	Rotation Hand Controller
РУС	Ручное Управление Спуском	Manual Controlled Descent
Ручн.	Ручной	Manual
Рыск.	Рыскание	Yaw

С

С	Север	North
СА	Спускаемый Аппарат	Descent Module
САС	Система Аварийного Спасения	Launch Escape System
СБ	Солнечная Батарея	Solar Array
СБИ	Система Бортовых Измерений	Onboard Measurement System
СБК	Сборник Конденсата	Condensate Accumulator
СБЛИЖ	Сближение	Rendezvous, Approach
СВ	Сверка Времени	Time Synchronization
Св.	Связь	Communication
СВО	Система Внутреннего Освещения	Internal Lighting System
СВО	Система Водообеспечения	Water Supply System
СВЧ	Сверхвысокая Частота	Ultra High Frequency
СГ	Свободный Гироскоп	Free Gyroscope
СГ	Силовой Гироскоп	Powered Gyroscope
СГ	Стыковочное Гнездо	Docking Drouge
СД	Солнечный Датчик	Solar Sensor
СДВ	Система Дыхательной Вентиляции	Ventilation Valve System
СДГ	Сигнализатор Давления в линии Горючего СКД	Propellant Line Pressure Warning Indicator
СДД	Сигнализатор Давления Двигателя	Engine Pressure Warning Indicator
СДК	Сигнализатор Давления в Камере Сгорания	Combustion Chamber Pressure Warning Indicator

СДН	Сигнализатор Давления Наддува	Pressurization Warning Indicator
СДО	Сигнализатор Давления в линии Окислителя СКД	Oxidizer Line Pressure Warning Indicator
СДР	Сигнализатор Давления за Редуктором	Pressure Reduction Warning Indicator
сек.	Секунда	Second
Сем.	Семинар	Seminar
СЖО	Сборник Жидких Отходов	Liquid Waste Receptacle
СИО	Система Исполнительных Органов	Actuator System
СИОС	Система Исполнительных Органов Спуска	Descent Reaction Control System
СИРТ	Система Измерения Расхода Топлива	Propellant Consumption Measuring System
СК	Стартовый Комплекс	Launching Complex
СК	Стыковочный Конус	Docking Cone
СКГС	Система Контроля Герметичности Стыка	Interface Pressurization Control System
СКД	Сближающе-Корректирующий Двигатель	Orbital Maneuver Engine
СКК	Система Координат, Связанная с Кораблем	Body-Axis Coordinate System
СКФ	Скафандр	Spacesuit
СЛГ	Салфетки Личной Гигиены	Personal Hygiene Napkins
СМ	Служебный Модуль	Service Module
СМ	Стыковочный Механизм	Docking Mechanism
СМ	Стыковочная Мишень	Docking Target
СМ	Стыковочный Модуль	Docking Module
С/М	Справочные Материалы (б/д)	Reference Materials Checklist
СМИ	Световой Маяк Импульсный	Flashing Light Beacon
СО	Солнечная Ориентация	Sun Orientation (Attitude, Pointing)
СОиЗ	Солнечная Ориентация и Закрутка	Sun Orientation and Spin (Rotation)
СОА	Система Очистки Атмосферы	Atmospheric Purification System
СОГС	Система Обеспечения Газового Состава	Atmosphere Revitilization System
СОЖ	Система Обеспечения Жизнедеятельности	Life-Support System
СОИ	Система Отображения Информации	Data Display System
СОП	Система Обеспечения Пищей	Food Supply System
СОП	Система Оповещения и Предупреждения	Caution & Warning System
СОТР	Система Обеспечения Теплового Режима	Thermal Mode Control System
СОУД	Система Ориентации и Управления Движением	Attitude and Motion Control System
СП	Самоподготовка	Self-Training, Tutorial
СП	Система Приземления	Landing System
СП	Спуск	Descent
СП	Стыковочная Плоскость	Docking Ring Interface
Сп.	Спасение	Rescue
СПАС	Спасатель	Rescuer
СПГС	Система Подачи Газовой Смеси	Gas Mixture Supply System
СПД	Сигнализатор Перепада Давления	Differential Pressure Warning Indicator
СПЖ	Система Пожаротушения	Fire Supression System,
СПС	Срочное Покидание Станции	Emergency Escape Station
СР	Система Разделения	Separation System
СРН	Система Радионаведения	Radio Guidance System
СРО	Светильники Рабочего Освещения	Work Lights
СРС	Система Радиосвязи	Radio Communication System
СС	Система Стабилизации	Stabilization System
ССБЗ	Система Связи "Борт-Земля"	Space-to-Ground Communication System
ССВП	Система Стыковки и Внутренего Перехода	Docking and Internal Transfer System
СТ	Станция	Station
С/Т	Свет/Тень	Day/Night
С/Т	Свет/Тень	Light/Shadow
СТА	Стыковочный Агрегат	Docking Assembly

СТД	Система Термодатчиков	Thermal Sensor System
СТЗ	Система Термозащиты	Thermal Protection System
СТР	Система Терморегулирования	Thermal Control System
С/Ф	Светофильтр	Light Filter
СУ	Стыковочный Узел	Docking Assembly
СУ	Стыковочное Устройство	Docking Device
СУБК	Система Управления Бортовым Комплексом	On-Board Complex Control System
СУД	Система Управления Движением	Motion Control System
СУС	Система Управления Спуском	Descent Control System
СУ-А	Стыковочный Узел Активный	Active Docking Node
СУ-П	Стыковочный Узел Пассивный	Passive Docking Node
СШ	Силовая Шина	Power Bus
СШ	Стыковочная Штанга	Cross Bar
СЭП	Система Электропитания	Power Supply System

Т

Табл.	Таблица	Table, Chart
Танг.	Тангаж	Pitch
ТАС	Тренажер Американского Сегмента	American Segment Trainer
ТБ	Топливный Бак	Propellant Tank
ТБ	Топливная Батарея	Fuel Cell
ТВ	Телевидение, Телевизионный	Television
ТВС	Телевизионная Система	Television System
ТД	Температурный Датчик	Temperature Sensor
ТД	Термодатчики	Thermal Sensors
ТДК	Тренажер Динамический Комплексный	Complex Dynamic Simulator
Темп.	Температура	Temperature
Теорет.	Теоретический	Theoretical
ТЗ	Теплозащита	Thermal Protection
ТЗК	Термозащитный Костюм	Thermal Protective Suit
ТК	Теплообменник-Конденсатор	Heat Exchanger/Condenser
ТК	Телевизионная Камера	Television Camera(TV Camera)
ТК	Транспортный Корабль	Transport Vehicle
ТКГ	Транспортный Корабль Грузовой	Cargo Transport Vehicle
ТК-БО	Телевизионная Камера БО	Orbital Module TV Camera
ТК-СА	Телевизионная Камера СА	Descent Module TV Camera
ТЛГ	Телеграф	Telegraph
ТЛФ	Телефон	Telephone
ТМ	Телеметрия	Telemetry
ТНГ	Тангента	Push-to-Talk Button
ТО	Техническое Обеспечение	Engineering
ТОКС	Тренажное Оборудование Космической Станции	Space Station Training Facilities
ТОРС	Тренажное Оборудование Российского Сегмента	Russian Segment Training Facilities
ТОРУ	Телеоператорное Ручное Управление	Teleoperator's Manual Control
ТП	Теоретическая Подготовка	Theoretical Training
ТП	Тормозной Парашют	Drogue, Braking Parachute
ТП	Точка Посадки	Landing Point
ТП	Точка Приземления	Landing Point
ТП	Точка Прицеливания	Aiming Point
ТР	Тренажер	Simulator, Trainer
ТРС	Тренажер Российского Сегмента	Russian Segment Trainer
ТСО	Тренажно-Стендовое Оборудование	Training Facilities
ТСЭ	Табло Сигнальное Электролюминесцентное	Electroluminiscent Indicator Display
Т/С	Тень/Свет	Night/Day
Т/С	Тень/Свет	Shadow/Light

Т-С	Тень-Свет	Sunset-Sunrise
Т-С	Тень-Свет	Shadow-Light
ТЧЗ	Тренажер по Частным Задачам	Part Task Trainer

У

УА	Угол Атаки	Angle of Attack
УД	Ударный Датчик	Shock Sensor
УЗМ	Умения, Знания, Мотивация	Skills, Knowledges, Attitude
УК	Учебный Курс (Программа)	Curriculum
УКВ	Ультракороткие Волны	Very High Frequency
УОИ	Устройство Отображения Информации	Data Display Device
УП	Угол Посадки	Landing Angle
УП	Учебное Пособие	Training Manual, Workbook
УПЧ	Усилитель Промежуточной Частоты	Intermediate Frequency Amplifier
Упр.	Управление	Control
УРД	Управляющий Реактивный Двигатель	Reaction Control System Jet
УРМД	Управляющий Реактивный Микродвигатель	Reaction Control Microthruster
УСМ	Универсальный Стыковочный Модуль	Universal Docking Module
УСОЗ	Угол Солнце-Объект-Земля	Sun/Spacecraft/Earth Angle
УУ	Узкоугольный Объектив	Narrow-Angle Objective
УУ ВТ	Узкоугольный Объектив Внешней Телекамеры	Narrow-Angle Lens of External TV Camera
УФ	Ультрафиолетовый	Ultraviolet
УЭГК	Управляющий Электродвигатель	Electro-Hydrautic Control Valve

Ф

Ф	Фаза	Phase
Ф	Фильтр	Filter
Ф	Форма	Form, Shape
Ф/А	Фотоаппарат	Photographic Camera
ФГБ	Функциональный Грузовой Блок	Functional Cargo Block
ФГС	Фильтр Газожидкостной Смеси	Gas-Liquid Mixture Filter
ФИКСИР	Фиксировать	Fix, Clamp, Stop
ФМ	Фазовая Модуляция	Phase Modulation
ФТ	Функциональный Тренажер	Functional Simulator
Фт.	Фут	Foot (Feet)
Фт/сек	Футов в секунду	Feet Per Second
ФУ	Фазовый Угол	Phase Angle
Ф/Э	Фотоэлемент	Photo Cell

Х

ХСА	Холодильно-Сушильный Агрегат	Cooling-Drying Unit

Ц

ЦАП	Цифровой-Аналоговый Преобразователь	Digital to Analog Converter
ЦВМ	Цифровая Вычислительная Машина	Digital Computer
ЦДВ	Центральное Дневное Время	Central Daylight Time
ЦИ	Цифровой Индикатор	Digital Indicator
ЦК	Цифровой Контур	Digital Circuit

ЦМ	Целевой Модуль	Specialized Module
ЦМ-Д	Целевой Модуль Дооснащения	Specialized Supplemental Module
ЦМ-Э	Целевой Модуль Экспериментальный	Specialized Experiment Module
ц.м.	Центр Масс	Centre of Mass
ц.т.	Центр Тяжести	Centre of Gravity
ЦО	Центральный Огонь	Central Light
ЦП	Центральный Процессор	Central Processing Unit
ЦПК	Центр Подготовки Космонавтов	Cosmonauts Training Center
ЦПК	Центр Подготовки Космонавтов им. Ю.А.Гагарина	Gagarin Cosmonauts Training Center
ЦСВ	Центральное Стандартное Время	Central Standard Time
ЦУП	Центр Управления Полетом	Mission Control Centre
ЦУП-М	Центр Управления Полетом- Москва	Mission Control Centre-Moscow
ЦУП-Х	Центр Управления Полетом- Хьюстон	Mission Control Centre-Houston
ЦУНП	Центр Управления Нештатным Полетом	Emergency Mission Control Centre
ЦУПН	Центр Управления Полезными Нагрузками	Payload Operation Control Centre
ЦФ	Центрифуга	Centrifuge

Ч

Ч/Б	Черно-Белый	Black & White
ЧМ	Частотная Модуляция	Frequency Modulation
ЧТВ	Часы Текущего Времени	Clock of Current Time
"C"	Частотный Диапазон "C" (3000-7000 МГц)	C-Band
"L"	Частотный Диапазон "L" (1100-2100 МГц)	L-Band
"Ku"	Частотный Диапазон "Ku" (11-14 ГГц)	Ku-Band
"S"	Частотный Диапазон "S" (2100-2300 МГц)	S-Band

Ш

Ш	Широта	Latitude
ШБ	Шар-Баллон	Spherical Tank
ШВ	Штепсельная Вилка	Plug
ШЛ	Шлемофон	Headset
ШР	Штепсельный Разъем	Connector
Ш/Р	Штатные Режимы (б/д)	Normal Modes Checklist
ШС	Штуцер Слива	Drain Outlet
ШТП	Широта Точки Посадки	Landing Site Latitude
ШУ	Широкоугольный Объектив	Wide-Angle Objective
ШУ ВТ	Широкоугольный Объектив Внешней Телекамеры	Wide Angle Lens of External TV Camera

Щ

ЩРП	Щиток Распределения Питания	Power Distribution Box

Э

Э	Экватор	Equator
Э	Экспедиция	Expedition

ЭД	Электродвигатель	Electric Motor
ЭД	Электронный Дисплей	Electronic Display
ЭИМ	Эффективная Излучаемая Мощность	Effective Radiated Power
ЭКГ	Электрокардиограмма	Electrocardiogram
ЭКГ	Электроклапан Горючего	Fuel Electric Valve
ЭКО	Электроклапан Окислителя	Oxidizer Electric Valve
Экз.	Экзамен	Examination
Эл.	Электрический	Electrical
ЭЛТ	Электроннолучевая Трубка	Cathode-Ray Tube
ЭМТ	Электромагнитный Тормоз	Electromagnetic Brake
ЭН	Электронагреватель	Electric Heater
ЭНА	Электронасосный Агрегат	Electric Pump Unit
ЭВМ	Электронная Вычислительная Машина	Computer
ЭО	Экспедиция Основная	Main Expedition (Long Duration Crew)
ЭП	Экспедиция Посещения	Visiting Expedition (Short Duration Crew)
ЭПК	Электропневмоклапан	Electropneumatic Valve
ЭПК-Н	Электропневмоклапан Наддува	Pressurization Electropneumatic Valve
ЭПК-П	Электропневмоклапан Подачи Кислорода	O2 Supply Electropneumatic Valve
ЭПК-РД	Электропневмоклапан Регулировки Давления	Pressure Regulation Electropneumatic Valve
ЭПК-СД	Электропневмоклапан Сброса Давления из Баллона СА	Pressure Relief Electropneumatic Valve (from Descent Module Tank)

Ю

Ю	Юг	South

Я

Я	Ячейка	Cell
ЯД	Ячейка Диодная	Diode Cell
ЯО	Язык Операций	Language of Operations
ЯП	Язык Подготовки	Language of Training
ЯР	Ячейка Релейная	Relay Cell
Ярк.	Яркость	Brightness